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Pedestrians and Bicyclists Count: Developing a Statewide Multimodal Count Program

by

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16. Abstract

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To this end, the research team conducted a comprehensive review of academic and applied literature pertaining to collecting pedestrian and bicycle data collection and benchmarking, with a focus on techniques for using count data to evaluate exposure rates and safety outcomes or trends, researched methods of counting bicycles and pedestrians including both manual counts and automated electronic counts using various technologies (including automated video-based counts), and identified potential funding sources and potential partners for systematic as well as incidental data collection. Finally, the research team conducted pilot data collection and analysis at three case study locations in New Orleans and Baton Rouge to test recommended count equipment and count methodology and advance fundamental elements of comprehensive evaluation of the safety impacts of complete streets-oriented infrastructure.

The results of this research indicate that the incremental development of systematic active transportation monitoring, in coordination with existing traffic monitoring activities and in cooperation with local and regional agencies interested in or already engaged in data collection and analysis, is feasible and scalable (geographically and fiscally) using a combination of traditional and emerging technologies. Moreover, significant expansion of long-duration count data availability is critical to all efforts to holistically evaluate safety impacts at the project level, and an area where state leadership and investment will have the greatest impact.

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LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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IMPLEMENTATION STATEMENT

The results of the research are directly applicable for DOTD, as well as for local and regional agencies interested in nonmotorized data collection, providing a framework and guiding principles for the planning and implementation of automated nonmotorized road user counts. Any such efforts implemented in Louisiana will be of immediate benefit to the state's efforts to implement and benchmark complete streets policies by providing data with which to more accurately assess safety outcomes and against which to measure change. Such data is of value to state, regional, and local entities for planning purposes, and fundamental to key avenues of future academic and applied research.

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INTRODUCTION

Government agencies at all levels nationwide are increasingly interested in adopting a “complete streets” approach to infrastructure development by implementing or upgrading facilities for walking, bicycling, and transit use. The complete streets approach represents a substantive shift in how infrastructure is planned, constructed, and evaluated. Evaluation of the efficacy of these investments—and planning and prioritizing future investments—requires new and innovative approaches to data collection and analysis in order to effectively measure infrastructure demand and performance for all user groups, including pedestrians and bicyclists.

In 2009, the Louisiana legislature passed Senate Concurrent Resolution 110, which directed the convening of the Complete Streets Work Group to develop statewide complete streets policy for Louisiana. This resulted in the adoption of an internal DOTD policy in 2010, demonstrating agency commitment to a multimodal approach for all new or substantially rebuilt infrastructure. This policy was recognized as the second-best state policy in the country by the National Complete Streets Coalition in 2011 *[1]*. As part of its efforts, the Complete Streets Work Group developed a list of recommended actions needed to advance policy implementation, including recommendations to require pedestrian and bicycle data collection and analysis as part of Traffic Impact Analyses and as a condition of permit approval *[2]*.

In recognition of the need to provide ongoing support to DOTD in the implementation of this policy, Act 470 of the 2014 Louisiana legislative session (RS: 48:22.1) mandated renewed engagement of stakeholders in the complete streets policy implementation process through new reporting requirements and the development of an advisory body known as the Complete Streets Advisory Council (LACSAC). The Act also specified that both process and outcome-oriented performance measures be developed and adopted by DOTD (in conjunction with the LACSAC) to evaluate the effectiveness of the complete streets policy.

A critical component of such performance measures, as identified by the advisory council, is the measurement of active transportation demand *[3]*. Understanding how many people are traveling on foot or by bicycle on Louisiana’s roadways is critical to (a) evaluating safety outcomes relative to rates of exposure, (b) identifying appropriate, context-sensitive complete streets infrastructure interventions, and (c) understanding overall statewide and location-specific transportation trends which will impact long-range planning and investment.

Methods of collecting this data vary, and few states have developed coordinated statewide active transportation count programs in support of policy implementation and benchmarking.

This study sought to identify opportunities to address existing gaps in the availability of data pertaining to pedestrian and bicycle activity, provide the methodological foundation for developing an efficient, effective program based on national best practices, and advance the state’s complete streets policy implementation and performance measurement efforts, as directed by the legislature.

