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

Phase 2 Final Report

ITRE Bicycle & Pedestrian Program

BikePed PROGRAM

ITRE Institute for Transportation Research and Education

NCDOT Project 2014-44

Bicycle and Pedestrian Data Collection

Phase 2 Final Report

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North Carolina Department of Transportation

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Abstract

This report builds on the results of the pilot project initiated under Phase 1 of the NC NMVDP. This report documents the updates to the protocols that were designed and tested through the pilot and further implemented through Phase 2 expansion of the NC NMVDP. Implementation results and recommendations for future work are shared.

The creation of the NC NMVDP was motivated by the need to establish a common, consistent system for quantifiably measuring non-motorized traffic volumes based on sound methods. Resultant high-quality data can be used in tools to measure existing trends and model future increases in non-motorized volumes at site, corridor, and regional levels. The bicycle and pedestrian counting program assists NCDOT and its local agency partners in evaluating facility usage over time, provides quantifiable evidence to support non-motorized facility inclusion through the Complete Streets process, improves municipal and regional planning for active travel, and may in time inform the project prioritization process.

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Executive Summary

The NC NMVDP is managed by the Institute for Transportation Research and Education (ITRE) for the North Carolina Department of Transportation (NCDOT). This program was established to test a regional bicycle and pedestrian count data collection protocol and to determine how to replicate the methodology across the state.

This report builds on the results of the pilot project initiated in NCDOT Divisions 7 and 9 under Phase 1 of the NC NMVDP. This report documents the updates to the protocols that were designed and tested through the pilot and further implemented through Phase 2 of the NC NMVDP. The program's geographic area currently encompasses the pilot region as well as Divisions 4, 5, 8, and 10. Implementation results and recommendations for future work are shared.

The creation of the NC NMVDP was motivated by the need to establish a common, consistent system for quantifiably measuring non-motorized traffic volumes based on sound methods. Resultant high-quality data can be used in tools to measure existing trends and model future increases in non-motorized volumes at site, corridor, and regional levels. The bicycle and pedestrian counting program assists NCDOT and its local agency partners in evaluating facility usage over time, provides quantifiable evidence to support non-motorized facility inclusion through the Complete Streets process, improves municipal and regional planning for active travel, and may in time inform the project prioritization process.

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Introduction

The NC NMVDP is managed by the Institute for Transportation Research and Education (ITRE) for the North Carolina Department of Transportation (NCDOT). This program was established to test a regional bicycle and pedestrian count data collection protocol and to determine how to replicate the methodology across the state.

The creation of the NC NMVDP was motivated by the need to establish a common, consistent system for quantifiably measuring non-motorized traffic volumes based on sound methods. Resultant high-quality data can be used in tools to measure existing trends and model future increases in non-motorized volumes at site, corridor, and regional levels. The bicycle and pedestrian counting program assists NCDOT and its local agency partners in evaluating facility usage over time, provides quantifiable evidence to support non-motorized facility inclusion through the Complete Streets process, improves municipal and regional planning for active travel, and may in time inform the project prioritization process. In Phase 1 and 2 of the program, NCDOT partnered with local agencies to select counting locations and to install and maintain the necessary permanent sensor network to establish statistically valid expansion factor groups. The count data collected are verified and validated through quality assurance and quality control (QA/QC) processes before being centrally warehoused using vendor-provided software. The data are provided to local agencies through preliminary quarterly and official annual data reports. Phase 1 and 2 of the program prioritized permanent continuous counters in order to develop adjustment factors that can be applied to short duration counts to produce annual statistics such as annual average daily pedestrian traffic (AADP) or annual average daily bicycle traffic (AADB). Short duration counts were collected only to inform the site selection for the permanent continuous counters.

Report Focus

This report builds on the results of the pilot project initiated in NCDOT Divisions 7 and 9 under Phase 1 of the NC NMVDP. This report documents the updates to the protocols that were designed and tested through the pilot and further implemented through the Phase 2 expansion of the NC NMVDP. Implementation results and recommendations for future work are shared.

A formal program evaluation was conducted by ITRE from March 2019 through February 2020. The evaluation used a survey of local agency partners, follow up structured conversations, discussions with program administrators and staff, and analyses of historic program records to compare program activity objectives with their actual implementation to articulate strengths, weakness, and recommendations for process improvements. Findings from this evaluation are included throughout this report. Key recommendations are summarized in Appendix 1.

Literature Review

When the NC NMVDP began in November 2013, very few states were establishing or making plans for regional or statewide non-motorized counting programs. At the time, Minnesota, Colorado, and Oregon DOTs were establishing formal programs along with North Carolina. In addition to these states, a 2019 scan of current U.S. practice by the Virginia Transportation Research Council identified bicycle and pedestrian counting efforts, guidelines, plans, and research in progress by state DOTs in Florida, Idaho, Louisiana, New Hampshire, Texas, Washington, Utah, Vermont, California, Michigan, North Dakota, and Ohio (Ohlms et al., 2019). Table 1 summarizes bicycle and pedestrian counting guidance by locality that were developed and released since the initial literature review that was conducted for the NC NMVDP Phase 1 pilot. The following provides highlights from these key sources.

FHWA Traffic Monitoring Guide (2013, 2016)

The FHWA Traffic Monitoring Guide (TMG) includes a chapter (Chapter 4) on non-motorized volume monitoring with guidance on selecting the appropriate counting equipment type. A simplified flowchart for selecting non-motorized count equipment is included that helps inform decision making based on user type to be counted (pedestrians only, bicyclists only, pedestrians and bicyclists combined, or pedestrians and bicyclists separately) and estimated cost.

NCHRP Web-Only Document 229: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection – Phase 2 (2016)

This report summarizes follow on research to the studies described in NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection. This research evaluated additional automated bicycle and pedestrian counting technologies that were not on the market at the time of the previous studies to determine their reliability in different settings. The report documents findings on the accuracy and consistency found for the different automated count technologies. In addition, the report provides a complete account of the process used to select technologies for testing, identify test sites, and evaluate the effectiveness of the technologies.

Exploring Pedestrian Counting Procedures: A Review and Compilation of Existing Procedures, Good Practices, and Recommendations (2016)

This report provides guidance and best practices for measuring pedestrian travel. The report outlines the available technologies for counting pedestrians along with their typical applications, strengths, and weakness as referenced from the FHWA Traffic Monitoring Guide and NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection. The report suggests that the most used pedestrian counting technologies include manual counts (both in-field and from video), automated video counts, passive and active infrared devices, and radio beams. Thermal cameras, laser scanners, and pressure or acoustic pads are used less frequently. Other technologies that can capture surrogate measures of pedestrian traffic volumes include Bluetooth or Wi-Fi technology, or traffic signals that record pedestrian pushbutton actuations.

Accuracy of Bicycle Counting with Pneumatic Tubes in Oregon (2016)

This study tested the accuracy of multiple types of pneumatic tube counters for counting bicycles: two bicycle-specific counters, three varieties of motor vehicle classification counters, and one volume-only motor vehicle counter. The counters were deployed on Oregon DOT's Traffic Systems Services Unit parking lot in Salem, Oregon for controlled testing and a two-lane section with 4- to 5-foot shoulders on the Historic Columbia River Highway for naturalistic testing. The counters in both test scenarios showed strong evidence of undercounting. The controlled environment test resulted in greater accuracy than the naturalistic, mixed-traffic test which showed more extreme undercounting.

Collecting Network-wide Bicycle and Pedestrian Data: A Guidebook for When and Where to Count (2017)

This report provides a guide for collecting network-wide bicycle and pedestrian count data specific to the Washington State Bicycle and Pedestrian Documentation Project. This guide includes a review of automated and manual counting methods, including those evaluated in NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection.

Innovative Ways to Count Pedestrians and Bicyclists (2015)

This summary report by the New Jersey Bicycle and Pedestrian Resource Center describes efforts by the New Jersey Department of Transportation to evaluate technologies for counting pedestrians and bicycles. The technologies considered include infrared beams, infrared counters, piezoelectric pads, laser scanners, pneumatic tubes, inductive loops, and computer vision.

Innovation in Bicycle and Pedestrian Counts: A Review of Emerging Technology (2016)

Alta Planning + Design published a white paper that reviews emerging technology and innovations in bicycle and pedestrian counts. This paper provides a summary of counter types from existing literature and practice by technology type, manufacturer, user type to be counted, count duration, and count purpose. The paper also reviews crowd-sourced data collection applications that rely on mobile devices such as smartphones, video detection systems, and low-cost counting hardware.

Bicycle and Pedestrian Count Programs: Summary of Practice and Key Resources (2018)

This research brief by the Pedestrian and Bicycle Information Center (PBIC) provides a summary of current practice and key resources for implementing, expanding, or maintaining bicycle and pedestrian count programs. The document focuses on key aspects of count programs, including site selection, equipment, and data management.

Bicycle and Pedestrian Count Programs: Scan of U.S. Practice (2019)

This study identified ways to plan and implement a non-motorized count program in Virginia. Its scope included reviewing existing U.S. national-level guidance and examples from state departments of transportation (DOTs) other than Virginia's to determine the most effective ways of implementing such a program. Through a state of the practice review and interviews with public agency staff and researchers involved in three statewide non-motorized count programs, the study concluded that the practice of non-motorized travel monitoring has evolved and expanded in recent years; that many commercially available counting technologies exist and have been evaluated; that the practice of non-motorized travel monitoring, as with motorized travel monitoring, has several aspects beyond purchase and installation of automatic count equipment; and that several states are developing non-motorized count programs and have begun using their data. These findings provide a foundational resource for state DOTs that are considering developing state-level counting programs.

Table 1. Summary of Bicycle and Pedestrian Counting Guidance by Locality

Locality	Bicycle and Pedestrian Counting Guidance Document	Authors	Year
National	Bicycle and Pedestrian Count Programs: Scan of U.S. Practice	Ohlms, P.; Dougald, L; MacKnight, H.	2019
National	Biking and Walking Quality Counts: Using "Bike-Ped Portal" Counts to Develop Data Quality Checks	McNeil, N.; Tufte, K.; Lee, T.; Nordback, K.	2019
National	Bicycle and Pedestrian Count Programs: Summary of Practice and Key Resources	Nordback, K.; O'Brien, S.; Blank, K.	2018
National	Bike-Ped Portal: Development of an Online Nonmotorized Traffic Count Archive	Nordback, K.; Tufte, K.; McNeil, N.; Harvey, M.; Watkins, M.	2017
National	Innovation in Bicycle and Pedestrian Counts: A Review of Emerging Technology	O'Toole, K.; Piper, S.	2016
National	Traffic Monitoring Guide (TMG)	Federal Highway Administration (FHWA)	2016
National	Innovative Ways to Count Pedestrians and Bicyclists	Bonanno, J.	2015
Arizona	Bicyclist and Pedestrian Count Strategy Plan	Kimley-Horn; Lee Engineering; Texas A&M Transportation Institute; Traffic Research & Analysis, Inc.	2018
Colorado	Colorado DOT Pedestrian and Bicycle Volume Data Collection Toolkit	Colorado DOT; Toole Design Group	2016
	Colorado DOT Non-Motorized Monitoring Program Evaluation and Implementation Plan	Colorado DOT; Toole Design Group	2016
Delaware	Delaware Department of Transportation Bicycle and Pedestrian Count Program Guide	Delaware DOT	2016
Florida	FDOT Statewide Non-Motorized Traffic Monitoring Program	Florida DOT; Marlin Engineering	2019
Idaho	Toolbox for Bicyclists and Pedestrian Counts	Idaho DOT; RBCI; Idaho Smart Growth	2013
Louisiana	Pedestrian and Bicycle Count Data Collection and Use: A Guide for Louisiana	Tolford, T.; Izadi, M.; Ash, C.; Codjoe, J.	2019
	Pedestrians and Bicyclists Count: Developing a Statewide Multimodal Count Program	Tolford, T.; Izadi, M.; Ash, C.; Codjoe, J.	2019
Michigan	Non-Motorized Data Collection and Monitoring: Program Guide and Implementation Plan	Michigan DOT; Toole Design Group; UNC Highway Safety Research Center	2019
Minnesota	The Minnesota Bicycle and Pedestrian Counting Initiative: Methodologies for Non-Motorized Traffic Monitoring	Lindsey, G.; Hankey, S.; Wang, X.; Chen, J.	2014
	Minnesota DOT Bicycle and Pedestrian Data Collection Manual	Minge, E.; Falero, C.; Lindsey, G.; Petesch, M.; Vorvick, T.	2017
North Carolina	Non-Motorized Site Selection Methods for Continuous and Short-Duration Volume Counting	Jackson, K.; Stolz, E.; Cunningham, C.	2015

Locality	Bicycle and Pedestrian Counting Guidance Document	Authors	Year
North Carolina	Quality Assurance and Quality Control Processes for a Large-Scale Bicycle and Pedestrian Volume Data Program	Jackson, K.; Worth O'Brien, S.; Searcy, S.; Warchol, S.	2017
New Hampshire	New Hampshire Bicycle and Pedestrian Transportation Advisory Committee: Counting Program Master Plan	Tufts, C.; Waitkins, M.; Hlasny, A.; Mellen, L.; Lemieux, D.	2015
Oregon	Bicycle and Pedestrian Counts at Signalized Intersections Using Existing Infrastructure	Kothuri, S.; Nordback, K.; Schrope, A.; Phillips, T.; Figliozzi, M.	2017
	Accuracy of Bicycle Counting with Pneumatic Tubes in Oregon	Nordback, K.; Kothuri, S.; Phillips, T.; Gorecki, C.; Figliozzi, M.	2016
Texas	Improving the Amount and Availability of Pedestrian and Bicyclist Count Data in Texas	Turner, S.; Benz, R.; Hudson, J.; Griffin, G.; Lasley, P.; Dadashova, B.; Das, S.	2019
Utah	Developing a Rubric and Best Practices for Conducting Counts of Non-Motorized Transportation Users	Burbidge, S.	2016
Vermont	Vermont Bicycle and Pedestrian Counting Program	Sentoff, K.; Sullivan, J.	2017
Virginia	Assessing the Feasibility of a Pedestrian and Bicycle Count Program in Virginia	Ohlms, P.; Dougald, L; MacKnight, H.	2018
	Automated Validation and Interpolation of Long-Duration Bicycle Counting Data	Bietel, D.; McNee, S.; McLaughlin, F.; Miranda-Moreno, L.	2018
	Designing a Bicycle and Pedestrian Traffic Monitoring Program to Estimate Annual Average Daily Traffic in a Small Rural College Town	Lu, T.; Buehler, R.; Mondschein, A.; Hankey, S.	2017
Washington	Collecting Network-wide Bicycle and Pedestrian Data: A Guidebook for When and Where to Count	Johnstone, D.; Nordback, K.; Lowry, M.	2017
	Optimizing Short Duration Bicycle and Pedestrian Counting in Washington State	Nordback, K.; Johnston, D.; Kothuri, S.	2018
	Bicycle and Pedestrian Count Portal	Washington DOT	2017
Arlington County	Bike Arlington: About Arlington's Automatic Counters	Bike Arlington	2019
	Bike Arlington: Counter Dashboard Disclaimer	Bike Arlington	2019
Los Angeles County; Southern California Association for Governments (SCAG)	2015 Los Angeles Bike and Pedestrian Count	Los Angeles County Bicycle Coalition	2015
Delaware Valley Regional Planning Commission (DVRPC)	DVRPC Travel Monitoring: Pedestrian and Bicycle Counts	DVRPC	2019

Locality	Bicycle and Pedestrian Counting Guidance Document	Authors	Year
San Diego Association of Governments (SANDAG)	San Diego Regional Bike and Pedestrian Counters	SANDAG; San Diego State University; County of San Diego Health and Human Services Agency	2013
	Designing and Implementing a Regional Active Transportation Monitoring Program through a County-MPO-University Collaboration	Ryan, S.; Saitowitz, S.	2013
City of Los Angeles	Conducting Bicycle and Pedestrian Counts: A Manual for Los Angeles County and Beyond	Kittelson & Associates, Inc.; Ryan Snyder Associates; Los Angeles Bicycle Coalition	2013
City of Orlando	MetroPlan Orlando: Pedestrian & Bicyclist Counts	MetroPlan Orlando	2016
	City of Orlando: Bicycle and Pedestrian Count Program Annual Report	City of Orlando	2016
City of Portland	Portland Bicycle Count Report: 2013-2014	Portland Bureau of Transportation	2014

NC NMVDP Organization

Program Description

The program began as a pilot project in November 2013 with the inclusion of NCDOT Divisions 7 and 9 in Phase 1. NCDOT Divisions 7 and 9 were selected for the pilot because these areas had the most comprehensive GIS dataset available on existing non-motorized facilities in NC at the time for use in site selection. Continuous counters were installed to monitor bicycle and pedestrian traffic at 13 locations by December 2014. Counting locations were spread across a variety of facility types to cover the automated detection of pedestrians on sidewalks, bicycles and pedestrians on shared use paths, bicycles in bicycle lanes, bicycles on sidewalks, and bicycles in shared lanes with motor vehicles. Pedestrian detection uses post-mounted passive infrared sensors. Bicycles are detected with inductive loops permanently cut into paved surfaces or buried under crushed gravel. The counting systems are called MULTI systems and are manufactured by Eco-Counter. The program expanded to NCDOT Divisions 4, 5, 8, and 10 under Phase 2 with the installation of continuous counters at 31 additional locations by June 2018. Continuous counters were installed at four additional locations under a separate NCDOT-funded research project. These counters were onboarded into the NC NMVDP and are included in the program's quarterly and annual data reporting.

Program development has focused on coordinated data collection. From the first pilot phase of the project through its second phase, ITRE tested and established coordinated data collection processes based on a linear set of research tasks. The program's administration and operations were restructured in late 2018 to better reflect the day-to-day, quarterly, and annual program processes that had been established since the inception of the program by establishing three coordination areas (Local Agency, Equipment, and Data) encompassed by overall program management.

The program model for Phase 1 and 2 was established under Memorandums of Agreement (MOAs) initiated between NCDOT and the local agency receiving the continuous count equipment. Under the signed MOAs, NCDOT owns the counting equipment until 24 months after the installation date. During this time, NCDOT is responsible for non-routine hardware and software maintenance, including battery replacement, replacing malfunctioning equipment, sensor replacement, and data transmittal charges (including GSM or cellular subscriptions). ITRE is contracted by NCDOT to perform the in-field counter maintenance. Twenty-four months after the installation date, the ownership of the counting equipment transfers to the local agency and the local agency is responsible for the counter maintenance and associated costs.

After the transfer of the counter ownership according to the signed MOA, the Phase 1 and 2 agencies transition from the NCDOT Ownership Model to the Collaborative Agency Model. For the useful life of the counting equipment, NCDOT will support data monitoring and management based on the processes and procedures established under the NC NMVDP. ITRE is contracted to provide the data monitoring and management support, including routine quarterly and annual data quality assurance & quality control (QA/QC), equipment validation, and data reporting. This scope includes limited support for field maintenance & troubleshooting. Agencies that have purchased and installed counters separately from the NC NMVDP can join the program under the Collaborative Agency Model by opting into the data management scope of work.

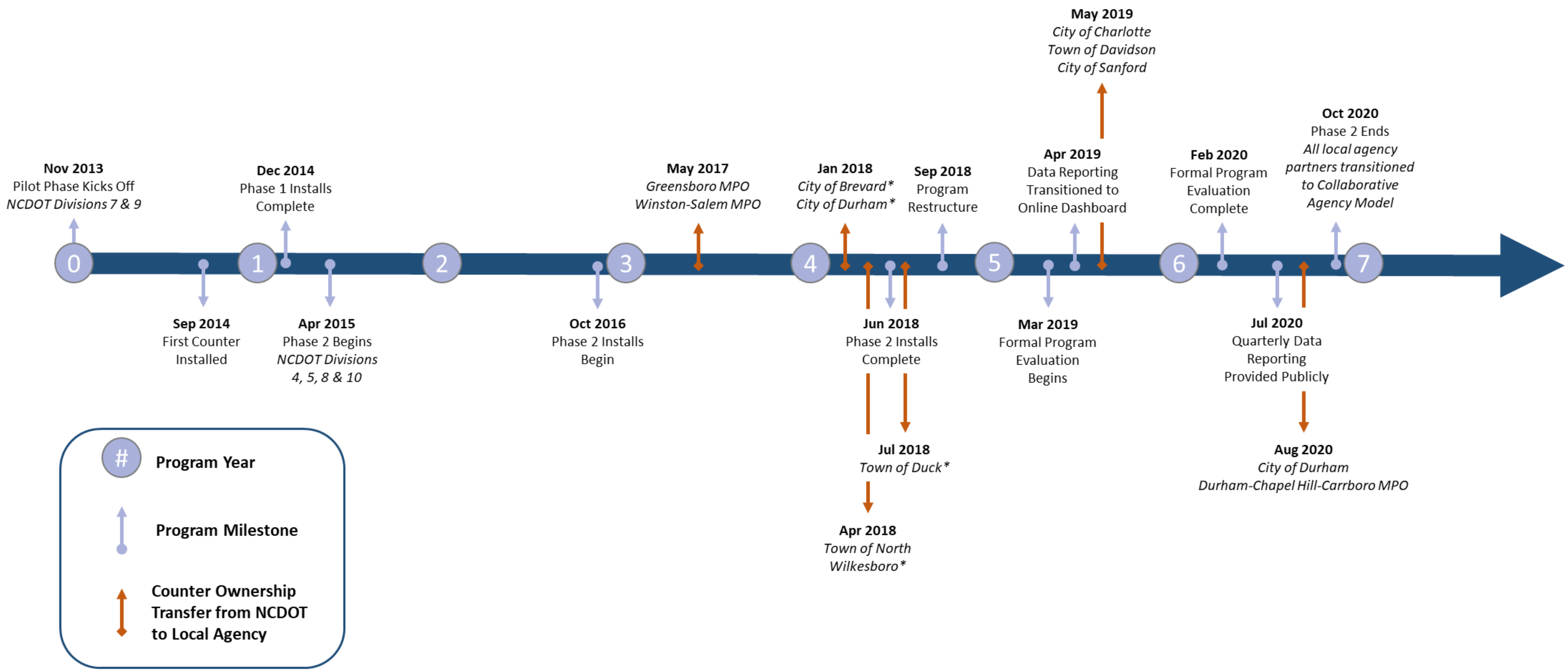
Figure 1 provides a timeline for the NC NMVDP from inception through the close of Phase 2. The timeline highlights program milestones and points where counter ownership was transferred from NCDOT to our Phase 1 and 2 local agency partners.

Program Coordination Areas

In late 2018, a new project manager took over leadership of the NC NMVDP and the program's administration and operations were restructured to better reflect the day-to-day, quarterly, and annual program processes that had been established since the start. The linear set of research tasks was reimagined and reorganized into a formal program structure based on three coordination areas (Local Agency, Equipment, and Data) encompassed by overall program management (Figure 2). The reorganization involved defining and assigning official roles to team members relative to the coordination areas and based on their individual expertise. This modular structure allows for: 1) each coordination area to be assigned a technical lead(s) for oversight of its day-to-day tasks, and 2) the ability to apply and scale services by opting partners into the scope of work for one or more coordination areas. The restructuring was informed by a series of team and one-on-one feedback meetings with key program staff that included reflection on the program's history. The restructuring has improved overall communication, coordination, and efficiency across and between the program's different interconnected functions and laid the foundation for future scaling of the program.

Two technical leads each were assigned to the Equipment Coordination (Hardware and Validation leads) and the Data Coordination (Monitoring/Processing and Analysis leads) areas. One technical lead was assigned to the Local Agency Coordination Area. Appendix 2 provides a detailed description of the roles and responsibilities within each program area.

Figure 1. NC NMVDP Timeline through Year 7 of the Program



*Installed under separate NCDOT-funded project

Figure 2. NC NMVDP Programmatic Organization

Program Framework

Figure 3 provides a logic model that depicts the NC NMVDP and the logical relationships among:

- The resources that are invested in the program (inputs),
- The activities that are implemented within the program's coordination areas and the participants who are engaged by the activities (outputs), and
- The intended results from the program activities based on short-, medium-, and long-term time horizons (outcomes). Long-term outcomes represent the ultimate impact(s) of the program.

Assumptions that guide and external factors that challenge the success of the program are provided. Short-term outcomes are associated with the Phase 1 pilot and Phase 2 through Year 5 of the program. Medium-term outcomes include those resulting from program adjustments during Year 6 of the program associated with the change in project leadership to be carried through Year 10. Long-term outcomes are those expected from Year 10 onward.

Year 1 through Year 5 of the NC NMVDP aligns with the program planning and implementation stages of development where inputs are established, activities are developed and performed, and short-term outcomes result. Year 6 onward represents the current program period and aligns with a transition towards the program maintenance state of development where medium- and long-term outcomes and continuous quality improvement through evolving established protocols are the focus.