OBJECTIVE

The purpose of this study was to research best practices and available methods and technologies for measuring active transportation activity, in order to provide DOTD with needed information in support of the development of an efficient, cost-effective bicycle and pedestrian count program.

Specifically, the objectives of the study included:

1. Research established and emerging methodologies for counting bicycles and pedestrians and identify best practices for statewide count programs
2. Evaluate available count technology equipment options and identify preferred alternatives suitable for statewide deployment
3. Identify potential funding sources for the implementation of a multimodal count program and opportunities to integrate active transportation counts into existing vehicular count programs

SCOPE

The study included the following research tasks, aimed at developing a foundation for implementing a statewide pedestrian and bicycle count program:

Task 1: Literature Review

The research team conducted a comprehensive review of academic and applied literature pertaining to collecting pedestrian and bicycle data collection and benchmarking, with a focus on techniques for using count data to evaluate exposure rates and safety outcomes or trends.

Task 2: Bicycle and Pedestrian Counting Research Methods Exploration

In this task the research team researched methods of counting bicycles and pedestrians including both manual counts and automated electronic counts. This included a comparative analysis of manual count methodologies used across the United States, and evaluation of various electronic sensing devices (e.g., infrared, pneumatic, inductive-loop, etc.) which can be used to measure user volumes of one or more modes. As part of this analysis, equipment needs and alternative options for completing the pilot case study (Task 5) were evaluated (in addition to the sensing equipment already owned by UNO). The team also researched applicable alternatives to counting, including but not limited to use of American Community Survey (ACS), Travel Survey of Population, and Smartphone App-based data collection methods. This task included interviews and conversations with academic and professional leaders involved in this field of research to aid in the identification of best practices for bicycle and pedestrian count application over large geographic areas (i.e., statewide programs).

Task 3: Video-Based Count Detection Assessment

This task was conducted by LTRC staff in coordination with this research effort, and involved evaluating methods for collecting count data using existing video cameras (e.g., DOTD’s network of ITS cameras on state routes). This included a review of literature pertaining to video capture methodology for bicycles and pedestrians (including but not limited to available technologies, best practices, and limitations), and an investigation into potential opportunities for both automated count data collection using algorithms to capture nonmotorized users and use of archived video as a proxy for short-term manual (field) counts using existing DOTD and LTRC equipment. This task resulted in recommendations pertaining to the feasibility and limitations of utilizing this data capture technology.

Task 4: Identify Funding Sources

The research team sought to identify potential funding sources for conducting counts, potential partners and opportunities to link counting as a requirement for developers and/or local governments when funding and/or access to state roadways is provided. This included evaluation of how existing pedestrian and bicycle count programs are funded, and opportunities to integrate bicycle and pedestrian counting with existing vehicular counting program, including traffic impact assessments as well as the replacement of DOTD owned equipment, over time.

Task 5: Case Studies

In this task the research team utilized knowledge gained from the literature review (Task 1) and technology and methods analysis (Task 2) to develop and pilot a proposed methodology for measuring the impacts of complete streets-oriented infrastructure interventions on safety outcomes. The team conducted three case studies utilizing data from New Orleans Regional Planning Commission's Bicycle and Pedestrian Program as well as the collection of new data (using existing and new sensing equipment as needed based on the findings of Task 2) as appropriate, and developed an inventory of all data required for analysis. New and existing infrared and pneumatic tube sensors were utilized to collect sample data and test proposed methods of data collection, management, and use. Additional technologies were investigated for suitability for potential future use. This task also included preliminary methodology development of benefit cost analysis and calculation of the return-on-investment (ROI) for the selected case studies, to the degree that sufficient data were available to do so.

Task 6: Final Report

This task involved preparation of this research report, documenting the entire research effort and summarizing all research tasks, and providing evidence-based recommendations for the development of a cost-effective, efficient bicycle and pedestrian count program commensurate with documented trends toward increasing rates of walking and bicycling and the unique safety considerations associated with travel by these modes. This report synthesizes findings and provides recommendations in support of continued complete streets policy implementation.

METHODOLOGY

Task 1: Literature Review

The research team conducted a review of academic and applied literature to assess the current state of the practice for pedestrian and bicycle planning and data collection, including retrieval and review of federal policy, guidance, and key research products, a review of synthesis studies and applied research reports documenting use and/or accuracy of specific automated count technologies. In addition, the team reviewed literature focused on the application of count data for various planning and evaluation purposes, including Average Annual Daily Traffic (AADT) estimation, factoring, and data expansion, techniques for normalizing crash data such as to derive exposure estimates, and the role of count data in benchmarking, impact assessment, and policy implementation.

Task 2: Bicycle and Pedestrian Counting Research Methods Exploration

First, an inventory was developed to methodically review existing count programs, focusing on statewide programs but with selected inclusion of local and/or regional programs that reflect current best practices, early leaders, and/or innovative technologies or methods.

Next, the various methods and technologies employed in service to collecting active transportation were reviewed, including those for manual counts, and automated counts conducted using a variety of established count technologies (i.e., infrared, pneumatic tubes, and inductive loops) as well as emerging technologies including video-based data collection, as well as indirect data collection methods and data sources (e.g., survey data, GPS data, Bluetooth data, and actuated signal counts). Periodic updates were made to the inventory of potential products and vendors throughout the course of this research. Guidance on how to plan and structure a count program was reviewed and summarized, including the following key steps in count program development and implementation:

- Documenting existing data and count activities
- Identifying program goals
- Site selection
- Count timing and duration
- Equipment selection and installation
- Equipment calibration and data validation
- Data processing, management, and quality control
- Data reporting and dissemination

In addition to published guidance and literature pertaining to these topics, the research team actively engaged with professionals in this field via meetings, phone, email, in-person dialogue, and webinars to glean additional and updated information from practitioners with extensive experience in developing and implementing count programs. These discussions informed the research and helped shape and guide the recommendations documented herein.

Task 3: Video-Based Count Detection Assessment

The research team included a review of literature and technology pertaining to video-based count detection as a component of Tasks 1 & 2 and developed a preliminary inventory of vendors of related technology and services. This review was provided to the LTRC support study team to guide their work on this task.

The LTRC support study team collected data at several locations (Government Street, Dalrymple Drive, and three locations on LSU's campus) in support of developing an original algorithm for extracting, classifying, and calculating pedestrian and bicycle counts from video data. Notably, video cameras were also installed at the first two case study locations in New Orleans (Tulane Avenue and Esplanade Avenue), though the data from these installations were ultimately not utilized for the purpose of algorithm development due to difficulties with the video feed (i.e., in maintaining uniform camera angles, capturing appropriate views of the right-of-way, and image obstructions) and technical difficulties with the equipment which were resolved in subsequent installations.

The camera system used in this study was the JAMAR Portable Video Camera System (Serial Number: 201702001) with a 64GB memory capacity for each filming. It can capture approximately 2 days of continuous footage with a standard resolution of 640x480 pixels and 4 to 9 hours with highest resolution at 1920x1080 pixels. This project utilized the standard resolution mode for capturing the video data. The height at which the camera is mounted on the pole was an average of 5.41 ft. and at an angle of 65-75 degrees from the pole for all sites. The camera was programmed to capture video at certain times throughout the day and night over a set duration of days.

During this initial feasibility study, the researchers focused on developing the HOG algorithm to detect pedestrians and bicyclists in the video data, with manual observation counts to validate the performance of the technique and provide an accuracy rate for the methodology used. The full methodology for this effort, along with a discussion of findings, is detailed in LTRC Final Report: ITS Support for Pedestrians and Bicyclists Count: Developing a Statewide Multimodal Count Program *[4]*.

Task 4: Identify Funding Sources

The purpose of this task was to identify the cost of existing multimodal and/or pedestrian and bicycle count programs, how they are paid for, and to develop cost estimates for typical components of a hypothetical statewide program. This was achieved principally through reviewing publicly accessible documents describing count program implementation and interviews (in-person and via email) with individuals responsible for managing pedestrian and bicycle monitoring programs across the country, as well as a compilation of estimated costs for various types of equipment and technology in common use.