The following sections summarize program activities and their objectives, implementation results, and recommendations organized by coordination area. While overall descriptions are inclusive of both Phase 1 and 2 of the NC NMVDP, activities that were specific to Phase 2 are highlighted including improvements that were applied based on Phase 1 outcomes.

Figure 3. NC NMVDP Logic Diagram

North Carolina Non-Motorized Volume Data Program (NC NMVDP)
Research project to test a bicycle and pedestrian count protocol for replication across the state.
Currently includes one of the most extensive statewide networks of continuous bicycle and pedestrian counting sensors and provides data management and reporting support for multiple local agency partners.

Inputs → Outputs → Outcomes

Inputs
Program Investments

Staff
-ITRE
-Subconsultants
-NCDOT
-Local Agency Partners
-Equipment Vendor

Grant Funding

Time

Equipment & Materials

Research
-Literature Review
-Best Practices
-Protocol Development & Testing

Steering & Implementation Committee
-Stakeholder Oversight

Outputs

Activities

Local Agency Coordination 1 2 3 4
-Training & Outreach
-Site Selection
-Agreement Execution

Equipment Coordination 1 3 4 5
-Procurement
-Inventory
-Installation & Onboarding
-Validation
-Maintenance

Data Coordination 1 3 4
-Monitoring
-Validation
-QA/QC
-Analysis
-Reporting
-Storage

Project Management 1 3 4
-Planning & Organization
-Budgeting
-Stakeholder Relations
-Interim Meetings

Participation

1 **NCDOT**
-Board of Transportation
-Divisions
-Research & Development Unit
-Steering & Implementation Committee

2 **Subconsultants**
-UNC System Partners
-Private Subcontactors

3 **Local Agency Partners**
-Regional Planning Organizations
-Municipalities

4 **Equipment Vendor**
-Eco-Counter
-MULTI Counting Systems
-Eco-Visio Software

5 **Contracted Services**
-Construction Contractors

Outcomes

Short (Year 1 - Year 5)

Local Agency Coordination
-Deliver presentations and trainings to increase awareness of the statewide effort to count bicycles & pedestrians and to recruit and prepare program participants
-Select continuous counting locations based on eligibility criteria, sampling strategy, local agency & NCDOT input, virtual audits, and field visits
-Execute encroachment agreements, interlocal agreements, and MOAs to govern the installation and ownership of the counting equipment

Equipment Coordination
-Procure, install, onboard, validate, and maintain counting equipment according to agreement provisions

Data Coordination
-Monitor, validate, QA/QC, analyze, report, and store count data

Project Management
-Ongoing program management including planning, organization, budgeting, and quarterly progress reporting

Medium (Year 6 - Year 10)

Local Agency Coordination
-Increase number of local agencies participating in the program through agreement type to opt counters into data monitoring & management services scope of work
-Develop and implement consistent schedule for delivering trainings & workshops to increase awareness of statewide counting program
-Deploy quarterly program newsletter through web platform to share updates on program processes, traning opportunities, and research results

Equipment Coordination
-Evaluate the latest advances in bicycle and pedestrian counting technology
-Reduce equipment down time related to maintenance events through improved communication with local agency partners and the primary equipment vendor

Data Coordination
-Transition to semi-automated web-based tool for quarterly & annual QA/QC
-Provide quarterly & annual data reports via vendor software dashboards instead of spreadsheet files

Project Management
-Adapt budget and program organization relative to efficiencies gained through improved partnerships and process automation

Long (Year 10 onward)

Local Agency Coordination
-Achieve program participation from local agency partners in all NCDOT Divisions

Equipment Coordination
-Maximize efficiencies related to equipment maintenance and validation by deploying the most effective bicycle and pedestrian counting technology matching to counting need

Data Coordination
-Maximine efficiencies related to data monitoring, validation, and QA/QC processing through process automation

Project Management
-Maximize budget and staffing efficiencies based on strengthened partnerships and process automation

Assumptions:
-Regional planning organizations, municipalities, and other program partners will have the necessary time and resources to contribute effectively to the program
-The program purpose aligns with the needs and goals of program partners to ensure enthusiastic buy in
-Funding and program oversight can be secured year over year
-Efficiencies can be achieved in count equipment type and data management processes

External Factors:
-Limited time, money, knowledge, and other resources prevent commitment from program partners
-Restrictions to program participation based on organizational power structures
-Program partners not enabled to contribute to decision-making related to program development

Local Agency Coordination

Activity 1: Training & Outreach

The objective of this activity was to deliver trainings and presentations to increase the awareness of the statewide effort to count bicycles and pedestrians and to recruit and train program participants.

Several resources were developed to provide information to local agency partners about the purpose of the NC NMVDP and expectations for their participation:

- Informational Webinar
    - Developed in Phase 2 as a tool to recruit local agencies into the program during its expansion into NCDOT Divisions 4, 5, 8, and 10.
    - Provided a high-level overview of the program, NCDOT's expectations, and a general process for the continued expansion of the program.
    - Provided a platform for program transparency to a broader audience of stakeholders and potential partners.
    - Was recorded and archived online for access by those who could not attend the live session.
- One-Day Workshop
    - Developed and piloted in Phase 1 and further applied in Phase 2 to initiate local agency partners into the program.
    - Provided training on the fundamentals of traffic monitoring, background on the program's goals and objectives, and guidance on the role of the local agency in the program.
    - Only local agency partners with representation at the workshop were eligible to continue participation in the program through Phase 2.
    - Held three workshops (one per every two NCDOT Divisions inducted into the program) to ensure adequate opportunities to attend for interested local agency partners.
- Local Agency Stakeholder Meetings
    - Two stakeholder meetings were held with local agency partners in Phase 2.
    - First meeting reviewed next steps in program participation process for local agency partners that had committed to continue with site selection process.
    - Second meeting reviewed agreement provisions including counter installation, maintenance, and data responsibilities to start coordination process for these tasks.
- Installation Video
    - Developed and piloted in Phase 1 and further applied in Phase 2 to train technicians and their supervisors on how to install and test non-motorized counting equipment.
    - Was archived online for access as a quick tutorial by NCDOT staff and local agency partners for future counting equipment installations.

The one-day workshop was the primary training in Phase 1, and additional resources were developed in Phase 2 as the NC NMVDP expanded from two NCDOT Divisions into four additional divisions. The frequency, number, and variety of presentations (in-person training, in-person stakeholder meetings, live webinar, and web-archived videos) were effective to both screen potential local agency partners and to provide committed partners with the information and tools needed to effectively collaborate with ITRE and NCDOT. This enabled consistent deployment of the NC NMVDP from the recruitment stage through site selection and installation of the counting equipment.

While presentations and trainings were given prior to counter installation, no additional presentations or trainings were provided (beyond the offer for one-on-one in-field cross-training with a local agency participant whenever ITRE was conducting maintenance or validation tasks) in the period between counter installation and counter ownership transfer until the change in project leadership in late 2018. Counter transfer could occur up to three years after local agency partners received their initial training if delays were experienced during the establishment of agreements and/or during the counter installation process. Further, the training offered upfront did not go into details about the ownership transfer process or specific needs, and written documentation of these details provided at the time of transfer proved an insufficient tool to educate the agencies. Local agency staff turnover also led to a gap in institutional knowledge about the counting program and the counting equipment.

The program team determined that presentations and trainings should occur on a regular cycle to ensure all local agency partners are provided consistent baseline information including guidance for performing their program responsibilities. Some improvements to local agency coordination were initiated beginning in late 2018 in preparation for the Phase 2 transfer of ownership process. An ownership transfer training packet was developed with the assistance of the equipment vendor to deliver to local agencies prior to receiving the ownership transfer memo. A phone meeting was also scheduled between local agencies and ITRE to set expectations for counter ownership as well as to answer any questions regarding maintenance or data services. After ITRE and local agencies reached a consensus about identifying staff who would be responsible for counters, data products, and additional trainings, a transfer of ownership memo was emailed, and counters were officially owned by the local agency. ITRE followed up at the transfer of ownership by scheduling an in-field meeting with the agencies for basic training on equipment maintenance and ensuring the local agencies were connected to the equipment vendor as their primary resource for equipment troubleshooting support moving forward.

In early 2019, a quarterly newsletter was developed to provide local agency partners information on program processes, training opportunities, research results, and any other information pertinent to program participation. The first newsletter was sent out in April 2019 using MailChimp and an updated NC NMVDP contact list.

On June 2nd, 2020, ITRE and Eco-Counter led a virtual workshop for local agency partners currently participating in the NC NMVDP. The purpose of the workshop was to:

- Review the expectations and responsibilities for local agencies participating in the NC NMVDP,
- Show how Eco-Counters work to count bicycles and pedestrians,
- Share new resources for inspecting, troubleshooting, and maintaining Eco-Counters, and
- Walk through how to view count data and do basic data visualization and analysis in the Eco-Visio software.

The presentations were recorded and additional resources were developed to assist local agency partners with caring for their counters and making the most of the data that they collect. These resources are available publicly on the program webpage.

Activity 2: Site Selection

The objective of this activity was to select continuous counting locations based on eligibility criteria, sampling strategy, local agency and NCDOT input, virtual audits, and field visits.

The site selection process for determining counting locations for the installation of counting equipment was developed and piloted during Phase 1 and further applied in Phase 2 of the NC NMVDP. The goal of the site selection effort is to create a prioritized list of recommended counting locations that can be used to guide equipment purchasing and installation. Eligibility criteria and a sampling strategy were driven by placing continuous counting locations into factor groups to inform future expansion of short-duration counts. A web-based site selection survey was deployed to prospective partner agencies that requested candidate counting locations for collecting bicycle and pedestrian counts on shared use paths, sidewalks, bike lanes, and shared lanes. Additional information could be entered on maintenance, volumes, user type, and a description about why the site was important for counting non-motorized users. Respondents could also report their willingness to participate in maintenance aspects. ITRE conducted virtual site audits using Google Earth and Streetview to filter all recommended sites into an initial ranking order that was prioritized according to the eligibility criteria including factor group, geographic area type, and anticipated travel pattern. The initial list of prioritized locations was used to schedule field visits. During the field visits, ITRE worked with local agency partners to develop a final set of counting locations and to determine the best location to install a continuous counter. Counters were placed in locations where volumes were believed to be high enough to establish a factor group that described temporal volume patterns. Several considerations were made to determine if a site was appropriate for installation:

- Bicycle inductive loops are affected by electromagnetic waves emitted by nearby utilities. An interference tester was used to determine exact locations where utilities would have minimal impact on bicycle counts.
- Pedestrian sensors were installed opposite of a physical feature that delineated the sensor zone. Per vendor instruction, physical features excluded glass and tall grass that could trigger miscounts. Appropriate physical barriers included: brick facades, concrete facades, wood facades, plaster facades, tree trunks, wooden fences, and bushes.
- Factor groups serve primarily to define temporal patterns in data volume, like changes in volumes over a day, week, and season. Therefore, volumes at a site must be high enough to statistically distinguish volume patterns over these time periods. Temporary counters were installed at Phase 2 locations to ensure that their volumes were sufficient before investing in permanent count equipment for a given site.

The multi-step site selection process that incorporated empirical data and stakeholder feedback was effective overall for selecting appropriate locations for the installation of continuous counting equipment. For the program pilot, the site selection survey was sent to prospective agencies before ITRE provided the one-day workshop training. To improve the transparency and efficiency of the recruitment and site selection process, an informational webinar was added to precede the deployment of the site selection survey in Phase 2. Local agency stakeholder meetings were also added in Phase 2 to review next steps in the program participation process for local agency partners that had committed to continue with the site selection process and to review agreement provisions including counter installation, maintenance, and data responsibilities to start the coordination process for these tasks.

For the Phase 2 expansion, rural locations (particularly rural bicycle shared-lane locations) were targeted for inclusion to ensure adequate representation of varied travel patterns based on the factor groups defined in the program pilot. Phase 2 candidates that did not proceed past the training or site selection steps were provided the same workshop training content, information on MOA expectations, and guidance on site selection criteria as agencies that continued forward to fully participate in the program. However, for rural agencies more interested in understating latent demand to make the case for new infrastructure to be built, the installation of one counter in their region on an existing facility was difficult to justify relative to the expected commitment and related costs for participation in the NC NMVDP.

Common factors cited as barriers to further participation in the program included: lack of time, lack of funds, and no staff or contract abilities to take over ownership or maintenance responsibilities. A missing piece of key information at the start of Phase 2 was the complete life cycle related to maintenance costs because ITRE did not fully know these values at the time that the informational webinar and workshops were conducted. Based on Phase 2 recruitment and site selection outcomes, to prevent inefficient use of time and resources and the perception of wasted effort, every effort should be made to secure a commitment to full participation in the program from local agency partners before the field visit stage of the site selection process. To inform a local agency's decision to commit to the program, better guidance on the criteria for selecting counting locations and a cost estimate for overall program participation, including for counter installation and maintenance as specified in the memorandum of agreement (MOA), should be provided to potential local agency partners if the site selection and agreements processes used in Phase 1 and 2 are applied in future program expansion efforts.

For context, Table 2 provides a summary of all local agencies that participated in site selection for Phase 1 and 2 for the NC NMVDP and indicates which agencies fully participated in the program through the installation of counting equipment. Note that Phase 1 agencies experienced a different training and site selection sequence and level of engagement compared to Phase 2 agencies. The recruitment process for Phase 1 agencies started with the site selection survey, while Phase 2 agencies were provided an informational webinar in advance of completing the site selection survey and additional follow up meetings.

Table 2. Local Agencies Involved in the NC NMVDP

AGENCY NAME	*NC NMVDP PHASE*	*PARTICIPATED IN SITE SELECTION PROCESS?*	*CURRENT PARTNER IN NC NMVDP?*
Winston-Salem Urban Area MPO	Phase 1	**Yes**	**Yes**
Greensboro Urban Area MPO	Phase 1	**Yes**	**Yes**
Durham Chapel-Hill Carrboro MPO	Phase 1	**Yes**	**Yes**
City of Durham	Phase 1	**Yes**	**Yes**
Town of Kernersville	Phase 1	**Yes**	No
Town of Sedalia	Phase 1	**Yes**	No
Town of Elon	Phase 1	**Yes**	No
Triangle Area RPO	Phase 1	**Yes**	No
City of Graham	Phase 1	**Yes**	No
Town of Summerfield	Phase 1	**Yes**	No
Burlington-Graham MPO	Phase 1	**Yes**	No
Guilford County Planning and Development	Phase 1	**Yes**	No
City-County Planning Board of Winston-Salem and Forsyth County	Phase 1	**Yes**	No
Town of Lewisville	Phase 1	**Yes**	No
Piedmont Triad RPO	Phase 1	**Yes**	No
City of Albemarle	Phase 2	**Yes**	No
City of Asheboro	Phase 2	**Yes**	No
City of Charlotte	Phase 2	**Yes**	**Yes**
City of Durham	Phase 2	**Yes**	**Yes**
City of Raleigh	Phase 2	**Yes**	**Yes**
City of Sanford	Phase 2	**Yes**	**Yes**
Capital Area MPO	Phase 2	**Yes**	**Yes**
Town of Davidson	Phase 2	**Yes**	**Yes**
Town of Brevard	*	**Yes**	**Yes**
Town of Duck	*	**Yes**	**Yes**
Town of North Wilkesboro	*	**Yes**	**Yes**
Durham-Wake Counties Research & Production Service District	Phase 2	**Yes**	No
Eastern Carolina RPO	Phase 2	**Yes**	No
Town of Apex	Phase 2	**Yes**	**Yes**
Town of Cary	Phase 2	**Yes**	**Yes**

*Installed under separate NCDOT-funded project; one City of Durham counter also included

AGENCY NAME	*NC NMVDP PHASE*	*PARTICIPATED IN SITE SELECTION PROCESS?*	*CURRENT PARTNER IN NC NMVDP?*
Town of Morrisville	Phase 2	**Yes**	No
Town of Nashville	Phase 2	**Yes**	No
Town of Pineville	Phase 2	**Yes**	No
Town of Smithfield	Phase 2	**Yes**	No
Town of Wake Forest	Phase 2	**Yes**	**Yes**
Triangle Area RPO	Phase 2	**Yes**	No
Upper Coastal Plain RPO	Phase 2	**Yes**	No

*Installed under separate NCDOT-funded project; one City of Durham counter also included

From Phase 1 through Phase 2, two counting locations were discontinued. Academy Drive in Winston-Salem was discontinued due to low volumes that could not establish statistically significant temporal patterns. The system at Academy Drive was uninstalled and moved to Polo Road in Winston-Salem. The counting location was converted to a “high-definition” (“HD”) configuration with more electromagnetic loops than the standard configuration to reduce error from counting motor vehicles in the shared lane. Polo Road was ultimately discontinued due to low pavement quality that led to pavement chips where the loops were installed.

One station on the Salem Lake Greenway in Winston-Salem was moved five years after installation due to the construction of a playground nearby that changed the volume patterns. The local agency decided that moving this counter would better capture the change in travel patterns that arose from the new feature. The counter was moved after its ownership was transferred to Winston-Salem from NCDOT.

A post that housed a pedestrian sensor and an Eco-Totem count display were hit and damaged by errant vehicles in Charlotte. Both incidents occurred in urban areas where the object was installed close to the motor vehicle travel lane. This highlights a potential risk to both equipment and motor vehicle operators when posts are installed in locations where the distance between the curb and the pedestrian zone is very small.

Bicyclists at certain sites often bypassed the sensor zone. This occurred where bicyclists preferred to ride in the center of the motor vehicle travel lane rather than on the shoulder or in the bike lane or where a driveway was used as a cut-through to avoid an intersection nearby. Determining bypass error statistics was incorporated in the validation process to quantify when users did not pass the detection zone versus when users passed the detection zone but were not counted by the sensor. Bicycle loops that were installed across shared vehicle lanes where bicyclists and motorists use the same lane produced counts with high margins of error (e.g., overcounts). The inductive loops and logger algorithms are designed to only count bicycles and should exclude motor vehicles. However, this observation supports the hypothesis that inductive loops are not the best method of collecting bicycle counts on shared lane facilities where bicycles are expected to share the same lane with motor vehicles.

Case study summaries describing examples of bicycle and pedestrian bypass error from Phase 1 and 2 of the NC NMVDP are provided in Appendix 3.

Activity 3: Agreement Execution

The objective of this activity was to execute encroachment agreements, interlocal agreements, and memorandums of agreement (MOAs) to govern the installation and ownership of the counting equipment.

Under Phase 1 and 2 of the NC NMVDP, local agency partners entered an agreement with NCDOT to install and maintain the counting equipment. This MOA provided details related to equipment specifications, responsibilities, timeline for installation, maintenance, equipment access, and data. An MOA is reviewed by the Board of Transportation and signed by the local agency and NCDOT to be fully executed. Under the signed agreement, NCDOT purchases the counting hardware and the local agency is responsible for the installation of the counters under the supervision of ITRE. Installation of the counters can be performed by local agency staff, by a contractor, or some combination of the two. NCDOT officially owns the equipment for the first two years after its installation after which the ownership is transferred to the local agency. ITRE as an agent of NCDOT is responsible for non-routine maintenance of the equipment during the first two years after its installation, a timeframe that should ideally track the equipment's two-year warranty period. ITRE staff provides the labor and expertise to ensure equipment is functional and NCDOT covers the cost of out-of-warranty equipment repairs and data services prior to the ownership transfer. All non-routine maintenance responsibilities transfer to the local agency upon ownership transfer including costs associated with battery replacement, equipment repair or replacement, and data services charges.

In Phase 2, one regional planning organization (Capital Area Metropolitan Planning Organization) opted for interlocal agreements between its local governments participating in the program and itself that were approved by local boards or councils in addition to the overarching MOA between itself and NCDOT. While this approach resulted in delays to counting equipment installation due to time needed to develop the interlocal agreements and get them approved, the final set of nesting agreements enabled intentional cost-sharing between the regional planning organization and its local governments that ultimately provided efficiencies for counter installation and maintenance at the equipment transfer of ownership.

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 (and ultimately maintain) the counter equipment on a state-maintained road. Encroachment agreements were not necessary on city-maintained facilities.

The current agreement model limits the cost burden on local agency partners during the first two years after the installation of the counting equipment. It also relies on ITRE's technical expertise to ensure the counting equipment is properly functioning and onboarded into the program and its data reporting cycle. This provides stability and consistency at the program planning and preliminary implementation stage. However, several issues arose from this cost-sharing model. Many smaller, typically rural municipalities were interested in participating in the program. However, they were unable to commit to the potential costs incurred after ownership transfer due to having more limited resources. These agencies were not able to dedicate staff to maintaining the equipment and were also less willing to take on the potential monetary risk of purchasing replacement parts after the warranty period. The permanent counters also did not typically meet the needs of the smaller agencies. Many smaller municipalities were more interested in collecting short duration counts on many facilities rather than continuous counts on one facility. The rural planning organizations were interested in participating in the NC NMVDP similarly to the Capital Area MPO's model to assist these smaller communities in participation, but they were instructed that the limited planning funds they had access to could not be used for these purposes. Only four counters in smaller rural municipalities were incorporated into the program as of 2019.

Additionally, the initial ownership transfer process attempted in Phase 1 left many local agencies unprepared for the effort and expertise required to properly maintain the counter equipment. Ownership transfer originally occurred when ITRE sent an email notifying the local agency of the transfer and evolved into an official memo that was sent by NCDOT to a local agency. This transfer occurred up to three years after the local agency partners had received trainings related to the NC NMVDP or equipment, and most local agencies did not take advantage of meeting ITRE staff in the field when maintenance was being conducted over this time period. Subsequently, the transfer-of-ownership process was reimagined in Phase 2 and included the development of a transfer training packet; meeting with local agencies to set expectations and answer questions; confirming the responsible, responsive staff within each agency; and following up with basic in-field training for the local agency after the counters were officially transferred. Several counters were also experiencing counting issues that were being troubleshooted by ITRE at the time of their official ownership transfer. Transferring the ownership and maintenance responsibilities mid-way through an equipment malfunction was not ideal for local agencies. ITRE also implemented a policy to ensure that counters were in working order and validated prior to transfer to local agencies. Some sites required at least two additional years of troubleshooting before ownership was transferred to the local agency due to equipment recalls and changes in utilities around equipment sites that negatively interacted with counts.

As one avenue for addressing uneven levels of investment and expertise between local agencies, NCDOT and ITRE developed an expanded program model named the Collaborative Agency Model where agencies who have purchased their own counter equipment can opt into the NC NMVDP's data monitoring and management services. A non-binding memo was developed in early 2019 to describe the scope of work to be performed by ITRE under contract to NCDOT to assist agencies with the activities associated with the data coordination area of the NC NMVDP.

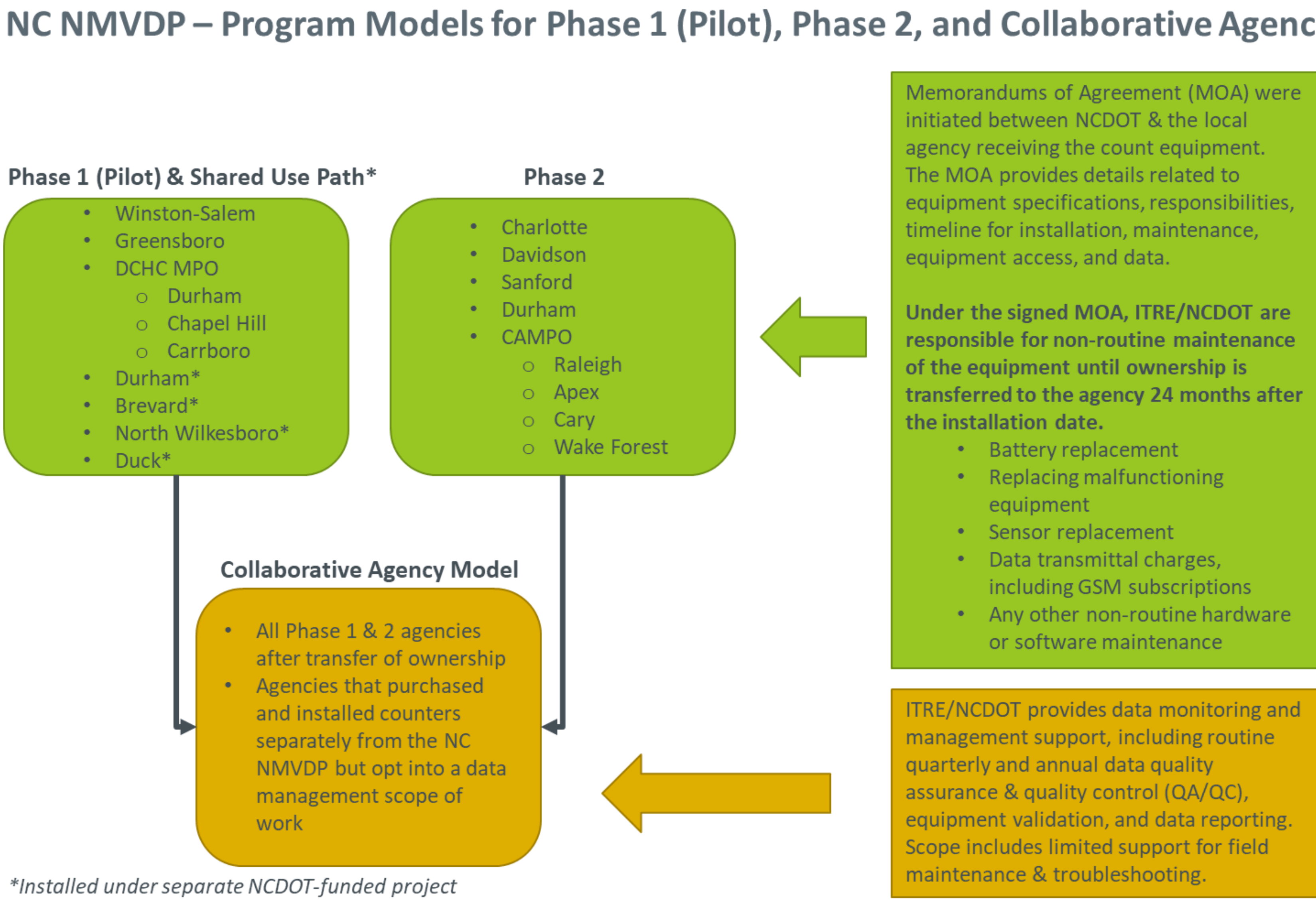
This new agreement type serves several functions:

- The expanded model distributes monetary costs incurred in purchasing new equipment.
- Local agencies are more invested in the proper maintenance of the equipment since they were directly involved in its purchase, installation, and initial training related to its use and care.

- Local agencies benefit from the NC NMVDP's expert data services including data monitoring to screen for potential maintenance issues, data quality assurance and quality control (QA/QC), equipment validation, and quarterly and annual data reporting.
- NCDOT benefits by growing the NC NMVDP by onboarding additional counters and their data while assuring the quality of the resulting statewide dataset through the application of standardized QA/QC and validation procedures.

Figure 4 summarizes the program model implemented in Phase 1 and 2 and the transition to the Collaborative Agency Model for all local agencies participating in the NC NMVDP. The Collaborative Agency Model was planned and developed under a separate research contract that becomes the scope of work for the NC NMVDP at the conclusion of Phase 2 in October 2020.

Figure 4. Program Models for Phase 1 (Pilot), Phase 2, and Collaborative Agency



Equipment Coordination

Activities 1-5: Procurement, Inventory, Installation, Validation, and Maintenance

The objective of these activities was to procure, install, validate, and maintain counting equipment according to agreement provisions.

Under Phase 1 and Phase 2 of the NC NMVDP, NCDOT was responsible for executing a purchase agreement with the equipment vendor and for purchasing new counters for installation with the goal of balancing budgetary constraints with anticipated program outcomes. All out-of-warranty equipment purchases for the replacement of malfunctioning counting systems or components were covered by NCDOT prior to the ownership transfer. Other costs covered by NCDOT during this period included replacement batteries and data services fees, including a subscription to Eco-Counter's API services. Local agencies were responsible for routine maintenance prior to transfer of ownership, which only included protecting the counters from environmental impacts such as construction or street maintenance. Upon ownership transfer, agencies were expected to employ various strategies for identifying funding sources to cover both fixed costs like equipment installation, automatic data transmission, and battery replacements as well as fluid costs like replacement counting systems and parts. Strategies include incorporating an estimate into the municipal annual budgeting process, incorporating the purchasing and maintenance of counters into greenway/shared use path construction scopes, or allocating funding from public transit plans.

Local agency partners were responsible for installing the continuous counters using in-house staff, a contractor, or a combination of both. ITRE provided guidance on pre-installation tasks such as marking utilities, acquiring tools and materials, coordinating traffic control, and any field set up needed in advance for equipment to be mounted, such as pouring concrete. ITRE also provided in field oversight during equipment installation, including testing for interference, assistance with installation diagrams and guidance on saw cuts, and testing installed equipment for proper functionality. ITRE staff documented details relevant to installation on a site installation sheet that was later digitized. Multiple photos of the installation process and site context were taken and archived.

After the equipment installation, ITRE onboarded the counters into vendor-provided counter management software and a standardized inventory tracking spreadsheet using metadata captured when the counting locations were specified at the procurement stage and on the site installation sheets. ITRE also conducted validation studies at each counting location. Validation serves to determine intrinsic error associated with each piece of equipment as well as verify that the counter is functioning. Validation occurred at the time of installation as well as when any part other than the counting system's external battery was replaced.

The initial validation process included the following steps:

- Field technicians initially test recently installed equipment in the field. Ten data points are collected by each sensor. If the sensor detects at least 80% of test points, then the counter is cleared for video validation.
    - Most counters pass this initial test and many at 100% accuracy, but passing this test does not necessarily mean that no adjustments need to be made to a counter's calibration settings since a larger sample size is needed to verify (especially to assess false positives).
- One or more standard video cameras are installed to observe the counting location for two to four days.
- ITRE staff and students review two days of video to determine a manual count of pedestrians and cyclists who enter the counter's detection zones.
- The manual count is then compared to the data recorded by the Eco-Counter over the same time period to determine the counter's accuracy and to calculate a correction factor.

ITRE staff also developed and maintained a detailed field maintenance log during Phase 2 to outline parts replaced, actions taken, troubleshooting performed, and field staff present during counter maintenance visits prior to ownership transfer. Vendor provided warranties, installation booklets, and site specifications were organized and archived. Labels indicating failing equipment were created to tag components that were removed from systems and were to be recycled or shipped back to the vendor for repairs. Journals were also kept by field technicians as a resource for documenting lessons learned.

Non-routine maintenance was required due to a variety of causes. Causes of counting equipment damage or malfunctioning included:

- Cell phone tower interference with data transmission from the system modem
- Utility interference that was not present at the time of installation
- Bug infestation of wooden posts that contained pedestrian sensors*
- Water runoff eroding area around the valve box that contained the system components
- Cigarettes burns on the pedestrian sensor lenses
- Wooden posts rotting*
- Water infiltration into system components*
- Degradation of wire casing (vendor recalled systems with this issue)
- Vendor system recalls*
- Inductive loops cut by road or lawncare crews
- Counter display or post struck by motor vehicle
- Graffiti and flyers on posts containing pedestrian sensors

  **indicates most common causes of counter/sensor damage*

High-quality installation and setup of counting equipment leads to better data outcomes and less field maintenance needs during the counter's lifetime. On-site installation must be coordinated between all agencies, contractors, and project personnel. All personnel responsible for the counting equipment should be present to become familiar with the location details, determine possible issues that could arise at the site, and develop plans for reacting to future development or construction that may impact bicycle and pedestrian traffic. Installation diagrams, GPS coordinates to identify the counting locations, names of contributing field staff, and other notes relevant to installation should be documented on a paper site installation sheet to be later digitized. Multiple photos of the installation process and site context should be taken and inventoried.

To get a better understanding of the costs and time associated with typical maintenance tasks so that local agencies could be provided with more clear expectations of cost estimates and best practice strategies to implement upon ownership transfer, ITRE conducted a review of the Phase 1 maintenance records. Based on this review of historic maintenance records for the two-year period from April 2016 through March 2018, at least 58 maintenance events were addressed through field visits for 19 counting systems representing 13 counting locations. The majority of these events were battery replacements (28; 48%) followed by modem failure with no data transmission (8; 14%), counting equipment replacement (7; 12%), general troubleshooting (6; 10%), debris removal (5; 9%), calibration settings adjustment (2; 3%), vandalism (1; 2%), and corrosion (1; 2%).

An estimate for the total cost related to time and labor for field maintenance and equipment validation is provided in Table 3 including the assumptions used. For the two-year period from April 2016 through March 2018, it is estimated to have cost $13,660 to cover the time and labor for maintenance and equipment validation for the Phase 1 counting systems while under the ownership of NCDOT. These costs include travel-related costs for ITRE staff which would not necessarily be an associated cost for a local agency in comparison.

Table 3. Estimate of Time and Labor Cost for Maintenance and Equipment Validation for Phase 1 Systems from April 2016 through March 2018

Assumptions	Amount
n	
Screenline Counting Locations (Stations)	13
Maintenance Field Visits*	51
Maintenance Trips*	29
Validation Events	13
hr	
Hours of Validation/ValEvent	12
Hours of Travel/MainTrip	2.5
Average Field Labor Time/MainFieldVisit	1.5
$USD	
Student Wage/Hour (Fully Loaded)	$13
Staff Wage/Hour (Fully Loaded)	$51
Shipping/ValEvent	$30
Mileage/Trip (Per Mile Cost)	$0.59
Tasks	**Cost**
Travel Time	$5,310
Car Rental	$2,450
Field Labor - Staff	$3,870
Validation Labor - Student	$2,030
Grand Total	***$13,660***

**A field visit occurs on a per counter basis; more than one field visit can occur during a maintenance trip by chaining multiple field visits in a single trip*

Table 4 provides a summary of the total cost for the Phase 1 and Phase 2 specified counting systems as well as all other replacement systems, components, and batteries not covered under warranty and purchased by NCDOT through July 2019.

Table 4. Estimate of Total Cost of Phase 1 and 2 Counting Systems and Replacement Items

Phase	Type	Total Cost
1	Phase 1 Specified Systems	$145,271
2	Phase 2 Specified Systems	$399,351
Both	All Other Replacement Systems/Components/Batteries	$26,442
	Grand Total	***$571,064***

Punctuality in addressing counting issues was variable between agencies. This was due to varying levels of agency investment in the counters and their data as well as diverse strategies for maintaining equipment that led to variable periods of equipment malfunction. Some agencies hired contractors who required more time and communication to resolve an issue and were generally less nimble, while others identified an in-house primary maintenance technician who could troubleshoot counters as needed as a part of their job duties. The original consequence per the MOA for a local agency not maintaining a counter was to decommission the counting location and remove the equipment. However, given the labor and capital already invested into creating a functioning system at a given site, decommissioning it was held as an absolute last resort, and all efforts were made to aid a local agency in getting malfunctioning sites up and running again. Overall, for several local agencies, inadequate resources, the unpredictability of maintenance issues, and resulting cost for multiple replacements and repairs are major barriers to fulfilling maintenance responsibilities.

The ultimate outcome from delayed maintenance is missing data during periods when the counting equipment was malfunctioning or inoperable. Table 5 provides a summary of historic missing count data by program year. A more detailed breakdown of historic missing data by individual counting location is provided in Appendix 4. Please note that many counting systems were affected in 2017 by a vendor recall related to degradation of wire coverings and resulting corrosion to system components. This issue resulted in a high rate of missing data particularly for counters located in Charlotte, NC.

Table 5. Historic Missing Count Data by Program Year

NC NMVDP - Historic Missing Count Data						
Year	Number of Screenline Counting Locations by Mode	Total Possible Days of Data	Missing Days of Data	Total Possible Hours of Data	Missing Hours of Data	Percent Missing
2015	24	8,760	131	210,240	3,144	1.5%
2016	28	10,220	490	245,280	11,762	4.8%
2017	48	17,520	3,571	420,480	85,704	20.4%

Maintenance of counters is a key component of the NC NMVDP. Maintenance events grew more frequent and required more time to resolve as the number of counters and their geographic coverage increased from Phase 1 through Phase 2. ITRE hired a full-time counter field technician in early 2018 to address the accumulation of maintenance needs more efficiently prior to the equipment ownership transfer. This staff member also serves as the equipment coordinator. Hiring a counter field technician and their assignment as equipment coordinator led to higher quality maintenance practices. This dedicated staff member was able to:

- Hone intuitive and investigative skills which are critical in determining counter malfunction causes,
- Become an expert on the environmental context of all counters in the program which led to more efficient troubleshooting,
- Oversee the improvement and expansion of field and equipment documentation, and
- Share their expertise with supporting technical staff to develop a skilled and informed team of field technicians.

The following measures are recommended to ensure effective communication, shortened maintenance timelines, and lower potential for damage to the counting equipment:

- Build familiarity with counter system operations and component functions
    - Utilizing clear and accurate terminology when describing the equipment minimized miscommunications among the NC NMVDP team as well as between the field staff and the vendor technical support staff.
- Develop a relationship with the equipment vendor to establish two-way communication between technology experts
    - The vendor often had insight into the hardware and software that was unavailable to the field staff, e.g., component recalls, software glitches, and firmware updates required.
    - Field staff also learned details about the systems over time from vendor technical support staff which led to more knowledgeable and independent field staff.
- Incorporate reasonable timelines for troubleshooting, procuring replacement parts, and maintaining systems
    - Shipping and receiving delays are common.
    - Weather related work delays occur frequently.
- Develop a robust documentation system that includes paper and electronic copies of field maintenance logs, vendor communications, labeling and inventorying of system components, site and equipment photos, and warranty documents
- Communicate with the local street maintenance teams to flag areas where bicycle loops are installed so that agencies can know when reinstallation will need to occur
- Communicate with lawn care contractors of adjacent apartment complexes to flag areas where sensor wires may be exposed and make every effort to minimizing wire exposure
- Visit sites at least every six months to inspect for sensor damage and to clean graffiti

NCDOT should 1) consider formalizing an assistance plan to address ongoing maintenance and troubleshooting support for local agencies even after ownership of counters has transferred and 2) reevaluate the current agreement model related to resource obligations for long-term maintenance of the counting equipment in anticipation of future program expansion. Proper training and knowledge sharing with local agency partners, appropriate expectations for recurring resource commitments for non-routine counter maintenance, and the efficient utilization of ITRE's technical expertise and toolkit for counter diagnostics are important considerations for properly maintaining the count equipment.

An overview of the counters installed in Phase 1 and 2 of the NC NMVDP by municipality, mode, and facility type is provided in Appendix 5. Case study summaries describing common and unique maintenance issues from Phase 1 and 2 of the NC NMVDP are provided in Appendix 6. The installation and onboarding form used in Phase 2 is provided in Appendix 7. The maintenance log form provided to local agencies in Phase 2 is provided in Appendix 8.

Data Coordination

Activities 1-6: Monitoring, Validation, QA/QC, Analysis, Reporting, and Storage

The objective of these activities was to monitor, validate, QA/QC, analyze, report, and store count data.

Data is manually monitored by an ITRE staff member on a weekly basis. This process was established in Phase 1 and further refined in Phase 2 to include improved record-keeping and a standardized internal email to update the entire program team on the weekly data monitoring results. Judgement is used to determine if the data transmitted indicated a counter malfunction. Data that were not transmitted for over three days, multiple days of daily volumes of zero, and overcounting were common indicators of maintenance needs. Data anomalies identified in the monitoring process are communicated to the equipment coordinator and field technicians so they can schedule and perform troubleshooting and maintenance on the affected counting equipment.

All counting systems in the NC NMVDP are validated to determine the margin of error inherent in the sensors. 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 because the sensor will detect one person instead of two. Possible error in inductance loops could occur when the loops detect vehicles other than bicycles, such as mopeds or other motor vehicles. Correction factors were determined based on validation testing in conjunction with guidance from NCHRP Report 797 and NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection.

Validation studies were conducted after any counting system was installed or replaced, or when any component other than the battery was replaced. Due to the high maintenance demand of the counters, many validation studies were conducted. An initial validation procedure was performed by field technicians at the counting site after maintenance events. Technicians would simulate ten counting events on each sensor. If the sensor detected at least 80% of the simulated counting events, then a video camera was installed to observe the site for a longer period (typically three to four days). If the sensor did not detect at least 80% of simulated counting events correctly, then the sensor was flagged for further maintenance. The two full days of video with the highest number of bicycle and pedestrian counts as collected by the counters were chosen for review. Correction factors were calculated as follows:

$$CF = \frac{\sum two\ day\ bidirectional\ manual\ count}{\sum two\ day\ bidirectional\ count\ as\ recorded\ by\ sensor}$$

A summary of correction factors as observed in the 2015 through 2019 period are provided in Figure 5 and Figure 6.

Figure 5. Pedestrian Validation Study Results – 2015 through 2019

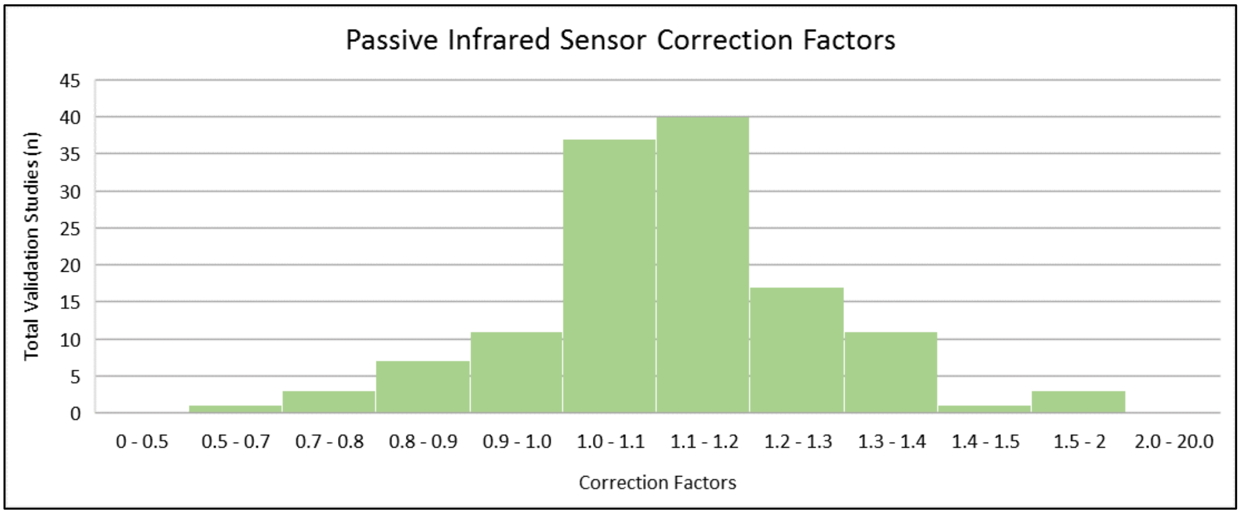
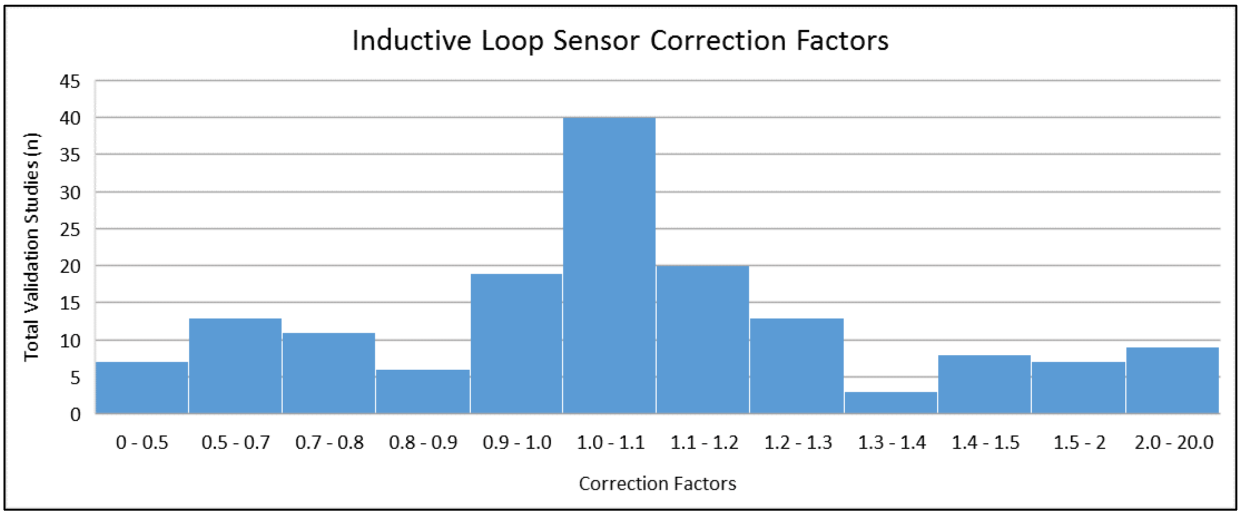


Figure 6. Bicycle Sensor Validation Results – 2015 through 2019



The results of the validation studies support the need for rigorous assessment of equipment beyond an initial in-field test through formal video-based validation studies to calculate correction factors for the sensors. Each study was performed after the recently installed or replaced system passed an initial in-field validation test. However, there were still instances of sensors that passed the initial field test but were recording data with unacceptable margins of error. Inductive loop sensors were especially prone to error outside acceptable range. This could be due to sensor damage upon installation, motor vehicle traffic encroaching on the sensor area more than anticipated, or sensors originally set to detection settings that are incompatible with the site.

Causes for correction factors that were out of acceptable range included: bicycle loops installed in lanes shared with motor vehicles, sensor settings that were incompatible with the sensor environment, and installation of counting systems with recalled parts.

ITRE suggests that agencies take the following steps to address validation issues:

- Observe vehicles passing near or over bicycle sensor areas for bicycle loops that are installed in roadways to determine if the counts are heavily influenced by motor vehicle traffic
- Avoid installing bicycle loops in roadways where motor vehicles and bicycles share facilities or in a manner where the bicycle loops do not encompass the entire riding surface allowing bikes to bypass
- Test sensitivity settings while in the field to determine which may be the most appropriate for the site

Since the NC NMVDP's inception, electric scooter-share became a popular mode of travel. According to the validation studies conducted under the NC NMVDP, electric scooters are not detected by inductive loops, but are detected by passive infrared sensors. Electric scooters are currently not included in a validation study's bicycle counts but are included in a study's pedestrian or sidewalk user counts.

ITRE developed and implemented QA/QC checks as a mechanism to identify invalid data recorded by malfunctioning equipment as well as to tag atypical days of valid data. Invalid data are scrubbed from the raw dataset to create a clean dataset. The original checks developed in Phase 1 of the program are outlined in Table 6. Initially, an Excel workbook was used to store a raw dataset, apply QA/QC checks, review flags, and scrub data for the dataset. Data for each counting location was downloaded from the vendor-provided software (Eco-Visio) to a local server and then copied into a sheet in the QA/QC workbook. All flagged data were manually reviewed by ITRE to determine if the flags identified invalid or atypical data. Checks were successful if only data produced by malfunctioning counters and data resulting from special events or inclement weather were flagged. Several scaling challenges arose from this approach as the NC NMVDP expanded. These include:

- The QA/QC Excel workbook was computing large datasets which caused the software to crash often; downloading data from Eco-Visio was time-consuming and copying data between workbooks was prone to errors.
- Large blocks of invalid data from failing sensors fed into statistical checks which invalidated the interquartile range and two direction-related check parameters.
- The user had to review all flagged data, which was a time-consuming process.
- Creating cleaned and corrected reports required a system that was time consuming and prone to user error.

This time-consuming and error-prone quality assurance process was not easily scalable as more counter systems were onboarded. The data checking system was also not effective for low volume counting locations or counting locations with long time periods of malfunction. Updates to the process were necessary to successfully scale the NC NMVDP. Addressing each of these issues led to the development of the semi-automated, web-based data reporting platform. This platform incorporates the following features to mitigate the issues:

- Incorporation of the Eco-Visio API to minimize data download time and risk of error

- Establishment of additional conditional checks that automatically remove data from malfunctioning sensors (see new tests in Table 6)
- A two-tiered flag process that auto-scrubs data outside a threshold set by the user to filter the number of days of data that need to be reviewed by the user
- An auto-reporting software that applies correction factors, aggregates data, and scrubs flagged data to create a file ready for upload into the Eco-Visio platform

Table 6. Summary of Data Checks Performed on NC NMVDP Continuous Count Data

Order	Test	Type	Description	Purpose
1	gap	Conditional	Test the number of hours in a day labelled NULL (no transmission)	Scrub no transmission days
2	zero	Conditional	Determines if daily sum equals zero, tests how many days in a row where daily sum equals zero	Scrub days with unreasonable length of consecutive zero counts
3	max_day	Conditional	Autoscrubs days with daily sums greater than a designated maximum value	Scrub days with physically impossible daily sums
4	max_hour	Conditional	Autoscrubs days containing an hourly sum greater than a designated maximum value	Scrub days with physically impossible hourly sums
5	3AM	Conditional	Tests if any hour between 3:00 AM and 5:00 AM has an hourly total greater than a designated maximum value	Flag days with unreasonably high "low-activity hours" volumes
6	prop	Conditional	Determines if any hour of the day accounts for an "unreasonable" proportion of the days total counts	Looks for "spikes" in hourly data; days where the volumes during certain hours are disproportionately higher than the rest of the day
7	dirsam	Statistical	Calculates mean and standard deviation of the ratio of NB/SB or EB/WB travelling users on the same facility, flags days with ratios outside of x standard deviations of the mean	Identifies outliers to the "normal trend" direction travelled on the same facility/side of street
8	diropp	Statistical	Calculates mean and standard deviation of the ratio of E/N side of street data with W/S side of street data, flags days with ratios outside of x standard deviations of the mean	Identifies outliers to the "normal trend" in facility occupancy on opposing sides of the street
9	interquartile	Statistical	Calculates the interquartile range of all remaining unflagged data, flags outlier data outside of Q3 + x*(Q3-Q1)	Identifies extreme outliers of dataset; volumes are too low and variable to include a lower bound
Key		Historic Test	These checks were developed during the NC NMVDP 2014 Pilot Phase (Phase 1). The statistical checks can only be performed after at least three months of verified data (no equipment malfunction) are collected.	
		New Test	Checks that were developed in 2018 – 2019 Phase 2 to remediate check issues related to large blocks of invalid data present in datasets. Parameter recommendations are currently in testing phase.	

Under Phase 1 and 2, data reporting in the NC NMVDP occurred on both a quarterly and an annual basis. Quarterly and annual data reports were provided to local agency partners in emailed Excel spreadsheets. Annual data reports and manually prepared summary reports were also uploaded to the NC NMVDP program webpage on the ITRE website. Beginning with 2020 Quarter 2, quarterly data reports are provided publicly through the Eco-Visio web application. Previously, only local agency partners currently participating in the NC NMVDP were provided access to quarterly data reports, and only annual data reports were available to the public. This change was implemented to ensure more timely access to verified count data collected by counters in the NC NMVDP. Quarterly data reports are published to the program webpage in addition to directly notifying local agency partners. Annual data reports were transitioned to the Eco-Visio web application beginning with the 2019 annual data report which includes all available historic count data for a given counting location.

Quarterly reporting is defined by the three-month seasonal period in which data were 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)

Quarterly reports were cleaned, but not corrected. Quarterly report cleaning was a manual process up to 2020 Quarter 2 when automated QA/QC checks were implemented supported by user review of flagged data. Data from known malfunctioning counters were removed and replaced with null values. No correction factors were applied to quarterly reports since validation studies were often pending for recently repaired or installed counters. The purpose of the quarterly reports was to update local agencies on the functional status of counters in their municipalities as well as provide preliminary count data and trends for sites. Quarterly reports will likely transition to the updated QA/QC process once the method is fully tested.

In late 2018, quarterly data reporting was transitioned from the emailed tabular spreadsheets and manually prepared summary reports to Eco-Visio, a vendor-provided web application. Local agency partners can download tabular data, map their counter locations, and analyze their data using charts and graphs through the web application's dashboard system. This technology update saved dozens of hours in report preparation and enables local agencies to access verified and validated data in a timely manner and in an accessible format. Login information and links to the quarterly data reporting dashboards are provided to local agency partners through a standardized email within 30 days of the last day of a quarterly data reporting period.

Annual reports were also transitioned from tabular spreadsheets and manually prepared summary reports to Eco-Visio's online dashboard system. Annual hourly data were cleaned and corrected per the updated QA/QC process. An automated report was generated that aggregated data at each station to the total screenline report across all facilities by mode. A screenline represents aggregate bidirectional data for a single mode (cyclist or pedestrian) across either one or two sensors, depending on site configuration. This means that counts are aggregated on both sides of a facility by mode, e.g., counts on both sidewalks along the segment are aggregated for pedestrians and counts on both bike lanes along a segment are aggregated for bicycles. Data were reported in hourly totals. Sensor hourly totals were multiplied by the correction factor as calculated in the applicable validation study. If any sensor was failing during a time period, the entire screenline count was scrubbed from the dataset. The auto-generated annual data report was uploaded into site profiles created by ITRE in the Eco-Visio counter management platform, which was referenced by the Eco-Visio dashboard platform. Only processed count data (cleaned quarterly or cleaned and corrected annual data) can be viewed in the quarterly and annual data reporting dashboards hosted by NCDOT's domain in Eco-Visio. Local agency partners can view raw count data from their counters through a separate log-in process to their own domain in Eco-Visio.

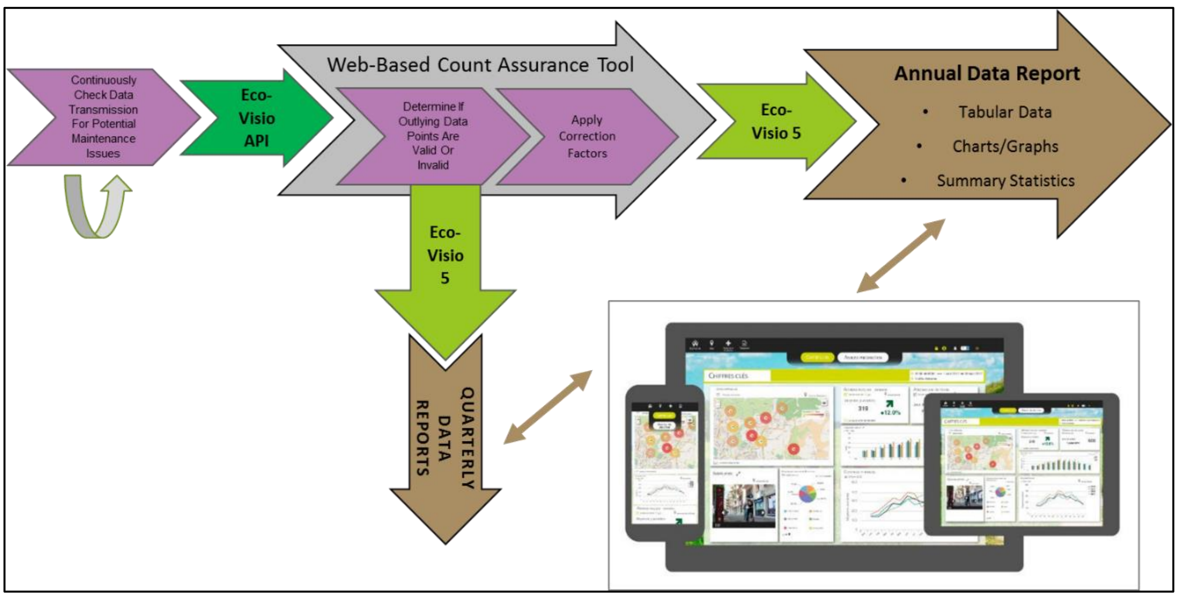
Eco-Visio dashboards display:

- Map pinpointing the location of either the midpoint between two counters for stations composed of two counters or the location of a singular counter at stations composed of one counter
- Line chart of all daily totals by mode at the station
- Tabular dataset of timestamped hourly aggregated screenline data available for download onto a local server
- Summary statistics, including:
    - Average volumes by hour of day
    - Average daily volumes by day of week
    - Average daily volumes by month
    - Daily mode split between bicycles and pedestrians
    - Daily average by mode

Each dashboard was incorporated into a publicly available Eco-Visio profile. Login information and links to each dashboard were published on the NC NMVDP landing webpage.

A summary of the updated data handling, cleaning, and reporting process is outlined in Figure 7.

Figure 7. Data Handling and Reporting Process



Based on lessons learned from early program implementation and updates to processes beginning in late 2018, data coordination processes have become more efficient and effective. Updates include consistent weekly data monitoring, transitions to semi-automated QA/QC processes and online data reporting using vendor software, and improved coordination between data and equipment technicians to reduce the amount of equipment downtime that results in periods of missing, unrecoverable count data. Further improvements could include providing ongoing training to local agency partners on Eco-

Visio and Eco-Link software and providing additional data statistics such as factors by time, season, and weather.

Moving forward, greater focus should be placed on data analysis, including developing a standard process for calculating statistics from the count data based on the needs of local agency partners. Local agency partners should be also be provided training resources so they can effectively access and analyze their own data along with consistent communication on the differences between raw, quarterly, and annual data with disclaimers specifying appropriate uses for each type.

A detailed description of the data processing, validation QA/QC, and reporting workflow is provided in Appendix 9. An updated factor group analysis is provided in Appendix 10 that reviews the factor group assignments for counting locations in Phase 1 of the NC NMVDP and revises assignments based on an updated methodology.

Future Work

From Phase 1 through Phase 2 of the NC NMVDP, programmatic processes were updated, streamlined, and better documented to better meet the needs of diverse agencies across North Carolina and to lay the foundation for future program expansion. Agencies planning or updating a regional approach to bicycle and pedestrian projects can adopt the lessons learned from the North Carolina model. Local agencies maintaining a smaller equipment inventory are encouraged to adopt standardized practices as resources allow. Collaboration between local agencies and regional entities was key to standardizing the data collection practices in North Carolina. Additional recommendations include:

- Equipment must be closely monitored and maintained. Agencies can often underestimate the labor and capital required to ensure that the counting systems are functioning properly.
- Statewide or regional agencies can leverage existing resources by partnering with agencies who have already installed counters in their municipality; the role of the statewide or regional count management entity in this case is to quality assure locally owned count systems and install counting systems to fill gaps in data collection.
- Data must be validated and verified. The originally proposed data handling and reporting system in the NC NMVDP was updated to better scale the program. Additional QA/QC checks were introduced to improve the performance of the QA/QC process. Data flagging and scrubbing was transitioned to automated reporting.
- Software updates can be leveraged to produce data reports more efficiently.
- Collaboration with local agencies, regional entities, and NCDOT can be further extended to develop a short duration counting area within the NC NMVDP.

Recommendations for Program Expansion

Moving forward, all agencies participate in the NC NMVDP under the Collaborative Agency Model and are provided the expert services that fall mostly within the Data Coordination area of our program, routine quarterly and annual data quality assurance and quality control (QA/QC), equipment validation, and data reporting. This scope includes limited support for field maintenance & troubleshooting. In addition, the verified and validated data collected by all counters in the program are stored in a centralized dataset that is made available to the public. A training workshop will be held for all agencies participating in the program on at least an annual basis.

The important tasks that are the responsibility of our local agency partners that own their counters are those related to the field maintenance, troubleshooting, and repair of their counting equipment. Figure 9 provides a flow chart representing data monitoring, maintenance, and validation for Eco-Counters in the NC NMVDP. This chart shows who is responsible for each task, whether the local agency, ITRE, Eco-Counter or a combination. This flow chart was developed as a reference so that expectations are aligned and so that the counters stay in good operating order to achieve high-quality count data.

The process starts with ITRE's weekly visual inspection of raw count data as it is transmitted by the counters included in our program. If a counter is flagged as malfunctioning based on data review, the local agency is notified by ITRE via email. Eco-Counter technical support staff is copied on this email so they can begin to assist promptly with diagnosing the issue. At this point in the process, the local agency is responsible for coordinating with Eco-Counter to schedule a site visit and troubleshoot the counter's issue. If new components or factory repairs are required that involve uninstalling the counter and returning it to Eco-Counter, the local agency will work with Eco-Counter to remove the system and ship it to the company. Eco-Counter will invoice the local agency directly for any repairs, components, or services. Once the counter is returned, the local agency will reinstall the counter. Depending on the circumstances, ITRE may at this point assist with a validation study to assess the accuracy of the counter after it is repaired. Validation is required when a sensitivity setting is changed or any part associated with the counting system is changed. Based on the results of the validation study, additional maintenance may or may not be needed. If so, ITRE will notify the local agency and the process will repeat until the issue is completely resolved.

Program Resources

Resources developed from the NC NMVDP are published on an official program webpage (Figure 8). Preliminary quarterly data reports, official verified and validated annual data reports that include our historic annual data, historic quarterly newsletters, and our program deliverables are archived on this webpage.

Figure 8. NC NMVDP Webpage

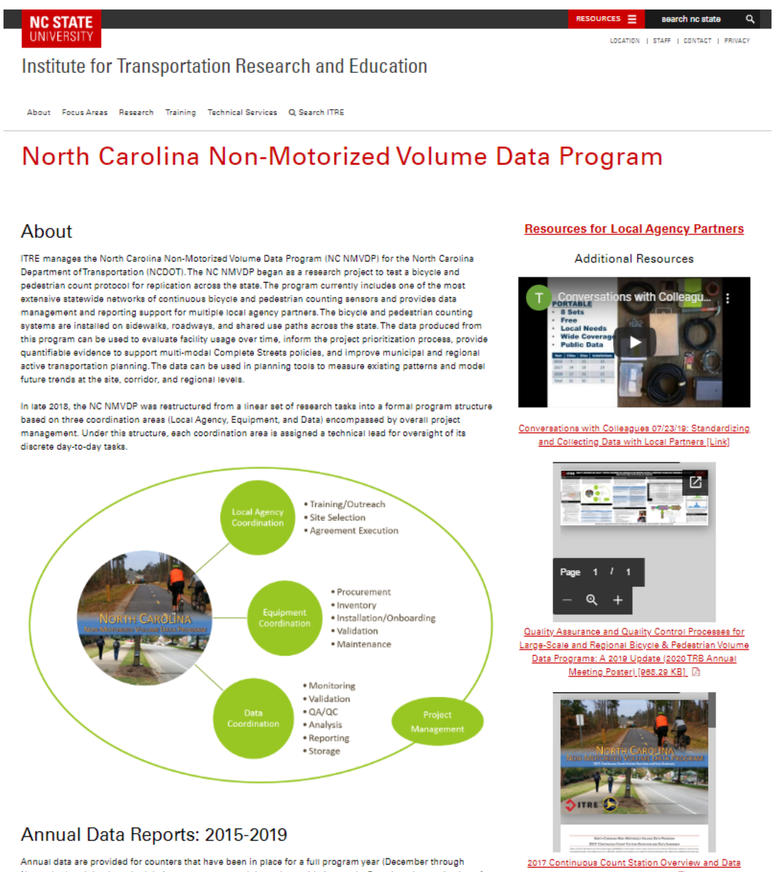
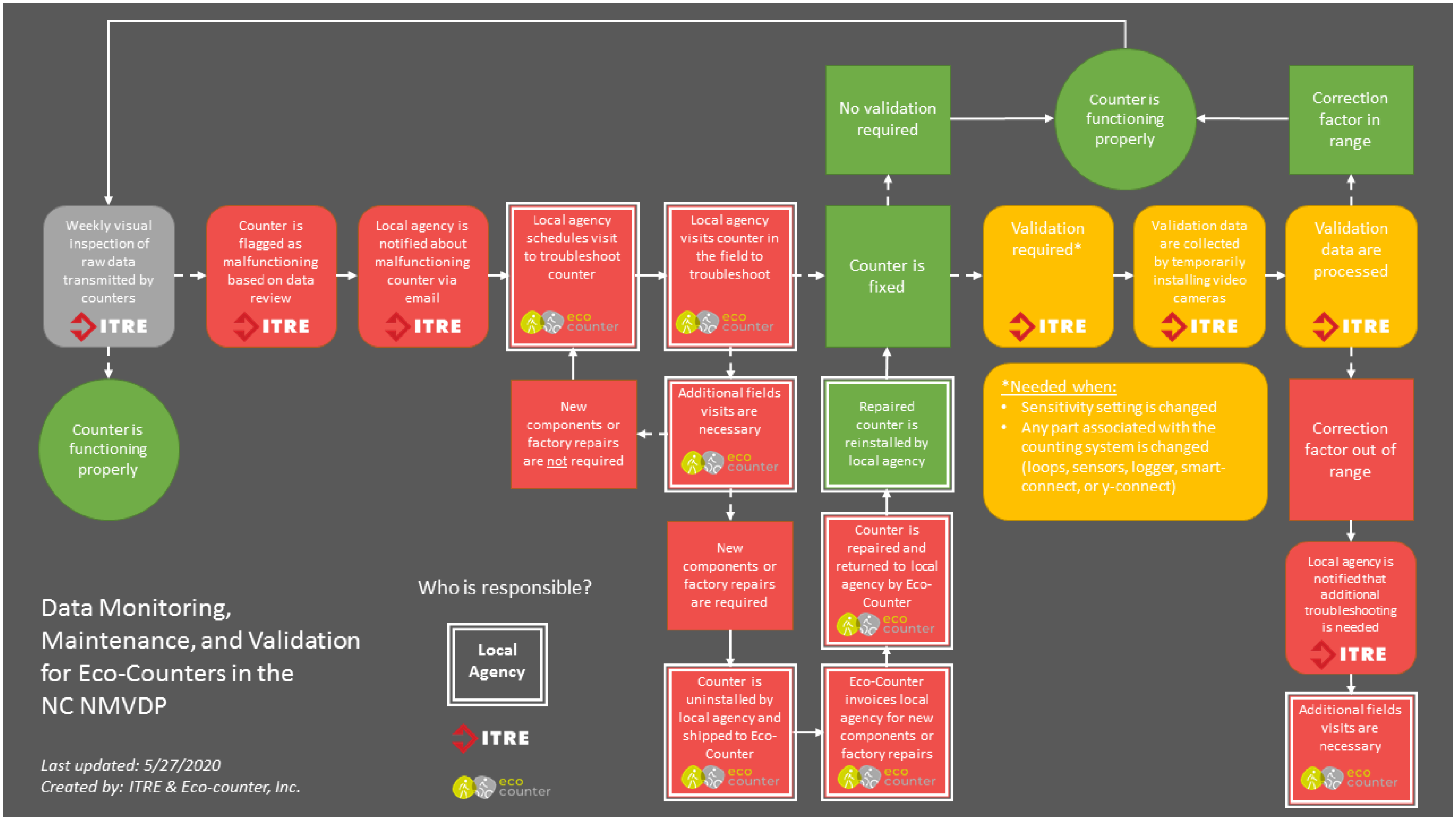


Figure 9. Data Monitoring, Maintenance, and Validation for Eco-Counters in the NC NMVDP – Collaborative Agency Model



Onboarding Counters via Data Management Scope of Work

Beginning in May 2019, NCDOT expanded the NC NMVDP under the Collaborative Agency Model to onboard counters that were purchased and installed outside of Phase 1 and 2 to accelerate the amount of data collected and analyzed through the program. The services provided to local agencies include data monitoring, data quality assurance and quality control (QA/QC), equipment validation, and data reporting.

The specific scope of work includes:

Task 1: Data Monitoring

- Review and inspect data for anomalies that trigger troubleshooting/maintenance
- Notify local agencies of data anomalies (i.e., data trends that trigger troubleshooting/maintenance process)
- Provide support for maintenance field work if needed to include troubleshooting remotely via telephone/email
    - Field visits may be permitted on rare occasions
- Notify local agencies of impending battery changes

Task 2: Data Quality Assurance/Quality Control

- Implement QA/QC processes to coincide with annual data reporting
- Document invalid and atypical data
- Record data cleaning actions and missing data

Task 3: Equipment Validation

- Perform validation study if triggered by a maintenance issue
- Calculate correction factors
- Inform local agency point of contact if further maintenance field work is needed based on the outcome of a validation study

Task 4: Data Reporting

- Report data quarterly and annually through Eco-Visio web-based software provided by Eco-Counter to include tabular data files and summary charts/graphs

As of October 2020, the following agencies have joined the program under the data management scope of work:

- Town of Carrboro
- Town of Cary
- City of Charlotte
- City of Greenville
- City of Raleigh – Department of Parks, Recreation, and Cultural Resources
- Isothermal Planning and Development Commission

- North Carolina Department of Human and Health Services (NC DHHS) – North Carolina Division of Public Health (NC DPH) – Community and Clinical Connections for Prevention and Health (CCCPH) Branch
    - Pedestrian Counter Loaner Program

Moving forward, the NC NMVDP will focus on further expansion under the Collaborative Agency Model by targeting and onboarding counters that are currently installed and operating in North Carolina.

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Appendices

Appendix 1. NC NMVDP Program Evaluation Results – Executive Summary

The program evaluation assessed the effectiveness of the North Carolina Non-Motorized Volume Data Program (NC NMVDP). The program evaluation results will inform strategic improvements to current program processes and guide efficient and productive expansion of the program in subsequent phases.

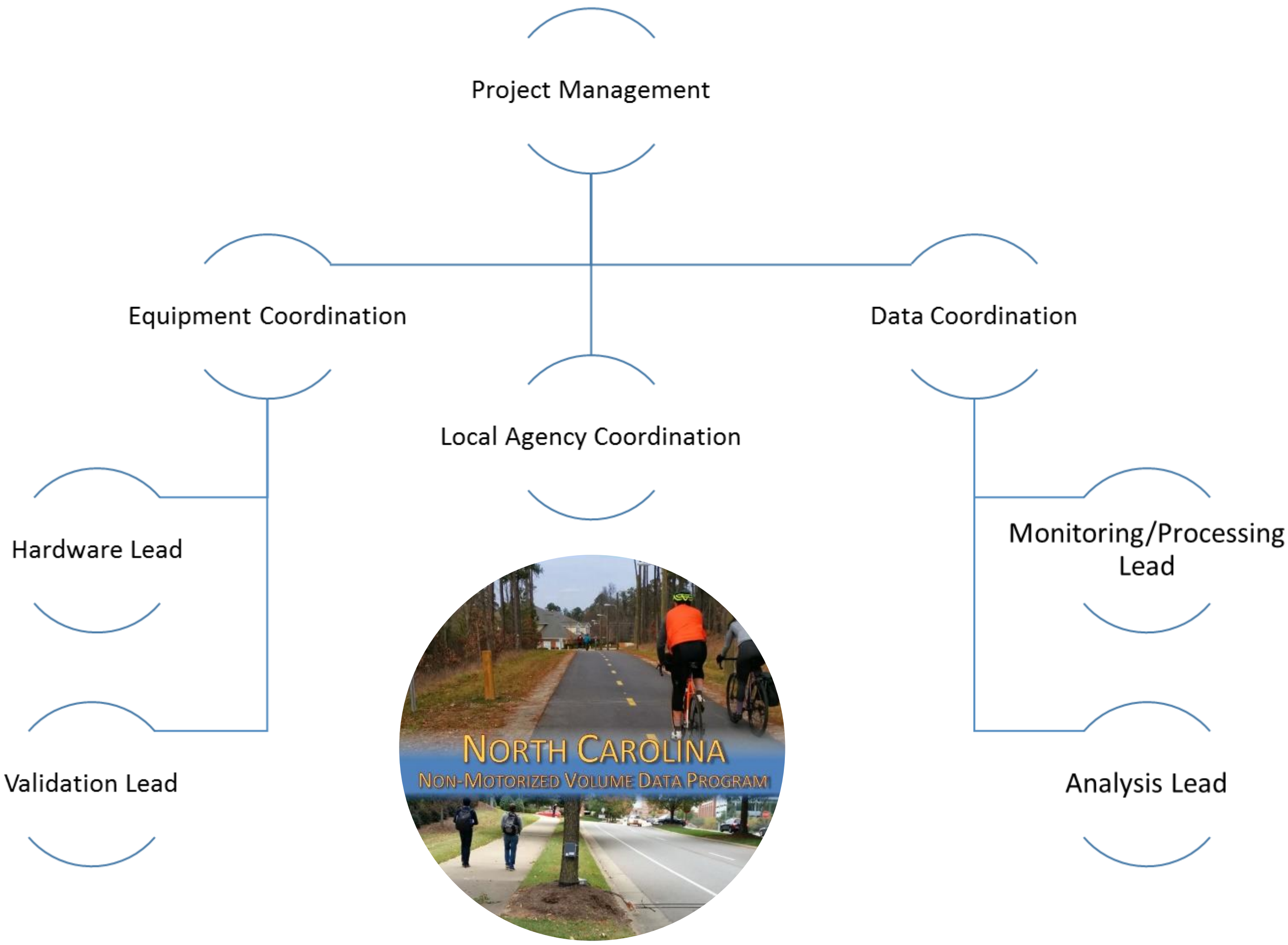
Based on an assessment of program objectives, activities, and their implementation, the following areas should be addressed to improve overall program delivery:

- **Improve communications related to program coordination and delivery of services**
    - Develop and implement a consistent schedule for delivering trainings and workshops to external partners to provide regular reinforcement of program responsibilities, reduce loss of institutional knowledge, and increase overall awareness of the statewide counting program
    - Deploy quarterly newsletter through web platform to share updates on program processes, training opportunities, and research results
    - Convene a stakeholder group to ensure regular discussions and ongoing feedback on program strengths and weaknesses to ensure needs are met
    - Reengage the program's Steering and Implementation Committee (St&IC) to provide consistent and regular project guidance and oversight
- **Determine the ultimate model for long-term equipment maintenance**
    - Define a formal plan for ongoing maintenance and troubleshooting support for local agencies with ownership transferred counters
        - Consider additional contracted field support to local agencies for higher level maintenance issues to leverage technical expertise and counter diagnostics toolkit
        - Improve frequency and consistency of training to empower local agencies to handle basic troubleshooting and maintenance
- **Determine the future program expansion model**
    - Reevaluate the current agreement model related to the ownership of equipment and corresponding resource obligations for long-term maintenance of the counting equipment
    - Explore applying a data monitoring and management scope of work to opt in local agencies that have purchased and maintain Eco-Counters that are not currently included in the program
        - Scale across the state by integrating count data from independently installed counters
        - Address gaps in geographic coverage by identifying and recruiting additional local agency partners and installing new counters based on best practice from Phase 1 and Phase 2 site selection and equipment installation protocols
    - Consider other equipment vendors based on improvements in technologies in comparison to the performance of Eco-Counters
    - Develop and pilot a short duration counting arm of the program
- **Develop a programmatic strategy for using count data to develop and apply statistics and performance measures**

  - Determine standard process for calculating metrics from the count data based on the needs of local agency partners

- **Determine timeline for NCDOT institutionalization of the NC NMVDP**
  - Determine if NC NMVDP or some portion of the program will ultimately be handled in-house at NCDOT

Appendix 2. NC NMVDP Coordination Areas – Roles and Responsibilities



<u>Project Management</u>

Planning/Organization

- Define and clarify project scope, plan, and schedule
- Define, clarify, and assign project positions, roles, and responsibilities
- Monitor coordination areas
- Ensure project goals and deliverables are met

Budgeting

- Develop, monitor, and revise (if needed) project budget

Stakeholder Relations

- Administrative communications to ensure stakeholder needs are met

Interim Meetings

- Coordinate and schedule project progress meetings

Local Agency Coordination

Training/Outreach

- Volume monitoring training workshop for prospective partner agencies
- Pre-installation and transfer of ownership meetings with agencies to review roles and responsibilities
- Present information about the NMVDP at state and national level through conferences and webinars

Site Selection

- Site selection survey to prospective partner agencies
- Field visits
- Prioritize and confirm sites for counter installation
- Generate preliminary list of equipment and cost estimates

Agreement Execution

- Monitor agreement execution to ensure timely completion
    - Memorandums of Agreement
    - Interlocal Agreements
    - Encroachment Agreements
    - Transfer of Ownership

Equipment Coordination – Hardware Lead

Procurement

- Provide list of equipment needs to project manager to give to NCDOT for purchasing based on site selection and when parts need to be replaced due to damage or malfunction

Inventory

- Inventory new equipment as it is received from Eco-Counter

Installation/Onboarding

- Coordinate with local agency and/or contractor on installation schedule
- Perform interference testing, prepare site diagrams, and mark pavement in preparation for installation
- Test and troubleshoot equipment to verify data transmission
- Fill out Onboarding Checklist form
- Complete onboarding in Eco-Visio via administrative account
    - Serial number activation
    - Verifying credentials

Local agency and/or their contractor is responsible for traffic control, marking of utilities, and physical installation of equipment including cutting loops and setting posts.

Maintenance

- Call Eco-Counter to determine if issue is a back-end issue that does not require a field visit
    - No data transmission
    - Data anomalies
- Determine who will perform maintenance field work if needed
- Prepare materials for field techs for maintenance trips
    - Briefing document with instructions, equipment guidelines, and summary of data anomalies and potential issues
    - Tools needed to perform maintenance

- Send maintenance tracking sheets to local agencies and remind them to complete them if equipment ownership has transferred
- Organize the maintenance tracking sheets in binders
- Track incoming and outgoing hardware packages to Eco-Counter
- Coordinate with validation lead if validation studies are triggered

Equipment Coordination – Validation Lead

Validation

- Coordinate the video data collection for validation after counter installation or when a validation study is triggered by a maintenance event (logger/sensor/Y or smart connect replacement and/or settings change)
    - Create camera installation schedule for the current month based on validation needs list provided by data coordinator
    - Notify Local Agency contacts and police departments prior to camera installs
    - Install and remove cameras based on schedule
    - Upload video to secure server
    - Verify video quality
    - Verify data transmission for video collection period
    - Assign student research assistant to video data reduction
- Calculate correction factor
- Share correction factor results with equipment lead and data monitoring/processing lead
    - If the correction factor for a counter is outside of tolerance range ($0.6 < CF < 1.4$; represents 40% error), maintenance may be needed
- Perform revalidation if triggered by maintenance issue, such as sensitivity setting changes and/or part/system replacement

Data Coordination – Monitoring/Processing Lead

Monitoring

- Review and inspect data for anomalies that trigger troubleshooting/maintenance
- Compose weekly maintenance/data issue(s) email and update technicians & project manager
    - Project manager will notify local agencies of data anomalies (i.e. data trends that trigger troubleshooting/maintenance process) based on analyses conducted by monitoring/processing lead
    - Project manager will notify local agencies of impending battery changes after equipment transfer of ownership based on record keeping conducted by monitoring/processing and hardware leads
- Determine who will perform maintenance field work if needed

Validation

- Confirm correction factor
- Discuss correction factor anomalies if needed
- Discuss maintenance field work with equipment coordinator if triggered by validation study
- Discuss revalidation approach with equipment coordinator if triggered by maintenance issue

QA/QC

- Implement QA/QC processes to coincide with data reporting at the quarterly and annual level

    - Document invalid and atypical data
    - Record data cleaning actions and missing data
- Continue ongoing refinement of QA/QC procedures
    - Re-evaluate data checks annually
    - Develop web-based application for automating QA/QC processes
- Continue ongoing refinement of TMG data processing and submission to Federal TMAS database

Reporting

Reportable data is prepared by monitoring/processing lead, reviewed by analysis lead, then reviewed/sent to local agencies by project manager

- Report data each quarter through standardized email to agencies provided within 30 days of the last day of a reporting period
    - Q1: Winter (December, January, February)
    - Q2: Spring (March, April, May)
    - Q3: Summer (June, July, August)
    - Q4: Fall (September, October, November)
- Report data annually through standardized email to agencies and posting to ITRE website
    - Annual counts data file
    - Annual site narratives (count station site overview and data summary)

Storage

- Ensure data consistency and integrity across all files
    - Raw data as downloaded from Eco-Visio
    - Scrubbed/cleaned data (quarterly reports)
    - Cleaned/corrected data (annual reports)
    - Validation data
- Develop relational database to connect all required records and documentation for each datastream using TMG station record formatting for station & datastream assignment (station > counter > sensor > datastream)
    - Maintenance records including field maintenance logs & Eco-Counter repair/service records such as shipping and case records
    - Validation records
    - Correction factor records

<u>Data Coordination – Analysis Lead</u>

Analysis

- Generate statistics and analyses for site narratives on an annual basis
    - Station description information with aerial site diagrams/street view images
    - 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

- Define the methodology for generating the statistics based on what is available each year, generate the annualized statistics, and estimate their level of reliability to communicate to the audience what range of values the true value could be

Appendix 3. Sensor Bypass Analyses

Counting Location	Libba Cotten Bikeway (Carrboro, NC)
Counting Location Identifier	CRB_LCB
Mode Affected by Bypass	Pedestrians
Description of Bypass Behavior	Pedestrians bypass the counter where the path crosses over the tracks around a bend in the trail. Instead of using the path, pedestrians walk down the train tracks parallel to the counter. Multiple pedestrians were observed playing on these tracks, attempting to balance on the outer rails or taking pictures. The rail line is an active rail spur and bypass by walking along these tracks represents not only a data issue due to pedestrian undercounting, but also a potential danger for conflict with locomotives using the rail line.
Bypass Frequency	2% (15 out of 693 observations from 32 hours of video-based validation)
Validation Video Image	

Counting Location	**New Hope Church Road (Cary, NC)**
Counting Location Identifier	CRY_NHC
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter by riding in center of the travel lane or near the centerline instead of on the shoulder where the sensors are placed. The roadway has low motor vehicle traffic in both directions, which incentivizes bicyclists to ride wherever they are comfortable due the low potential for conflict. Bypass also occurs when bicyclists turn from New Hope Church Road into the American Tobacco Trail trailhead without slowing and making a wide arc from the travel lane prior to passing the counter.
Bypass Frequency	5% (9 out of 168 observations from 29 hours of video-based validation)
Validation Video Image	

Counting Location	Old NC Highway 86 (Carrboro, NC)
Counting Location Identifier	CRB_OLD
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter when approaching the intersection by moving from the shoulder into the travel lane for through or left turn movements. The roadway has low motor vehicle traffic in both directions, which incentivizes bicyclists to ride wherever they are comfortable due the low potential for conflict. If a bicyclist is anticipating that they will make a left turn towards the school at the intersection, then they distance themselves from the shoulder and ride in the middle of the road or along the center dividing line. When they reach the intersection, they are free to make the right turn unimpeded because traffic volumes are typically low.
Bypass Frequency	54% (106 out of 198 observations from 30 hours of video-based validation)
Validation Video Image	 

Counting Location	**Ridge Road (Raleigh, NC)**
Counting Location Identifier	RAL_RID
Mode Affected by Bypass	Pedestrians
Description of Bypass Behavior	Pedestrians bypass the counter when they leave the sidewalk and use the bike lane as an alternative path. Runners will use the bike lane to go around slower pedestrians on the sidewalk or will use the bike lane as their primary pathway.
Bypass Frequency	10% (55 out of 533 observations from 28 hours of video-based validation)
Validation Video Image	

Counting Location	**South Tryon Road (Charlotte, NC)**
Counting Location Identifier	CLT_STR
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter when they ride on the sidewalk instead of in the bike lane. Electric scooters traveling on the sidewalk are counted as pedestrians. Electric scooters traveling in the bike lane are not counted by the electromagnetic loops. High motor vehicle traffic and congestion incentivizes bicyclists to use the sidewalk instead of the bike lane for safety. Electric scooters often exceed the speed of bicyclists and their users appear comfortable traveling in the bike lane. Increased regulations on scooter share has reduced this form of bypass to negligible levels.
Bypass Frequency	13% (46 out of 341 observations from 28 hours of video-based validation)
Validation Video Image	 

Counting Location	Pecan Avenue (Charlotte, NC)
Counting Location Identifier	CLT_PCN
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter when they ride on the sidewalk instead of in the bike lane. Electric scooters traveling on the sidewalk are counted as pedestrians. Electric scooters traveling in the bike lane are not counted by the electromagnetic loops. High motor vehicle traffic and congestion incentivizes bicyclists to use the sidewalk instead of the bike lane for safety. Electric scooters often exceed the speed of bicyclists and their users appear comfortable traveling in the bike lane. Increased regulations on scooter share has reduced this form of bypass to negligible levels.
Bypass Frequency	11% (22 out of 204 observations from 28 hours of video-based validation)
Validation Video Image	

Counting Location	**Rocky Branch Trail (Raleigh, NC)**
Counting Location Identifier	RAL_RBT
Mode Affected by Bypass	Pedestrians
Description of Bypass Behavior	Pedestrians bypass the counter when they cut the corner to head down Dorothea Avenue towards Western Boulevard. Bicyclists do not bypass the counter and are channelized across the sensor by the wooden bollards that are placed across the path.
Bypass Frequency	10% (19 out of 190 observations from 32 hours of video-based validation)
Validation Video Image	 

Counting Location	**Hargett Street (Raleigh, NC)**
Counting Location Identifier	RAL_HAR
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter by riding in center of the travel lane or near the centerline instead of at the far edge where the sensors are placed. There are no bike lanes, but sharrow markings indicate that the travel lane is shared with bicyclists. The roadway has low motor vehicle traffic in both directions, which incentivizes bicyclists to ride wherever they are comfortable due the low potential for conflict.
Bypass Frequency	4% (5 out of 140 observations from 28 hours of video-based validation)
Validation Video Image	  

Counting Location	Hillsborough Street (Raleigh, NC)
Counting Location Identifier	RAL_HIL
Mode Affected by Bypass	Bicyclists; Pedestrians
Description of Bypass Behavior	Bicyclists bypass the counter on the south side when they move from the bike lane into the travel lane to avoid conflicts with on-street parking or based on a preference to ride in the travel lane. Bicyclists bypass the counter on the north side based on a preference to ride in the travel lane, especially when traveling in large groups during group rides. Pedestrians bypass the counter on both sides when they use the bike lane instead of the sidewalk. Electric scooters traveling on the sidewalk are counted as pedestrians. Electric scooters traveling in the bike lane are not counted by the electromagnetic loops. Electric scooters often exceed the speed of bicyclists and their users appear comfortable traveling in the bike lane to avoid pedestrian congestion on the sidewalks. Since the location is positioned between downtown Raleigh and North Carolina State University, the sidewalks are heavily used by students commuting to shops or residences east of the campus.
Bypass Frequency	Bicyclists: 21% (81 out of 385 observations from 31 hours of video-based validation); Pedestrians: 6% (85 out of 1,436 observations from 31 hours of video-based validation)
Validation Video Image	

Counting Location	Louis Stephens Road (Cary, NC)
Counting Location Identifier	CRY_LOU
Mode Affected by Bypass	Pedestrians
Description of Bypass Behavior	Pedestrians bypass the counter when they use the roadway instead of the sidewalk. This bypass behavior was not present prior to COVID-19. It appears to be influenced by social distancing behavior when the sidewalk is congested. Some pedestrians enter the roadway to pass others on the sidewalk coming from the opposite direction. Most pedestrians return to the sidewalk after they pass.
Bypass Frequency	West side: 9% (10 out of 116 observations from 19 hours of video-based validation)
Validation Video Image	 

Counting Location	Main Street (Durham, NC)
Counting Location Identifier	DRH_MAI
Mode Affected by Bypass	Bicyclists
Description of Bypass Behavior	Bicyclists bypass the counter when they ride on the sidewalk instead of in the bike lane. Pedestrians bypass the counter when they use the bike lane instead of the sidewalk. This location is close to the main campus of Duke University, and students use a variety of means to travel along the corridor, including electric scooters, bicycles, and skateboards. They ride on the sidewalk, in the bike lane, and in the travel lane.
Bypass Frequency	Bicyclists: 7% (11 out of 154 observations from 32 hours of video-based validation); Pedestrians: 4% (15 out of 351 observations from 32 hours of video-based validation)
Video Validation Image	 

Counting Location	Olive Chapel Road (Apex, NC)
Counting Location Identifier	APX_OLI
Mode Affected by Bypass	Bicyclists; Pedestrians
Description of Bypass Behavior	Bicyclists bypass the counter when they travel towards the center of the lane instead of over the sensor on the shoulder. The shoulder is very narrow with guardrail on the north side as the roadway approaches a bridge across I-540. Pedestrians bypass the counter when they use the roadway instead of the sidewalk. This bypass behavior was not present prior to COVID-19. It appears to be influenced by social distancing behavior when the sidewalk is congested. Some pedestrians enter the roadway to pass others on the sidewalk coming from the opposite direction. Most pedestrians return to the sidewalk after they pass.
Bypass Frequency	Bicyclists: 9% (6 out of 66 observations from 28 hours of video-based validation); Pedestrians: 6% (28 out of 471 observations from 28 hours of video-based validation)
Video Validation Image	  

Appendix 4. Detailed Summary of Historic Missing Count Data

Municipality	Location	Mode	2015 % Invalid Data	2016 % Invalid Data	2017 % Invalid Data
Brevard	Brevard Greenway	Bike	n/a	0.0%	0.0%
Carrboro	Old Highway 86	Bike	3.3%	0.8%	15.1%
Carrboro	Libba Cotton Bikeway	Bike	3.3%	0.0%	6.6%
Chapel Hill	Martin Luther King Jr Blvd	Bike	3.8%	0.0%	89.9%
Charlotte	Tenth St	Bike	n/a	n/a	61.6%
Charlotte	Pecan Ave	Bike	n/a	n/a	58.4%
Charlotte	South Tryon St	Bike	n/a	n/a	33.7%
Charlotte	Stonewall St	Bike	n/a	n/a	29.0%
Charlotte	Blue Line Trail	Bike	n/a	n/a	29.0%
Charlotte	4th St Extension	Bike	n/a	n/a	1.4%
Charlotte	Selwyn Ave	Bike	n/a	n/a	0.3%
Duck	Duck Trail	Bike	n/a	n/a	61.4%
Durham	American Tobacco Trail - Downtown	Bike	n/a	0.0%	33.2%
Durham	American Tobacco Trail - I-40 Pedestrian Bridge	Bike	0.3%	4.7%	0.0%
Greensboro	Walker Ave	Bike	0.5%	1.1%	50.4%
Greensboro	Elm St	Bike	4.9%	4.9%	12.3%
Greensboro	Spring Garden St	Bike	1.6%	30.6%	0.0%
Greensboro	Lake Daniel Greenway	Bike	0.3%	0.0%	0.0%
Wilkesboro	Yadkin River Greenway	Bike	n/a	n/a	0.0%
Winston-Salem	The Strollway	Bike	0.3%	17.8%	36.2%
Winston-Salem	Salem Lake Greenway	Bike	0.3%	0.0%	4.4%
Winston-Salem	4th St	Bike	0.5%	0.3%	0.0%
Winston-Salem	West End Blvd	Bike	0.3%	0.0%	0.0%
Brevard	Brevard Greenway	Pedestrian	n/a	0.0%	0.0%
Carrboro	Old Highway 86	Pedestrian	3.8%	1.9%	15.1%
Carrboro	Libba Cotton Bikeway	Pedestrian	3.3%	0.0%	6.6%
Chapel Hill	Martin Luther King Jr Blvd	Pedestrian	3.8%	9.8%	89.9%
Charlotte	4th St Extension	Pedestrian	n/a	n/a	1.6%
Charlotte	Elizabeth Ave	Pedestrian	n/a	n/a	1.6%
Charlotte	North Tryon St	Pedestrian	n/a	n/a	7.9%
Charlotte	Pecan Ave	Pedestrian	n/a	n/a	60.0%
Charlotte	Stonewall St	Pedestrian	n/a	n/a	18.4%
Charlotte	South Tryon St	Pedestrian	n/a	n/a	33.7%
Charlotte	Selwyn Ave	Pedestrian	n/a	n/a	6.0%
Charlotte	Tenth St	Pedestrian	n/a	n/a	52.1%
Charlotte	Blue Line Trail	Pedestrian	n/a	n/a	32.6%
Duck	Duck Trail	Pedestrian	n/a	n/a	7.9%
Durham	American Tobacco Trail - Downtown	Pedestrian	n/a	0.0%	33.2%
Durham	American Tobacco Trail - I-40 Pedestrian Bridge	Pedestrian	0.8%	4.1%	8.5%
Greensboro	Elm St	Pedestrian	1.1%	0.3%	4.1%
Greensboro	Spring Garden St	Pedestrian	0.3%	0.0%	0.0%
Greensboro	Walker Ave	Pedestrian	1.4%	3.8%	0.5%
Greensboro	Lake Daniel Greenway	Pedestrian	0.5%	19.4%	7.9%
Wilkesboro	Yadkin River Greenway	Pedestrian	n/a	n/a	0.0%
Winston-Salem	4th St	Pedestrian	0.3%	0.3%	0.5%
Winston-Salem	West End Blvd	Pedestrian	0.5%	0.0%	2.5%
Winston-Salem	Salem Lake Greenway	Pedestrian	0.3%	0.0%	4.4%
Winston-Salem	The Strollway	Pedestrian	0.3%	34.2%	60.5%
		All Systems	***1.5%***	***4.8%***	***20.4%***

Appendix 5. Counters Installed in Phase 1 and 2 by Municipality, Mode, and Facility Type

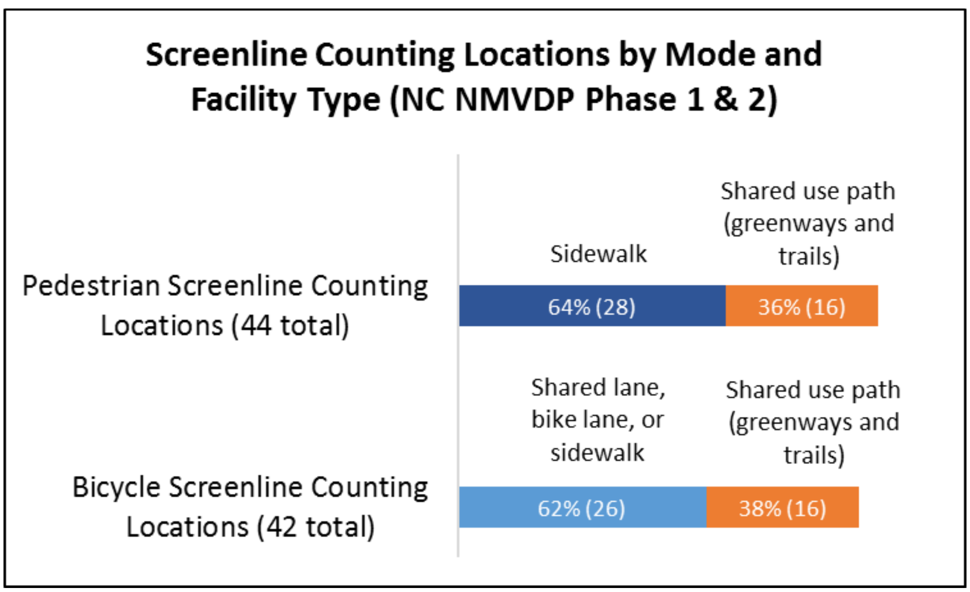
Counter Summary	
Total Stations (Counting Locations)	47
Total Loggers	71
Total Sensors	141

Pedestrian Sensors	67
Bicycle Sensors	74
Sidewalk Bicycle Sensors	11

Total Stations (Counting Locations) by Phase	
Phase 1	13
Phase 2	31
SUP*	4

*Counters purchased and installed under a separate research project and onboarded into the NC NMVDP

Loggers by Municipality	
Apex	4
Brevard	1
Carrboro	3
Cary	4
Chapel Hill	2
Charlotte	18
Davidson	4
Duck	1
Durham	5
Greensboro	7
North Wilkesboro	1
Raleigh	11
Sanford	1
Wake Forest	2
Winston-Salem	7



Appendix 6. Maintenance Case Study Examples

Maintenance Case Studies – Site Flooding

APX_BCG – Beaver Creek Greenway – Apex, NC (35.73071, -78.88124)

This Eco-Counter system is located on the Beaver Creek Greenway and consists of an Eco-Combo logger housed in a small RainBird enclosure, a two-loop zelt, and pyro sensor in a wooden post. The site is adjacent to a small creek and an urban drainage area that frequently experiences heavy rainfall runoff during thunderstorms. In February 2019, the counter system experienced some flooding and was impacted by minor erosion of the soil surrounding the RainBird enclosure. The counter system exhibited some operational issues, so it was inspected and the Eco-Counter technical support staff recommended installing a new battery. On March 5, 2019, maintenance and repairs were performed. A new battery and Smart Connect were installed and the RJ45 metal shields were removed, as recommended by Eco-Counter technical support staff.

On April 17, 2019, additional site repairs and improvements were made. The RainBird enclosure was raised approximately five inches in elevation and a short, ten (10) inch diameter section of PVC pipe was placed around the RainBird enclosure to shield it from flood waters. Three (3) cubic feet of additional gravel was spread around the RainBird enclosure and the wooden post to stabilize the area and reinforce the system components. The goal was to reduce the potential for surface water flooding of the enclosure and protect the counter system during future rainfall events.

During a visit to the site in August 2019, it was discovered that the reinforced RainBird enclosure had been displaced from its original location and was laying on the ground approximately three feet away. The affixed zelt and pyro sensor cables acted as a tether and kept the system components housed in the RainBird from being washed away. It was apparent the site had been flooded once again. After it was re-installed in its original location, additional repairs were required to the Eco-Counter system. The pyro sensor cable suffered damage, so the cable and the sensor had to be replaced. Five long pieces of metal rebar were placed around the PVC pipe protecting the RainBird and driven into the ground for more support. Four additional cubic feet of gravel were installed around the RainBird enclosure and the wooden post to stabilize the area and reinforce the system components. The counter system was inspected and placed back into operation after the bike and ped counts and system parameters were verified.

Follow-up inspections and system maintenance occurred on March 27, 2020 and June 8, 2020. These visits were not associated with any flood events.

CRY_NHC – New Hope Church Road – Cary, NC (35.81677, -78.92767)

This Eco-Counter system is housed in a large in-ground RainBird enclosure located on the south side shoulder of New Hope Church Road. The counter system consists of an Eco-Combo logger and zelt. It is configured to detect only bicycle traffic using a stretch “high definition” (“HD”) zelt loop system. This system detects the cyclists traveling in both the east and westbound direction of New Hope Church Rd.

During a site inspection visit on April 17, 2019, standing water was discovered in the large in-ground RainBird enclosure. The Eco-Counter system components were completely submerged. This was apparently caused by recent thunderstorms and the resulting stormwater flowing along the grassy shoulder of the roadway and infiltrating the gaps in the cover of the RainBird enclosure. Due to the heavy clay soil composition at this site, the rainwater was not able to drain out of the enclosure. ITRE staff physically bailed out the standing water using a plastic bottle. The counter system was inspected and appeared not to be immediately impacted by this issue. Bicycle counts and counter operation were verified, and a follow-up visit was planned to resolve this issue.

On May 22, 2019, ITRE staff returned to the site to install a 1 ½ inch diameter PVC pipe to function as a drain and carry away any water that may infiltrate the RainBird enclosure. A trench was dug from the base of the enclosure to an adjacent drainage ditch and the pipe was installed in such a way as to allow any water that may enter the enclosure to drain away freely.

This effort appears to have resolved the standing water issue, and the counter system operated without any issues until November 19, 2019. Bicycle count data stopped transmitting at that time. A site visit and inspection were made on December 6, 2019 to troubleshoot the system. With the assistance and recommendation of the Eco-Counter technical support staff, the complete counter system was removed and returned to Eco-Counter for assessment and repairs. On April 16, 2020, the newly repaired counter system was re-installed at the site and operation resumed successfully. No other issues have occurred since that time.

CRY_LOU_ E & W – Louis Stephens Drive – Cary, NC (35.80595, -78.86149); (35.80602, -78.86175)

These two Eco-Counter systems are housed in large in-ground RainBird enclosures located adjacent to the sidewalks on the east and west side of Louis Stephens Drive. The flooding issue occurred on April 9, 2019 after heavy rain and thunderstorms moved through the area. The resulting stormwater infiltrated the gaps in the cover of the RainBird enclosures. The rainwater was not able to drain out of the enclosures due to the heavy clay soil composition at this location. The standing water was bailed out using a paper cup. Both of the counter systems were inspected, and the following issues were determined.

1. CRY_LOU_E - Battery overconsumption was detected. All metal shields on the RJ45 cable connectors were removed, per recommendation by Eco-Counter technical support staff. A temporary 898 battery was installed until a new 899 battery was shipped and installed. Follow-up site visits for maintenance issues occurred on 7/31/2019, 8/14/2019, 4/9/2020, and 4/14/2020.
2. CRY_LOU_W - Battery overconsumption was detected. All metal shields on the RJ45 cable connectors were removed, per recommendation by Eco-Counter technical support staff. The Y connect had failed and was replaced. Follow-up site visits for maintenance issues occurred on 4/25/2019, 7/31/2019, and 8/14/2019.

This site is relatively flat and does not have adequate slope to allow the rainwater to flow away from the in-ground Eco-Counter systems. In addition, the sidewalks, roadway, and curbs prohibit the installation of any type of drainage pipes.

RAL_HAR_N – East Hargett Street – Raleigh, NC (35.77808, -78.62943)

During a site inspection visit on March 25, 2020, water was discovered in the square (B125) in-ground enclosure at this counter location. The Eco-Counter system components were completely submerged. ITRE staff was able to bail out most of the water, but it continued to flow into the enclosure as quickly as it could be bailed out. This was apparently caused by recent thunderstorms and the resulting stormwater was flowing along the historical granite stonework that was acting as the curb. The water on the road and the surrounding soil was seeping through the gaps in the stonework and infiltrating the in-ground enclosure. The primary source of water was from the curb, but the soil was so saturated from all of the rain that it appeared to be migrating into the enclosure from the surrounding soil and even from the floor of the enclosure. These in-ground enclosures are not watertight. This site is flat and does not have adequate slope to allow the rainwater to flow away from the in-ground Eco-Counter systems. In addition, the historical granite curbs are insufficient to handle the heavy storms and rainwater and prevent it from inundating the Eco-Counter enclosures. The sidewalks, roadway, and granite curb are obstructions that prohibit the installation of any type of drainage features.

Walnut Creek Trail at the Walnut Creek Wetlands Center – Raleigh, NC (35.76046, -78.62622)

On December 18, 2019, a technical training meeting was conducted on-site at this location with several City of Raleigh staff members. The Eco-Counter system is located on the greenway in a low-lying floodplain adjacent to the Walnut Creek Wetlands Center. Initial Eco-Link communication with the counter system was not successful. Upon opening the small RainBird enclosure, we discovered the logger system was completely submerged in standing water. A thorough inspection of the system and cable connections revealed evidence of corrosion in the RJ45 connectors. The Eco-Counter technical support staff recommended removal of the entire counter system and returning it to them for assessment and factory repairs. The City of Raleigh staff handled this shipping and repair effort and re-installed the repaired system when repaired and received.

Maintenance Case Studies – Electrical or Cellular Interference

DRH_ATT – American Tobacco Trail at Highgate Drive – Durham, NC (35.909089, -78.941716)

This Eco-Counter system is located on the American Tobacco Trail approximately 320 feet south of the Highgate Drive access. The counter system consists of an Eco-Combo logger, a "standard definition" ("SD") zelt, and pyro sensor that are housed in a wooden post and small RainBird enclosure. The system counts bicycles and pedestrians traveling north and south on the shared use path. The count data are uploaded to the cloud via the GSM network system. There is a cellular network tower located approximately 125 feet east of the Eco-Counter.

During its time in operation, this system has experienced numerous modem and data transmission issues. Frequent site maintenance visits to inspect and investigate the problem did not reveal an obvious system issue. The problem appeared to be an erratic, but recurring modem connection issue. Historical maintenance records show these modem and cellular connectivity issues date back to February 2017. Multiple phone calls have taken place with the Eco-Counter technical support staff to troubleshoot the system. Complete Eco-Counter systems have been removed and replaced due to modem failure and related issues. System batteries have also been replaced on several occasions.

On February 19, 2019, Eco-Counter technical support staff along with ITRE staff replaced the counter system with a fully operational spare system. Eco-Counter technical support staff began an intensive diagnostic effort by monitoring the data transmission to resolve this connectivity issue. It appeared that the counter modem would initially establish a cellular connection after a site maintenance visit, but eventually lose that ability to re-establish the connection.

On April 10, 2019, an onsite test by ITRE staff to evaluate the possibility of physically relocating the Eco-Counter system to improve cellular connectivity and modem operation was performed. ITRE staff used the original counter system and physically moved it first north and then south along the greenway trail until a successful modem test could be performed and a cellular connection was established. Each test scenario determined a successful cellular connection and modem operation was established one hundred feet in either direction. This confirmed the counter system was experiencing some type of cellular interference or cellular connectivity issue with the nearby cellular tower. The erratic cellular interference and service disruption at the original counter system location led us to speculate there may also be ongoing signal and/or antenna modifications being performed by the cellular providers utilizing the nearby tower.

On June, 10, 2020, after significant system testing, site visits, software updates and technical discussions, the Eco-Counter technical support staff along with the ITRE staff scheduled an on-site Team Viewer session to reconfigure the current Eco-Counter using a UPSDA command session to modify and improve its cellular capabilities. This effort appears to have resolved the cellular connectivity problems and the Eco Counter system is performing satisfactorily.

Maintenance Case Studies – Damaged Pryo Sensors

WLK_YDK – Yadkin River Greenway – Wilkesboro, NC (36.15243, -81.14793)

Pyro sensor damage was discovered during a routine site visit on August 16, 2019.

The sensor lens was damaged by what appeared to be a sharp object that punctured both plastic lenses. A new pyro was ordered by the local agency and the new pyro was installed during a return site visit on November 6, 2019. The system resumed normal operation and bicycle and pedestrian counts were verified for accuracy.

BRV_BGW – Brevard Greenway – Brevard, NC (35.25736, -82.70774)

The first incident of pyro sensor damage was discovered during a site maintenance visit on October 26, 2017. The sensor lens was damaged possibly by a bird pecking at the plastic lens. A new pyro was ordered and replaced by the local agency.

A second incident of pyro sensor damage was discovered during a site maintenance visit on September 17, 2019. The sensor lens was damaged by what appeared to be a sharp object that punctured both plastic lenses. ITRE staff replaced it with a new spare pyro sensor during the visit. Pedestrian counts were verified, and the replacement sensor was working properly.

W-S_STR – The Strollway – Winston Salem, NC (36.08705, -80.24386)

Pyro sensor damage was discovered during a site maintenance visit on October 25, 2016. The sensor lens was damaged by what appeared to be a sharp object that punctured one of the plastic lenses but not the other. A new pyro sensor was ordered and installed by the local agency.

Maintenance Case Studies – Obstructed Pyro Sensors

BRV_BGW – Brevard Greenway – Brevard, NC (35.25736, -82.70774)

This Eco-Counter site has dense vegetation growing on the opposite side of the greenway path that causes movement of the foilage and corresponding false pedestrian counts as the wind blows. This is a challenging site situation that usually causes pedestrian overcounting. This situation usually requires the removal and clearing of the vegetation and/or adjusting the pyro sensor detection range within the Eco-Counter settings menu. This is accomplished using the Eco-Link software which allows the user to adjust the pyro sensor detection range and verifying its counting accuracy and performance while onsite.

CRY_BCT – Black Creek Trail – Cary, NC (35.78200, -78.81105)

This site has small saplings and vegetation growing on the opposite side of the greenway path and causes false counts and pedestrian overcounting. This situation typically requires the removal of the vegetation and/or adjusting the pyro sensor settings using the Eco-Link software.

CRB_OLD_E – Old NC 86 – Carrboro, NC (35.93403, -79.10204)

During a routine review of the pedestrian count data, several anomalies relating to suspicious and unique peak activity periods were being detected, so a site visit was conducted. A small area of grass growing around the metal post that housed the pyro sensor had not been mowed by the local agency maintenance crew. The uncut grass had grown high enough to obstruct and interfere with the sensor. The grass would blow in the wind and generate false pedestrian counts which resulted in overcounting and unique periods of activity. The problem was resolved once the maintenance crew cut the grass that was interfering with the pyro sensor operation.

Neuse River Trail at Royal Forest Dr – Raleigh, NC (35.93357, -78.56800)

During an unrelated visit to the Neuse River Trail, ITRE staff walked past this counter site and discovered an obstruction covering the two pyro sensor holes in the wooden post. The obstruction was determined to be a mud dauber wasp nest. ITRE staff were able to remove the obstruction and verified the pedestrian count activity. The system resumed normal operation without any issues.

RAL_CCG – Crabtree Creek Greenway near Generation Drive – Raleigh, NC (35.83915, -78.66806)

ITRE was aware of construction on the greenway in the vicinity of this counter which appeared to be related to zero pedestrian counts captured at the location. A site visit was scheduled for April 21, 2020. ITRE staff discovered an orange construction safety cone had been placed over the wooden post that houses the pyro sensor. The cone was obstructing the sensor and preventing the detection of pedestrians. ITRE staff removed the cone from the wooden post and the pedestrian counts were verified for accuracy before leaving the site.

APX_SAL_W – North Salem Street – Apex, NC (35.73142, -78.85116)

During a routine review of the pedestrian count data, ITRE staff identified zero pedestrian counts at the counter located in historic downtown Apex, NC. This area was undergoing renovation and construction related to retail storefronts. ITRE staff was aware of this activity and its proximity to the counter. A site visit was scheduled for July 8, 2018. ITRE staff discovered construction scaffolding had been placed along the storefront and sidewalk area to facilitate the building renovation while providing a safe passageway for the retail customers and pedestrians who were passing by the area. The crews who installed this scaffolding and safety barrier had placed large wood panels in front of the Eco-Counter pyro sensor to create a protective buffer for passing pedestrians. One of these panels was obstructing the sensor and its pedestrian detection capabilities. A phone call was made to the local agency and they passed on the request to have the construction contractor cut a small opening in the wood panel to allow the sensor to function properly without being obstructed. This resolved the issue and the pedestrian counts resumed as expected.

Maintenance Case Studies – Other Observations and Challenges

RAL_RID_E & W – Ridge Road – Raleigh, NC (35.81138, -78.68441)

This Eco-Counter is in an older, established residential neighborhood with high pedestrian volumes using the sidewalks for walking, jogging, and daily recreational activity. High bicycle volumes are also present in the bike lanes.

The selected installation sites were challenging due to the tight constraints associated with the narrow grassy strip between the curb and the adjacent sidewalk. This area was also occupied by landscape plantings and small ornamental shrubs and flowering trees. Given these factors, a self-contained urban post system was installed that contained the Eco-Combo Multi 2G logger, zelt, pyro, and associated batteries all in one metal post. This system installation requires the placement of a small concrete footing in a 12 to 14-inch diameter hole. A traditional system installation requires the in-ground installation of a small RainBird enclosure, the adjacent post structure, and the associated conduit to contain all the cabling to connect the respective counter and sensor components. In addition, the urban post system provides better access to counter system components as well as improved operational reliability. The counter system is contained in a more watertight, above ground environment which seems to reduce maintenance and downtime. In most site installations with this configuration, scheduled battery replacement is usually all that is required.

DVD_CON_S – Concord Road – Davidson, NC (35.495911, -80.841254)

This Eco-Counter system is located on a busy residential traffic thoroughfare that handles high traffic volume. Commercial trucks and buses are also frequently seen passing through the area. This counter system utilizes a stretch “high definition” (“HD”) zelt configuration to detect a bicycle as it passes across the inductive loops. This requires the installation of inductive wire loops in the roadway and/or bicycle lane surface.

During a routine site visit on February 27, 2019, evidence of a small pothole was present along the edge of one of the inductive wire loops. The local agency was contacted and their input and assistance were requested. The immediate concern was if there was any damage to the integrity of the inductive wire loop. If so, this would require additional time and effort to repair or replace. A plan was developed with the assistance of the local agency and the pothole repairs were successfully completed on May 1, 2019. Close inspection of the wire loops did not reveal any damaged or broken wires, so the inductive loop could remain in place without having to be replaced. A “cold patch” asphalt repair material was installed in the pothole once the wires were securely protected. Bicycle counts were verified, and the count data were monitored for accuracy once the repairs were completed. No additional repairs were required.

Maintenance Case Studies – Structural Damage and Failure of the Wooden Post

Eco-Counter provides a wooden post as an option to securely house the pyro sensor. The post is a natural product that blends into the environment at a greenway or park installation. The wood is not treated with a chemical preservative to protect it against insects, rot, or moisture infiltration. Generally, treated wood products are recommended for most ground contact installations in the southeast region of the United States.

There have been three instances of wooden post failure reported by two local agencies including in the NC NMVDP. The failures appear to be directly related to damage caused by moisture infiltration and subsequent termite infestation at the ground line of each post. The Eco-Counter locations are:

- W-S_STR – The Strollway – Winston Salem, NC
    - 9/15/2014: System Installation
    - 11/01/2018: Wooden Post Failure – Date of Replacement
- W-S_ SLG – Salem Lake Greenway – Winston Salem, NC
    - 10/22/2014: System Installation
    - 5/30/2019: Wooden Post Failure – Date of Replacement
- GSO_LDG – Lake Daniel Greenway – Greensboro, NC
    - 9/19/2014: System Installation
    - 1/14/2019: Wooden Post Failure – Date of Replacement

Eco-Counter also offers a synthetic composite post (recycled post) that is made with recycled plastic. The recycled post was used as the replacement post in all three of the above installations. This product is more suitable for site installations in the North Carolina area.

Maintenance Case Studies – Insect Infestation

ITRE staff have encountered suspicious anomalies in bicycle and pedestrian count data associated with an insect infestation in the wooden or metal post containing the pyro sensor. Insect infestation has also been found in the in-ground RainBird enclosures. The electronics may draw them to the counter system, or they may seek shelter in the posts to establish their colonies.

Ants are the primary pest infestation. They have been discovered and treated at the following Eco-Counter locations:

- BRV_BGW – Brevard Greenway – Brevard, NC
- DRH_ATD – American Tobacco Trail at Lakewood Avenue Bridge – Durham, NC
- APX_BCG – Beaver Creek Greenway – Apex, NC
- RAL_NRG – Neuse River Greenway – Raleigh, NC

Maintenance Case Studies – Eco-Counter System Relocation

On May 30, 2019, ITRE staff helped the cooperating local agency in Winston Salem, NC to remove, relocate, and reinstall the Eco-Counter system at the Salem Lake Greenway site (W-S_SLG).

The greenway and an adjacent area had recently undergone some renovation and improvements with the construction of a new public restroom facility and the addition of a children's playground. These improvements and renovations changed the existing pathways and pedestrian greenway so some of the pedestrian activity was bypassing the original counter location. The decision was made to remove the existing Eco-Counter system and relocate it to a new site that would capture pedestrian and bicycle activity more effectively. This new location on the greenway is approximately 200 yards east of the original site installation.

With the assistance of the Salem Lake Park maintenance crew and several volunteers from the local agency, the relocation was completed in one day. The greenway was constructed with a native sand and fine gravel mix, so it was easily excavated from around the original buried inductive loop system. This pre-form inductive loop system was then carried to its new location and carefully placed in a wide shallow trench that was excavated in the greenway path. The two-loop system was gently covered with approximately 2 inches of the native sand and fine gravel mix. A new replacement recycled post was installed along with counter system components in the small RainBird enclosure.

The key factor to consider in this type of system relocation is justifying the removal of the original counter system and the feasibility and potential cost savings in utilizing the original system versus replacement with a newer system. The decisive factor in this case was related to the capability to safely remove and reuse the preformed inductive loop system. This would not have been possible if the inductive wire loop was originally installed in an asphalt paved greenway path. Another key point in this process was the assistance from the local agency staff, including park maintenance personnel. Their contributions and access to excavation machinery made the relocation much easier and more efficient.

Appendix 7. Installation and Onboarding Form Used in Phase 2

NC NMVDP Installation Procedures Checklist

Pre-Installation

Site Name: ____ _ ____ _ ____

Interference reading at Site Visit:

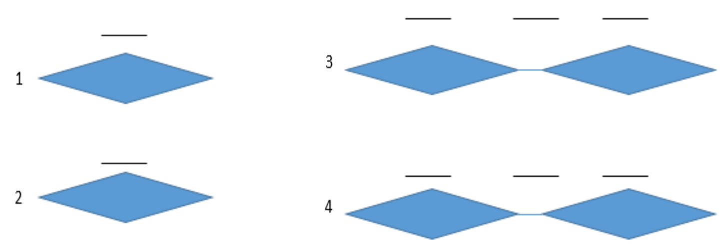
Serial Number:

NCDOT ID:

Agency/Contractor Contact(s):

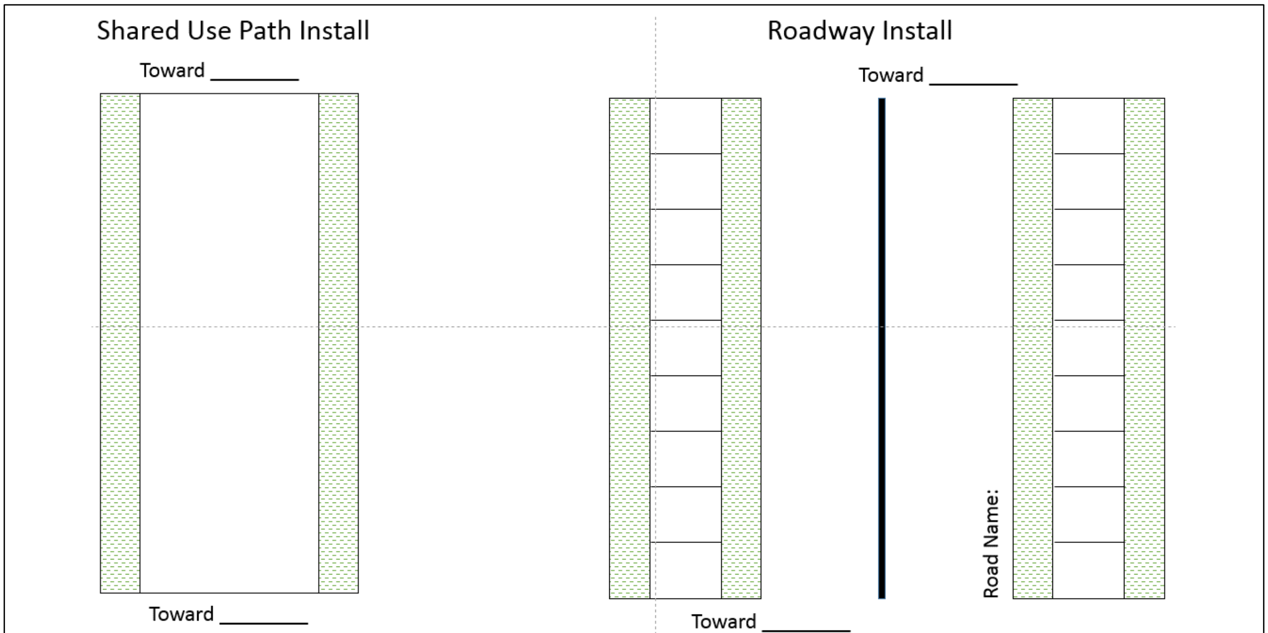
Cell Number(s):

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



Single Loop Length (in.)	Distance Between Loops (in.)	Overall Distance w/ 2 Loops (in.)
59	3.00	121.00
55	4.00	114.00
51	4.75	106.75
47	5.50	99.50
43	6.25	92.25

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



Installation Notes

Installation Date:	Start Time:	End Time:

Verify Serial Number: ☑

Interference Reading at Installation:

ITRE Installer:

GPS Coordinates:

Example: 35°46'49.3"N 78°40'41.6"W
Example: 35.785895, -78.671442

Connect to the Logger on Eco Link:

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

Eco Link Information

Download Eco-Link

- For PC
- For Android (App Store)

Username:
Password:

☑ ***Manually adjust sensor so inbound is toward city center***

PED Inbound Direction:	PED Outbound Direction:
Toward:___________________________________	Toward:_______________________________

BIKE Inbound Direction:	BIKE Outbound Direction:
Toward:___________________________________	Toward:______________________________

☑ Give key/tools to local agency contact | NAME: ______________________________

☑ Write installation date on battery

☑ Explain basic maintenance procedures

Equipment Validation (before sealing loops) Eco-Counter Customer Support: 1-866-518-4404 / 1-514-849-9779

Pedestrian Test (Sidewalk or SUP)

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					On sidewalk or SUPs less than 6 ft., complete 10 passes. On facilities wider than 6 ft., complete 20 passes.														
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																				
Notes:																				

Bicycle Test (Roadway)

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					Bike loops in roadway may not detect direction, unless HD. Test passes 9-20 only where 2 loops present.														
																				
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																				
Notes:																				

Bicycle Test (Sidewalk or SUP)

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					Test passes 1-8 on sidewalk. Test all 20 passes on SUP.														
																				
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																				
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																				
Notes:																				

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

Onboarding Equipment into NMVDP

After installation, update the following documents and processes to incorporate the new sites:

- ☑ Equipment Inventory
- ☑ Photos
- ☑ Eco-Visio (www.eco-visio.net/Ecovisio/)
- ☑ Weekly Maintenance Checks
- ☑ QA/QC Workbook
- ☑ Validation Workbook

Procedure Completion Date / PI Notified:

Installation Notes:

Appendix 8. Maintenance Log Form Used in Phase 2

ON-SITE ECO-COUNTER MAINTENANCE **Date:**______________**Start Time:**__________**End Time:**____________

Site Name:	Serial Number:	Local Personnel:	Eco-Counter Technician:
____ – ____ – ____			

Counter Issues/Symptoms:____

Data Retrieved Y/N:______________________**Modem Test Performed Y/N, Pass/Fail:** ______________

Maintenance Conducted:____

____

____

Parts Replaced:____

Settings Changed Y/N:____________________**Validation Required/In Progress Y/N:**______________

Follow-Up Required Y/N:____

Pedestrian Test

Actual Direction	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 Direction	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
	Curb Side - - - - - - - Loop1 - - - - - - - Far Side								Between Loops				Near Side - - - - - - - Loop2 - - - - - - Lane 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 Direction	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: 1-866-518-4404 (toll free) | 1-514-849-9779

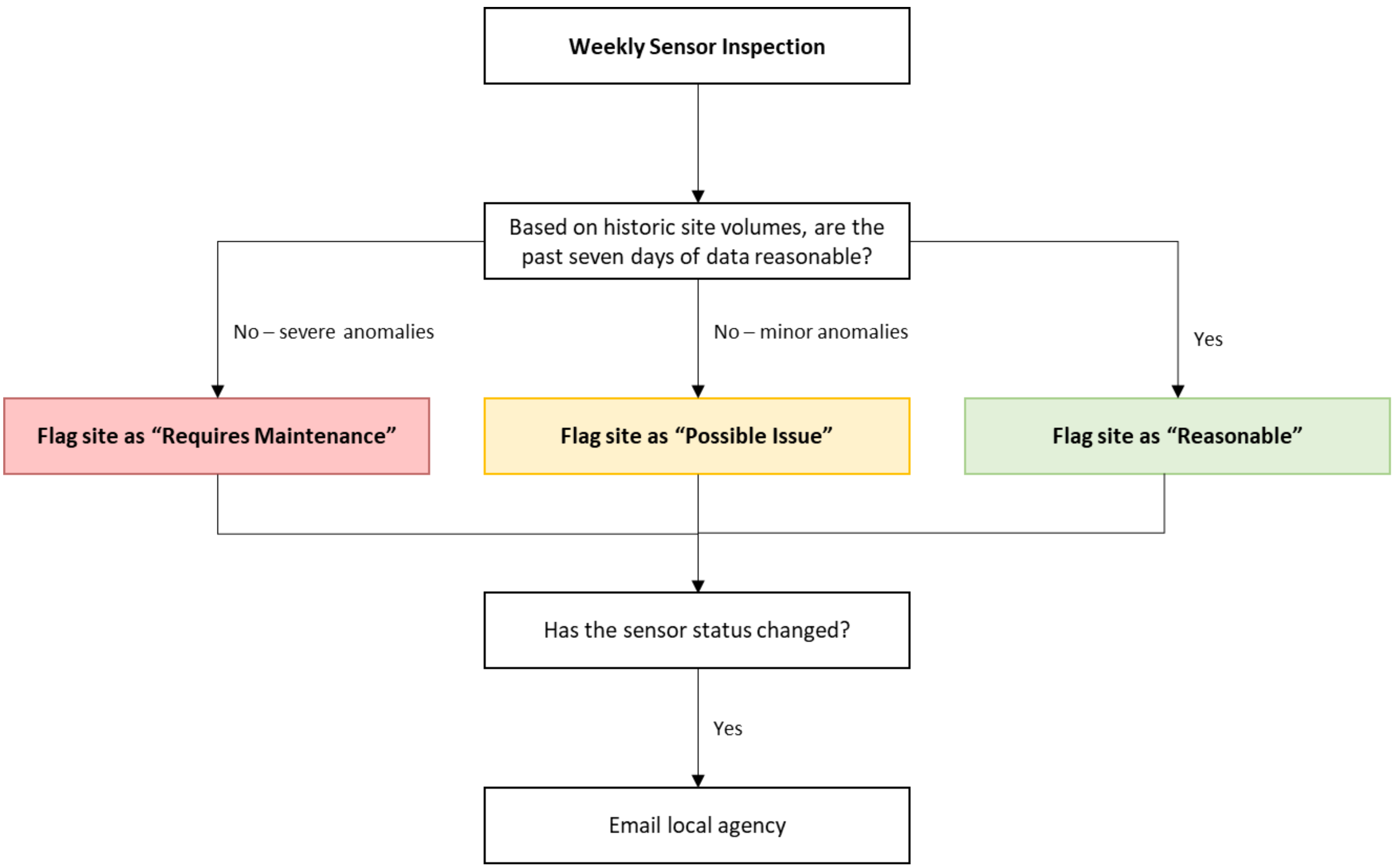
Appendix 9. Detailed Data Processing, Validation, QA/QC, and Reporting Workflow

Monitoring

Data monitoring is conducted on a weekly basis. An ITRE staff member manually reviews the volumes, disaggregated by sensor and direction, at each site and flags potential errors that could indicate equipment malfunction. Frequent errors include unrealistically high volumes, severe changes in directional splits, or multiple days of zero data transmission. Anomalies are identified based on visual inspection; more sophisticated statistical methods are applied on a quarterly and annual basis.

Sites are sorted into functional, questionable, or malfunctioning categories depending on the severity of any data anomalies that occur. A list of sites in each category is sent to field staff, and any updates or changes in site status are communicated by e-mail to local agencies. Figure 10 illustrates this process.

Figure 10. Data Monitoring Process



As the NC NMVDP has expanded to offer data management services to additional local agencies, the number of sites to be reviewed each week has increased substantially. Two major efforts are currently underway to further optimize the weekly inspection process. A relational database, combining historic sensor inspection results and field maintenance records for each site, is in the development stage. Once completed, this database will allow for easier detection of site issues based on historical trends at that location. Efforts are also underway to incorporate automated statistical checks into the weekly inspection model.

Validation

ITRE validates all counters to calculate a correction factor. Correction factors are developed from field (manual) counts and account for systematic inaccuracies in installed continuous count equipment. Correction factors are used to adjust the raw counts to represent more closely what is happening on the ground. A validation study is conducted when a counter is first installed. Additional validation studies are conducted only if:

- The first round of validation was out of acceptable error range and led to further maintenance
- Any sensitivity settings are changed
- Any part associated with the counting system is replaced (loops, sensors, logger, smart-connect, or y-connect)

Re-validation is not needed if a battery or a modem is replaced.

A validation study is conducted by installing a video camera to observe the actual field counts and then comparing those field counts to the data recorded by the Eco-Counter to determine the margin of error in the raw counts captured by the counter. Correction factors are calculated as follows:

$$CF = \frac{\sum two\ day\ bidrectional\ manual\ count}{\sum two\ day\ bidirectional\ count\ as\ recorded\ by\ sensor}$$

All hourly data are multiplied by the sensor's correction factor to correct for the inherent error in the system. Validation also verifies whether the sensor is collecting data within an appropriate margin of error. For example, a correction factor of 1.10 indicates that a counter is under counting by 10%, which we deem acceptable. However, a correction factor of 3.00 indicates that a counter is under counting by 300% (only counting every third user), which indicates that the counter is not working correctly. Based the NC NMVDP’s current protocol, acceptable correction factors are within the range of 0.6 < CF < 1.4, which indicates over or under counting by a maximum of 40%.

Data that is included in a quarterly report may be removed from an annual report if it is discovered through the validation process that a counter is not counting properly. Correction factors are not applied for quarterly reports since a current correction factor may not be calculated for a system at the time of quarterly reporting. The validation process does not require any involvement from local agency personnel, but the final correction factors are be shared after all counters have been validated.

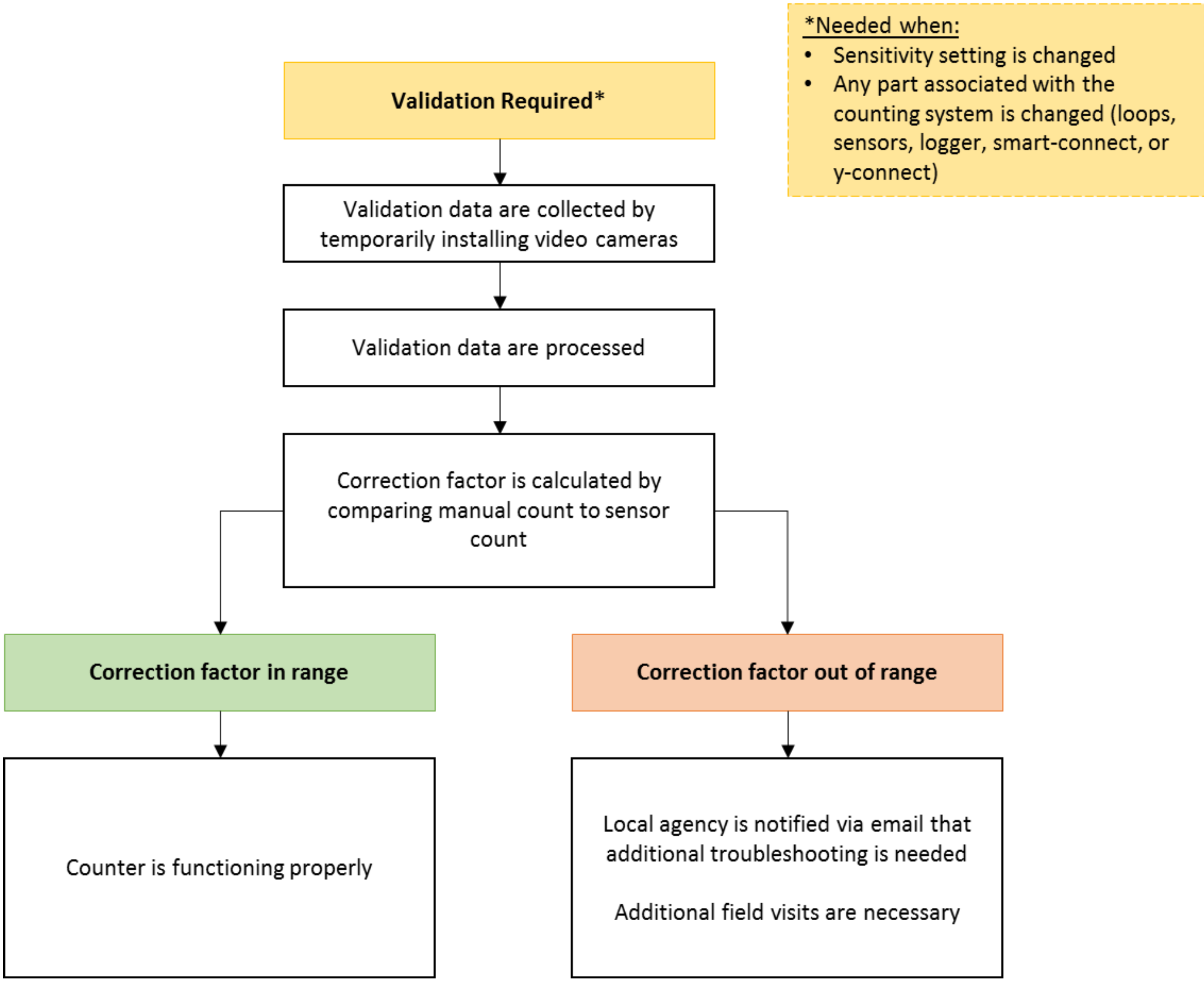
Video cameras are mounted via a mounting bracket attached using two standard hose clamps. This process takes approximately thirty minutes to an hour and does not require any assistance from local agency personnel. Typically, the cameras are installed on utility poles, road-adjacent signage, or on sufficiently sized trees.

Including the mounting bracket, the camera weighs approximately one pound and the straps are only tightened to the minimum amount required to hold the camera in place. This power source for the camera is stored in a green security case that is 9 inches wide by 15 inches long by 9 inches tall. The cameras are typically installed for two full days. The cameras may be installed for a longer period if a location experiences unfavorable weather or low daily volumes.

While the validation process has remained consistent from Phase 1 through Phase 2 of the program, the steps that are used to validate the Eco-Counter systems have adapted over time in response to both issues and changing requirements that were encountered as the program grew. Various changes had to be implemented to handle the increasing scope of the program, the revalidating of sites already in the program due to additional maintenance, and the handling of increased volume of data associated with onboarding additional counting locations into the program. While the original method could handle the 13 counting locations in Phase 1, it needed to be adjusted to accommodate the increasing number of counters currently managed by the program. Figure 11 provides a general overview of the validation process that is applied when counting equipment is first installed or when triggered by certain maintenance events. The following changes were implemented in late 2019 to improve the efficiency and scalability of the validation process:

- Creation of a validation lead dedicated to managing validation studies for NCDOT and local agency owned counters and responsible for all validation tasks within the Equipment Coordination and Data Coordination areas of the NC NMVDP
- Creation of scheduling tools and enhancements to video data reduction workbooks to improve the efficiency of data coding and the calculation of correction factors
    - Google Sheets was used to create a centralized collaboration tool where student research assistants were assigned video analysis tasks for sites requiring validation.
    - Google Sheets was used to create centralized video data reduction workbooks for data coding that could be audited in real-time by the validation lead.
        - Additional columns were added to the data entry sheets to capture data more consistently for analyzing pedestrian occlusion, bicycle or pedestrian bypass, scooter volumes, and the presence of dogs or strollers.
        - When data entry is completed, the validation lead adds the counts as collected by the Eco-Counters retrieved from Eco-Visio and the spreadsheet tool automatically calculates the correction factors for the counting site.

Figure 11. Validation Process

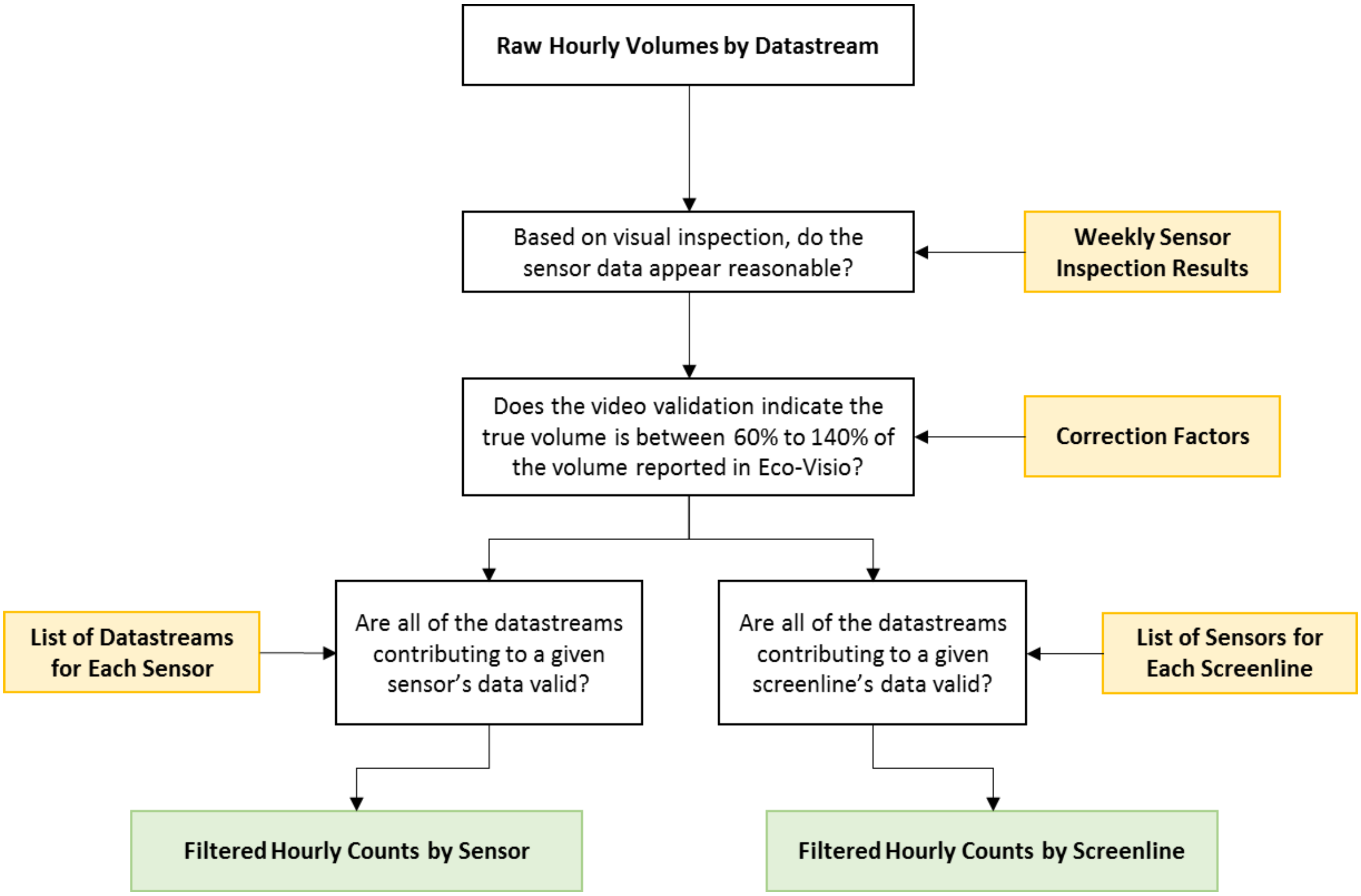


QA/QC

The quarterly quality assurance and quality control (QA/QC) process has transitioned through three major stages. Initially, quarterly reports were generated by manually checking each site before sending the data to local agencies. Date ranges where a site was known to be malfunctioning were replaced with null values.

In late 2019, the quarterly review process was expanded to include semi-automated filtering. Raw data, disaggregated to its component datastreams, was assessed based on weekly inspection results from the previous three months. Any periods where a sensor's correction factor was less than 0.6 or greater than 1.4, indicating that the true volume was less than 60% or greater than 140% of the reported volume, were dropped automatically. Aggregate sensor- and screenline-level data was only considered valid for a given day if all datastreams contributing to the sensor or screenline passed the visual inspection and correction factor checks. Figure 12 illustrates this process.

Figure 12. QA/QC Overview



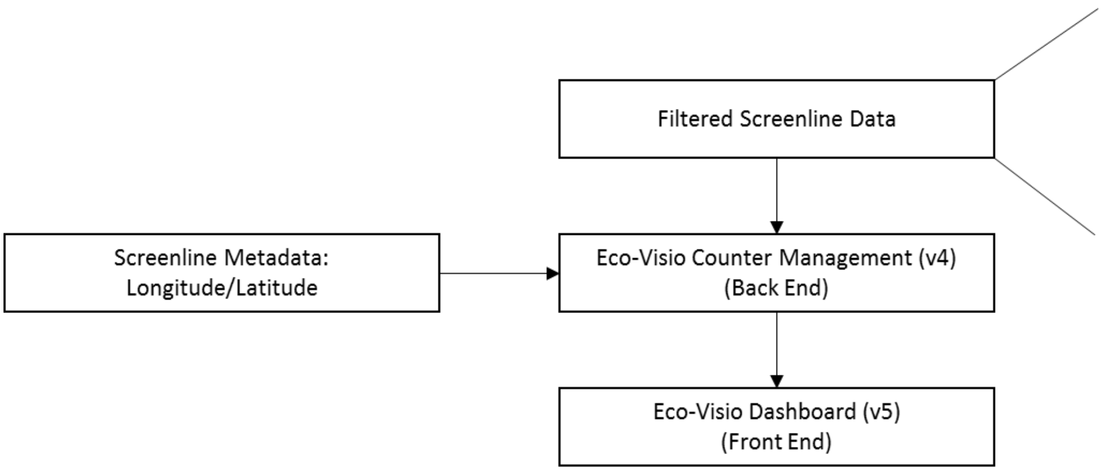
Beginning with Quarter 2 in 2020, quarterly reviews were transitioned to using the same automated filtering tool as annual counts. However, no correction factors are applied. This allows for a more statistically robust approach that will scale up more easily as the NC NMVDP continues to incorporate new sensors from additional agencies under the Collaborative Agency Model.

Reporting

Under Phase 1 and 2 of the NC NMVDP, data reporting occurred on both a quarterly and an annual basis. In late 2018, data reporting was transitioned from a series of tabular spreadsheets and manually prepared summary reports to Eco-Visio, a vendor-provided web application. Local agency partners can download tabular data, map their counter locations, and analyze their data using charts and graphs through the web application's dashboard system. This technology improved the efficiency of report preparation and enables local agencies to access verified and validated data in a timely manner and in an accessible format.

The reporting pipeline for quarterly and annual data is similar. The QA/QC process for both results in a scrubbed list of hourly counts for each screenline in the NC NMVDP. These data files, along with the latitude and longitude of each screenline, are uploaded to Eco-Visio's back end dashboard, where they are automatically processed into a report-ready format. The reporting pipeline is shown in Figure 13.

Figure 13. Data Reporting Pipeline

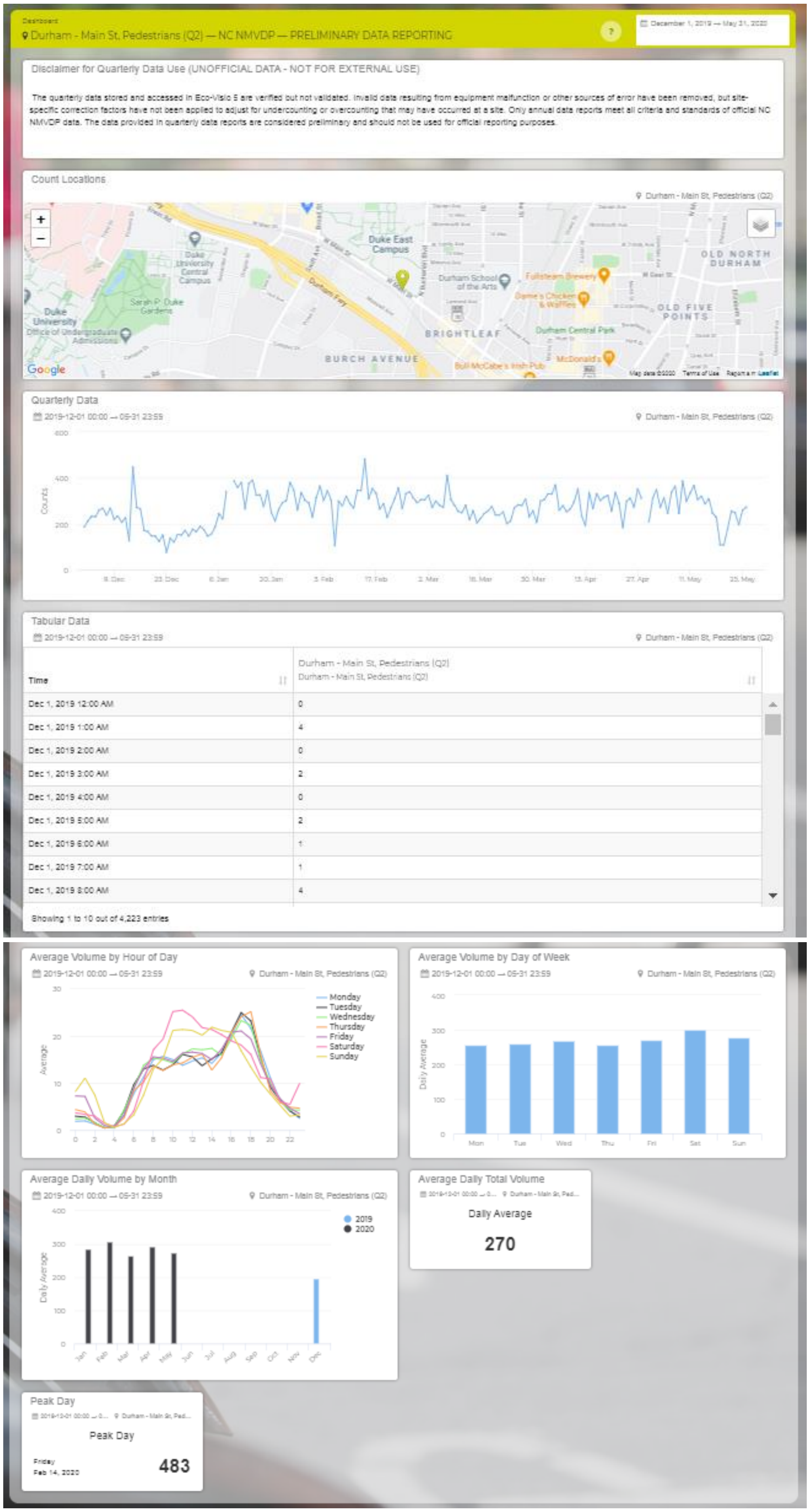


5/31/20	04:00	0
5/31/20	05:00	0
5/31/20	06:00	0
5/31/20	07:00	1
5/31/20	08:00	0
5/31/20	09:00	13
5/31/20	10:00	14
5/31/20	11:00	8
5/31/20	12:00	4
5/31/20	13:00	0
5/31/20	14:00	0
5/31/20	15:00	0
5/31/20	16:00	1

Beginning in June 2020, quarterly data reports were made available to the public. Before that time, quarterly reports were only sent to local agencies for preliminary use, and data were released to the public on a year-by-year basis after the annual reporting process was completed.

Eco-Visio dashboards display both counts and metadata about a given counting location across several widgets: a map pinpointing the location of either the midpoint between two counters for stations composed of two counters or the location of a singular counter at stations composed of one counter, a line chart of all daily totals by mode at the station, a tabular dataset of timestamped hourly aggregated screenline data available for download onto a local server, average volumes by hour of day charts, average daily volumes by day of week, the average daily volume by month, the daily mode split between bicycles and pedestrians, and the daily average by volume. Each dashboard is incorporated into a publicly available Eco-Visio profile. Login information and links to each dashboard are published on the NC NMVDP landing webpage. An example of a quarterly report in Eco-Visio is show in Figure 14. Note the periods of missing data that correspond to areas of the dataset that were scrubbed out due to the quarterly QA/QC process.

Figure 14. Example Quarterly Data Report



Appendix 10. Factor Group Analysis

Average-Midday Index and Weekday-Weekend Index were calculated for all sites in the North Carolina Non-Motorized Volume Data Program (NC NMVDP) with valid data for the 2019 collection period; cleaned and corrected data produced between December 1st, 2018 and November 30th, 2019 were included in the calculations. The two indexes were used to validate Phase 1 proposed factor groups for Phase 1 counting stations with valid data in 2019. Original factor groupings did not reflect discrete index ranges; counting station factor groups should likely be reclassified. A seasonal factor index (SFI) to describe seasonal non-motorized temporal volume patterns was developed for testing. Factor grouping ranges were proposed for each index based on the distribution of indices and observed similarities between counting stations with similar index ranges. The number of counting stations for each AMI x WWI x SFI was counted to determine which temporal patterns are adequately represented according to Nordback et al. (2013)'s[1] factor group recommendations (three counting stations per bicycle factor group and four to five counting stations per pedestrian factor group). Next steps include testing AADT estimates using the proposed factor grouping against Miranda-Moreno et al. (2013)'s[2] factor grouping methodology and testing whether short-duration counts of a facility can accurately predict the facility's factor group.

Factor Group Indices

Miranda-Moreno et al. (2013) proposed Average Midday Indexes (AMIs) and Weekday-Weekend Indexes (WWI) to group counting locations. Average AMI is calculated using the following equation:

$$AMI = \frac{\sum_{11}^{12} v_h}{\sum_{7}^{8} v_h} \tag{1}$$

Where:

- AMI = Average Morning/Midday Index, and
- v_h = Weekday average hourly count for hour, *h*.
- The calculated AMI values were grouped using the following criteria: hourly noon activity (AMI <= 0.7), hourly multipurpose (0.7 < AMI <= 1.4), and hourly commute (AMI > 1.4).

Weekday-Weekend Index is calculated using the following equation:

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

Where:

[1] Nordback, K., Marshall, W., Janson, B., & Stolz, E. Estimating Annual Average Daily Bicyclists: Error and Accuracy. Transportation Research Record: Journal of the Transportation Research Board, 2013. 2339:90-97.
[2] Miranda-Moreno, L.F., Nosal, T., Schneider, R.J., & Proulx, F. Classification of Bicycle Traffic Patterns in Five North American Cities. Transportation Research Record: Journal of the Transportation Research Board, 2013. 2339:68-79.

- WWI = weekend/weekday index,
- V_{we} = average weekend daily traffic, and
- V_{wd} = average weekday daily traffic.
- Calculated groupings are grouped together as WWI < 0.8 representing commute groupings, 0.8 < WWI < 1.2 representing multipurpose groupings, and WWI > 1.2 representing weekend multipurpose groupings.

Average Midday-Morning Index (AMI)

Station (Municipality)	Mode	(n)	AMI	Phase 1 Factor Group
South Elm Street (Greensboro)	Ped	912	3.53	Urban Mixed
Strollway (Winston-Salem)	Bike	1,008	2.85	Urban Mixed
West 4th Street (Winston-Salem)	Ped	736	2.84	Urban Mixed
Walker Avenue (Greensboro)	Ped	776	2.49	Urban Mixed
Lake Daniel Greenway (Greensboro)	Bike	540	2.19	Urban Mixed
South Elm Street (Greensboro)	Bike	912	1.88	Urban Mixed
Spring Garden Street (Greensboro)	Ped	1,040	1.79	University Commute
West 4th Street (Winston-Salem)	Bike	1,036	1.76	Urban Commute
Spring Garden Street (Greensboro)	Bike	1,040	1.13	University Commute
West End Boulevard (Winston-Salem)	Bike	240	1.13	Urban Mixed
Walker Avenue (Winston-Salem)	Bike	1,040	1.02	Urban Mixed
Libba Cotten Bikeway (Carrboro)	Ped	468	0.76	University Mixed
American Tobacco Trail at Highgate Road (Durham)	Ped	528	0.74	Rural Recreation
West End Boulevard (Winston-Salem)	Ped	880	0.73	Urban Mixed
Libba Cotten Bikeway (Carrboro)	Bike	456	0.49	University Commute
Old NC 86 (Carrboro)	Ped	224	0.30	Urban Commute

Phase 1 Factor Group	AMI Min	AMI Max
Urban Mixed	0.73	3.53
University Commute	0.49	1.79
Urban Commute	0.30	1.76
University Mixed	0.76	0.76
Rural Recreation	0.74	0.74

Weekday-Weekend Index (WWI)

Station (Municipality)	Mode	Weekday (n)	Weekend (n)	WWI	Phase 1 Factor Group
American Tobacco Trail at Highgate Road (Durham)	Bike	133	55	2.17	Rural Recreation
American Tobacco Trail at Highgate Road (Durham)	Ped	133	54	1.77	Rural Recreation
Strollway (Winston-Salem)	Bike	252	102	1.64	Urban Mixed
South Elm Street (Greensboro)	Ped	228	92	1.63	Urban Mixed
Walker Avenue (Greensboro)	Ped	194	79	1.58	Urban Mixed
Lake Daniel Greenway (Greensboro)	Bike	135	54	1.33	Urban Mixed
West 4th Street (Winston-Salem)	Ped	184	75	1.22	Urban Mixed
Strollway (Winston-Salem)	Ped	247	102	1.21	Urban Mixed
South Elm Street (Greensboro)	Bike	228	92	1.07	Urban Mixed
West End Boulevard (Winston-Salem)	Ped	220	89	0.99	Urban Mixed
Walker Avenue (Greensboro)	Bike	260	105	0.94	Urban Mixed
Old NC 86 (Carrboro)	Ped	56	23	0.93	Urban Commute
Libba Cotten Bikeway (Carrboro)	Ped	118	49	0.92	University Mixed
West End Boulevard (Winston-Salem)	Bike	60	24	0.90	Urban Mixed
Spring Garden Street (Greensboro)	Bike	260	105	0.76	University Commute
West 4th Street (Winston-Salem)	Bike	259	104	0.72	Urban Commute
Spring Garden Street (Greensboro)	Ped	260	105	0.47	University Commute
Libba Cotten Bikeway (Carrboro)	Bike	115	49	0.33	University Commute

Phase 1 Factor Group	WWI Min	WWI Max
Urban Mixed	0.94	1.64
University Commute	0.33	0.47
Urban Commute	0.72	0.72
University Mixed	0.92	0.92
Rural Recreation	1.77	2.17

Seasonal Index Development

Seasonal ratios were calculated for each counting site in the NC NMVDP. Seasonal Average Daily Volume was calculated for each season at each counting site. Seasonal average daily volume is defined using the same calculation methodology as the annual average daily traffic (AADT), but only for the three months of each season. Winter is calculated as from December 1st to February 28th/29th, spring ranges from March 1st to May 31st, summer ranges from June 1st to August 31st, and fall ranges from September 1st to November 30th. The most useful seasonal index was the seasonal ratio that yielded the highest variability across stations which was identified as the ratio with the highest standard deviation. The standard deviation of each index is outlined in the figure below.

Index	Standard Deviation
Winter/Spring	0.21
Winter/Summer	0.28
Winter/Fall	0.20
Spring/Summer	0.31
Spring/Fall	0.26
Summer/Fall	0.75

According to the analyses, a Summer/Fall index is most helpful in differentiating seasonal temporal patterns for non-motorized counting stations in North Carolina.

Proposed Summer/Fall Factor Groupings

Factor Group	**Mode**	**index_min**	**index_max**
Summer Seasonal	Bike	2.0	5.0
Recreation	Bike	1.4	2.0
Mixed Use	Bike	1.0	1.4
University Seasonal	Bike	0.0	1.0
Seasonal Vacation	Ped	2.0	5.0
Primarily Fitness	Ped	1.2	2.0
Recreation & Entertainment, and Downtown Business Districts	Ped	0.8	1.2
Mixed Use	Ped	0.0	0.8

Proposed Weekend-Weekday Index

Factor Group	**Mode**	**index_min**	**index_max**
Popular Recreation & Entertainment	Ped	1.3	3.0
Mixed Use	Ped	0.7	1.3
Primarily Commute	Ped	0.0	0.7
Primarily Recreation - High Volume	Bike	1.3	4.0
High Volume Recreation - Mixed Use	Bike	0.8	1.3
University Commute	Bike	0.0	0.8

Proposed Morning-Midday Index

Factor Group	**Mode**	**index_min**	**index_max**	**Qualitative Description**
Downtown Business District	Ped	2.0	5.0	Business district in small to large cities
Near Urban	Ped	1.3	2.0	Higher density, adjacent to downtown
Mixed Use 1	Ped	0.7	1.3	Diverse
Mixed Use 2	Ped	0.0	0.7	Transit commute, primary schools, low volume recreation
Popular Recreation	Bike	2.0	4.0	Higher volume used primarily for recreation
Recreation or Downtown Business	Bike	1.2	2.0	Suburban recreational routes or downtown business districts
Mixed Use, Some Commuting	Bike	0.8	1.2	Diverse
Primarily Commute	Bike	0.0	0.8	Higher volume downtown business and university

Existing Temporal Cross-Section Factor Groups Represented in the NC NMVDP

Bicycle Factor Groups	**Mixed Use**	**Recreation**	**Summer Seasonal**	**University Seasonal**
Mixed Use, Some Commuting				
High Volume Recreation - Mixed Use	1			1
Primarily Recreation - High Volume	1			
University Commute				1
Popular Recreation				
Primarily Recreation - High Volume	1	1		
Primarily Commute				
High Volume Recreation - Mixed Use	1			
University Commute	2			3
Recreation or Downtown Business				
High Volume Recreation - Mixed Use	2		1	
Primarily Recreation - High Volume	2	3		
University Commute	1			1

Pedestrian Factor Groups	**Mixed Use**	**Primarily Fitness**	**Recreation & Entertainment, and Downtown Business Districts**	**Seasonal Vacation**
Downtown Business District				
Mixed Use			3	
Popular Recreation & Entertainment			4	
Primarily Commute	1			
Mixed Use 1				
Mixed Use	2		5	2
Popular Recreation & Entertainment			3	
Primarily Commute	1			
Mixed Use 2				
Mixed Use	1	1		
Popular Recreation & Entertainment	1	1	1	
Primarily Commute			1	
Near Urban				
Mixed Use	1	1	1	
Primarily Commute	2			

Proposed Factor Group Summary

Factor groups with the recommended number of stations are listed below. Qualitative similarities, if any, are outlined below each cross-sectional temporal factor group.

- Pedestrian – At Least Four Stations (recommended)
    - Recreation & Entertainment, and Downtown Business Districts/**Downtown Business District**/*Popular Recreation & Entertainment*
        - Apex – Salem Street, Greensboro – South Elm Street, Davidson – South Main Street, Greensboro – Walker Avenue
            - Each of these sites is in a business district with restaurants and retail stores.
    - Recreation & Entertainment, and Downtown Business Districts/**Mixed Use 1**/*Mixed Use*
        - Charlotte – Selwyn Avenue, Charlotte – West 4th Street Extension, Winston-Salem – West End Boulevard, Wilkesboro – Yadkin River Greenway
            - Each of these sites is located adjacent to a public park in a suburban area.
- Pedestrian – Three Stations (acceptable)
    - Recreation & Entertainment, and Downtown Business Districts/**Downtown Business District**/*Mixed Use*
        - Charlotte – North Tryon Street, Winston-Salem – West 4th Street, Raleigh – Cameron Street
            - Stations are diverse: 4th street is a downtown business district, Cameron Street is located within a shopping complex, and North Tryon Street is a gateway to a downtown business district. All are high volume pedestrian sites in relatively urban areas.
    - Recreation & Entertainment, and Downtown Business Districts/**Mixed Use 1**/*Popular Fitness & Entertainment Centers*
        - Durham – American Tobacco Trail at Highgate Road, Raleigh – Neuse River Greenway, Charlotte – Pecan Avenue
            - Two trails are high volume recreational stations, while Pecan Avenue connects an entertainment and restaurant center to a dense urban-adjacent neighborhood.
- Bicycle – Three Stations (recommended)
    - University Seasonal/**Primarily Commute**/*University Commute*
        - Carrboro - Libba Cotten Bikeway, Durham – Main Street, Charlotte – South Tryon Street
            - Libba Cotten Bikeway and Main Street are along university commute routes. However, South Tryon Street is not; it is the main connector route from south Charlotte to uptown Charlotte. This indicates that commuting to a downtown business districts likely decreases in the summer.

- Recreation/**Recreation or Downtown Business**/*Primarily Recreation – High Volume*
  - Sanford – Endor Iron Furnace Greenway, Cary – New Hope Church Road, Durham – American Tobacco Trail at Highgate Road
    - Each facility is on a popular recreational bicycle trail or leads to a popular recreational bicycle trail.

Conclusions

The following conclusions can be made from the above analyses:

- Qualitative factor groupings may not be appropriate in determining facilities with similar daily, weekly, and seasonal temporal patterns.
- Temporal patterns of bicycle and pedestrian facilities are diverse, even among facilities with similar primary trip purposes or land use patterns.
- Bicycle factor groupings may be different from pedestrian factor groupings given the unique facility purposes of adjacent bicycle and pedestrian facilities.
- Certain qualitative factors can predict certain temporal patterns; for example, most urban business districts have at least twice as many midday weekday users as morning users, most popular primarily recreational bicycle trails have at least twice as many weekend users as weekday users, and most facilities near a university will have less users in the summer than the fall. However, daily, weekly, and seasonal patterns are difficult to predict.
- Proposed cross sectional factor names were sometimes in conflict. Some factors groupings were categorized as a primarily commuting pattern for one temporal index, and a mixed use pattern for another. More rigorous investigation into common qualitative, land use, and trip purpose patterns is required to determine more accurate describe factor groups.

Next steps include:

- Conducting analyses to calculate daily adjustment factors for the above proposed groupings and optimize index grouping ranges
- Testing simpler groupings like WWI x AMI or WWI x SFI to determine if the gains in error minimization are worth the investment in more factor groups
- Testing if factor group assignment of a facility without a permanent count station can be correctly determined using temporal patterns of a short-duration count
- Further investigation into other bicycle and pedestrian indices to support regional factor groupings

Complete Index Results

Pedestrian Midday/Morning Index

Station	Mode	(n)	AMI
Salem Street	Ped	872	4.06
South Main Street - Davidson	Ped	1,028	3.66
South Elm Street	Ped	912	3.53
North Tryon Street	Ped	1,040	3.02
West 4th Street	Ped	736	2.84
Elizabeth Avenue	Ped	1,040	2.68
Walker Avenue	Ped	776	2.49
Cameron Street	Ped	1,024	2.25
Brevard Greenway	Ped	524	2.21
Spring Garden Street	Ped	1,040	1.79
University City Boulevard Sidepath	Ped	1,036	1.52
Stonewall Street	Ped	960	1.51
Griffith Street	Ped	1,032	1.50
Strollway	Ped	988	1.40
Hillsborough Street	Ped	436	1.23
Pecan Avenue	Ped	788	1.22
Rocky Branch Trail	Ped	820	1.19
Yadkin River Greenway	Ped	1,032	1.09
West 4th Street Extension	Ped	1,032	1.06
American Tobacco Trail at Lakewood Avenue Bridge	Ped	640	1.05
Hargett Street	Ped	1,040	1.05
Concord Road	Ped	248	1.03
Neuse River Greenway	Ped	1,032	0.97
Main Street - Durham	Ped	1,040	0.92
Duck Trail	Ped	400	0.86
Libba Cotten Bikeway	Ped	468	0.76
Selwyn Avenue	Ped	1,036	0.75
American Tobacco Trail at Highgate Road	Ped	528	0.74
Olive Chapel Road	Ped	200	0.74
West End Boulevard	Ped	880	0.73
Blue Line Trail	Ped	608	0.68
Main Street - Wake Forest	Ped	620	0.65
Beaver Creek Greenway	Ped	768	0.63
Endor Iron Furnace Greenway	Ped	740	0.46
South Tryon Street	Ped	740	0.39
Louis Stephens Drive	Ped	568	0.37
Ridge Road	Ped	668	0.33
Old NC 86	Ped	224	0.30

Bicycle Midday/Morning Index

Station	Mode	(n)	AMI
Brevard Greenway	Bike	564	3.89
Strollway	Bike	1,008	2.85
Lake Daniel Greenway	Bike	540	2.19
Neuse River Greenway	Bike	1,032	2.08
South Elm Street	Bike	912	1.88
West 4th Street	Bike	1,036	1.76
Endor Iron Furnace Greenway	Bike	744	1.71
Beaver Creek Greenway	Bike	316	1.65
Duck Trail	Bike	1,032	1.53
University City Boulevard Sidepath	Bike	1,012	1.51
American Tobacco Trail at Highgate Road	Bike	528	1.49
Pecan Avenue	Bike	1,004	1.33
Selwyn Avenue	Bike	1,040	1.30
New Hope Church Road	Bike	620	1.27
Spring Garden Street	Bike	1,040	1.13
West End Boulevard	Bike	240	1.13
Yadkin River Greenway	Bike	1,040	1.05
Walker Avenue	Bike	1,040	1.02
Blue Line Trail	Bike	200	0.89
American Tobacco Trail at Lakewood Avenue Bridge	Bike	828	0.81
Main Street - Durham	Bike	1,040	0.72
Rocky Branch Trail	Bike	852	0.70
Stonewall Street	Bike	1,028	0.68
Libba Cotten Bikeway	Bike	456	0.49
South Tryon Street	Bike	540	0.33
Cornwallis Road	Bike	1,028	0.11

Pedestrian Weekend/Weekday Index

Station	Mode	Weekday (n)	Weekend (n)	WWI
Neuse River Greenway	Ped	258	105	2.02
American Tobacco Trail at Highgate Road	Ped	133	54	1.77
Louis Stephens Drive	Ped	142	57	1.69
South Elm Street	Ped	228	92	1.63
Salem Street	Ped	218	88	1.58
Walker Avenue	Ped	194	79	1.58
South Main Street - Davidson	Ped	257	103	1.46
Concord Road	Ped	62	26	1.43
Blue Line Trail	Ped	152	63	1.43
Pecan Avenue	Ped	197	78	1.38
American Tobacco Trail at Lakewood Avenue Bridge	Ped	160	63	1.36
Beaver Creek Greenway	Ped	192	76	1.34
Selwyn Avenue	Ped	259	105	1.27
Main Street - Wake Forest	Ped	260	104	1.24
West 4th Street	Ped	184	75	1.22
Strollway	Ped	247	102	1.21
Duck Trail	Ped	100	45	1.15
West 4th Street Extension	Ped	258	104	1.13
Cameron Street	Ped	256	104	1.10
Olive Chapel Road	Ped	51	21	1.09
Stonewall Street	Ped	240	99	1.09
Main Street - Durham	Ped	155	66	1.08
Rocky Branch Trail	Ped	205	82	1.05
Endor Iron Furnace Greenway	Ped	185	71	1.03
Brevard Greenway	Ped	131	54	0.99
West End Boulevard	Ped	220	89	0.99
Hargett Street	Ped	260	105	0.94
Old NC 86	Ped	56	23	0.93
Libba Cotten Bikeway	Ped	118	49	0.92
North Tryon Street	Ped	260	105	0.87
Yadkin River Greenway	Ped	258	103	0.86
Ridge Road	Ped	167	67	0.81
Griffith Street	Ped	258	104	0.73
Hillsborough Street	Ped	109	42	0.64
University City Boulevard Sidepath	Ped	259	105	0.53
South Tryon Street	Ped	185	76	0.52
Spring Garden Street	Ped	260	105	0.47
Elizabeth Avenue	Ped	260	105	0.28

Bicycle Weekend/Weekday Index

Station	Mode	Weekday (n)	Weekend (n)	WWI
Endor Iron Furnace Greenway	Bike	186	75	2.21
American Tobacco Trail at Highgate Road	Bike	133	55	2.17
Selwyn Avenue	Bike	260	105	2.06
Neuse River Greenway	Bike	258	105	2.03
Beaver Creek Greenway	Bike	79	29	2.00
Blue Line Trail	Bike	50	22	1.94
New Hope Church Road	Bike	155	62	1.80
American Tobacco Trail at Lakewood Avenue Bridge	Bike	207	84	1.72
Strollway	Bike	252	102	1.64
Brevard Greenway	Bike	141	59	1.53
Lake Daniel Greenway	Bike	135	54	1.33
Pecan Avenue	Bike	251	103	1.15
Yadkin River Greenway	Bike	260	105	1.12
Rocky Branch Trail	Bike	213	86	1.09
South Elm Street	Bike	228	92	1.07
Duck Trail	Bike	258	102	1.04
Walker Avenue	Bike	260	105	0.94
West End Boulevard	Bike	60	24	0.90
Stonewall Street	Bike	257	104	0.80
Spring Garden Street	Bike	260	105	0.76
West 4th Street	Bike	259	104	0.72
Main Street - Durham	Bike	260	105	0.63
South Tryon Street	Bike	135	55	0.59
Cornwallis Road	Bike	257	105	0.43
University City Boulevard Sidepath	Bike	253	104	0.40
Libba Cotten Bikeway	Bike	115	49	0.33

Pedestrian Summer/Fall Index

Station	Mode	Factor Group	SFI
Duck Trail	Ped	Seasonal Vacation	3.42
Rocky Branch Trail	Ped	Seasonal Vacation	2.50
Endor Iron Furnace Greenway	Ped	Primarily Fitness	1.40
Blue Line Trail	Ped	Primarily Fitness	1.27
Strollway	Ped	Primarily Fitness	1.26
West 4th Street Extension	Ped	Recreation & Entertainment, and Downtown Business Districts	1.16
Stonewall Street	Ped	Recreation & Entertainment, and Downtown Business Districts	1.11
Walker Avenue	Ped	Recreation & Entertainment, and Downtown Business Districts	1.09
Neuse River Greenway	Ped	Recreation & Entertainment, and Downtown Business Districts	1.07
Pecan Avenue	Ped	Recreation & Entertainment, and Downtown Business Districts	1.04
Salem Street	Ped	Recreation & Entertainment, and Downtown Business Districts	1.03
Yadkin River Greenway	Ped	Recreation & Entertainment, and Downtown Business Districts	1.01
West 4th Street	Ped	Recreation & Entertainment, and Downtown Business Districts	1.00
West End Boulevard	Ped	Recreation & Entertainment, and Downtown Business Districts	0.98
North Tryon Street	Ped	Recreation & Entertainment, and Downtown Business Districts	0.98
Beaver Creek Greenway	Ped	Recreation & Entertainment, and Downtown Business Districts	0.98
South Tryon Street	Ped	Recreation & Entertainment, and Downtown Business Districts	0.94
Hargett Street	Ped	Recreation & Entertainment, and Downtown Business Districts	0.93
South Elm Street	Ped	Recreation & Entertainment, and Downtown Business Districts	0.92
South Main Street - Davidson	Ped	Recreation & Entertainment, and Downtown Business Districts	0.92
American Tobacco Trail at Highgate Road	Ped	Recreation & Entertainment, and Downtown Business Districts	0.87
Selwyn Avenue	Ped	Recreation & Entertainment, and Downtown Business Districts	0.87
Cameron Street	Ped	Recreation & Entertainment, and Downtown Business Districts	0.85
Libba Cotten Bikeway	Ped	Mixed Use	0.78
Elizabeth Avenue	Ped	Mixed Use	0.78
Griffith Street	Ped	Mixed Use	0.75
Ridge Road	Ped	Mixed Use	0.73
Main Street - Durham	Ped	Mixed Use	0.69
Louis Stephens Drive	Ped	Mixed Use	0.69
University City Boulevard Sidepath	Ped	Mixed Use	0.62
Hillsborough Street	Ped	Mixed Use	0.61
Spring Garden Street	Ped	Mixed Use	0.50

Bicycle Summer/Fall Index

Station	Mode	Factor Group	SFI
Duck Trail	Bike	Summer Seasonal	5.44
Endor Iron Furnace Greenway	Bike	Recreation	1.60
Neuse River Greenway	Bike	Recreation	1.47
American Tobacco Trail at Highgate Road	Bike	Recreation	1.43
New Hope Church Road	Bike	Recreation	1.42
Selwyn Avenue	Bike	Mixed Use	1.36
American Tobacco Trail at Lakewood Avenue Bridge	Bike	Mixed Use	1.28
West 4th Street	Bike	Mixed Use	1.25
Cornwallis Road	Bike	Mixed Use	1.24
Pecan Avenue	Bike	Mixed Use	1.23
Yadkin River Greenway	Bike	Mixed Use	1.15
South Elm Street	Bike	Mixed Use	1.11
Beaver Creek Greenway	Bike	Mixed Use	1.11
Rocky Branch Trail	Bike	Mixed Use	1.06
Stonewall Street	Bike	Mixed Use	1.05
Strollway	Bike	Mixed Use	1.00
Walker Avenue	Bike	University Seasonal	0.97
Main Street - Durham	Bike	University Seasonal	0.95
South Tryon Street	Bike	University Seasonal	0.85
Libba Cotten Bikeway	Bike	University Seasonal	0.82
Spring Garden Street	Bike	University Seasonal	0.79
University City Boulevard Sidepath	Bike	University Seasonal	0.51