Task 5: Case Studies

The research team conducted three case studies: two in New Orleans and one in Baton Rouge, using existing equipment owned by the University of New Orleans as well as new, functionally-identical equipment purchased as part of this research grant (two units each of EcoCounter EcoTubes pneumatic tube counters and EcoPyro Infrared Sensors). The case studies included collection of new data in accordance with national best practices for automated data collection at locations with existing sidewalks and on-street bicycle infrastructure, representative of typical “improved” conditions for active transportation in an urbanized area (i.e., sidewalks on both sides of the ROW and simple on-street dedicated bicycle lanes) in the case of the two New Orleans locations, and a typical “pre-intervention” location in Baton Rouge where a major street redesign to (in part) more effectively accommodate pedestrians and bicyclists is currently underway.

These case study locations were selected following review and discussion by the Project Review Committee, and included:

- **Tulane Avenue** (US 61), New Orleans
- **Esplanade Avenue,** New Orleans
- **Government Street** (State Rt 73), Baton Rouge

These sites were proposed based on the existence of some previous count data, moderate to high levels of anticipated pedestrian and/or bicycle traffic, ROW configurations conducive to automated count data collection, and/or recent or planned active transportation infrastructure improvements. For each study location, existing data (including auto and/or nonmotorized count data, relevant safety data, information about land use and activity generators, etc.) was reviewed.

The research team installed automated count equipment (infrared sensors and pneumatic tubes) at a location generally representative of the overall study area, and calibrated and validated these units using manual in-person and/or recorded video methods, using this data to calculate adjustment factors to account for inherent systemic error. The literature review and interviews conducted revealed a strong preference for the industry leader in active transportation count equipment (EcoCounter) at this time due to the product’s reliability and ease of use. Entities in Louisiana currently collecting nonmotorized count data are already using this brand of equipment, including UNO. The following units were purchased to supplement existing (identical) equipment inventory maintained by UNO to facilitate the collection of short-term bi-directional pedestrian and bicycle data for typical street cross-sections such as those proposed for this case study:

- 1 15 ft. bi-directional PYRO-box infrared sensor
- 1 Eco-TUBES system with direction detectives and 2 sets of selective tubes

A minimum of two weeks of automated data were collected for each study location. In addition, a minimum of four hours of manual field validation were collected from which to develop overall correction factors to account for common sensor errors (e.g., occlusion, when two or more pedestrians or bicyclists pass simultaneously and are registered as only one user), as well as errors resulting users not passing through the observation plane in the predicted location and being missed by the sensors entirely (e.g., bicyclists on the sidewalk or on the roadway in the motorized travel lane; pedestrians in the street).

This data was evaluated to determine general traffic patterns by hour of day and day of week to identify the general typology of active transportation activity (i.e., factor group). Where appropriate (based on factor group/pattern categorization), preliminary temporal adjustment factors, developed based on existing PBRI data for a permanent counter installed on the Jefferson Davis Parkway Trail in New Orleans, were applied to derive estimated average annual daily pedestrian and bicycle traffic.

Note that under ideal conditions, correction factors would be applied directly to the raw data, and all other adjustments completed subsequently. For these case studies, very different installation contexts and situational factors at each location meant that validation had to be completed at each location, rather than only once and then a single correction factor applied. Time limitations meant there were challenges in obtaining large enough sample sizes (ideally, more than 100 users per sensor unit) to have full confidence in the correction factors developed. Thus, these adjustments are only applied to the final AADT calculations, in order to retain the integrity of the raw data as recorded. Since most other analysis of these data are of user patterns, the order of application of the correction and expansion factors makes no significant mathematical difference.

Next, crash data provided by DOTD were evaluated to understand overall safety outcomes to date on the case study corridors. Processing of this dataset consisted of the following:

- For each DOTD crash database CRASH_TB file, all crashes for which the subject corridor was either the primary or intersecting road were extracted.
- For crashes where the study corridor was the intersecting road, only crashes identified as being intersection crashes were retained. All crashes occurring on access-restricted roadways (interstates and expressways) were excluded.
- The resulting extraction was joined (by crash number) to the DOTD_TB file to incorporate the most accurate latitude and longitude data, then joined to relevant attribute columns from the PEDES_TB and VEHIC_TB tables (the latter being pre-filtered for bicycle-involved crashes only (vehicle type: F).
- The resulting table is exported as a .xlsx file and then imported into ArcGIS to display coordinates spatially and results exported as a shapefile.
- This shapefile was then edited to extract only crashes occurring within the study area, i.e., the portion of the corridor where an infrastructure intervention impacting pedestrians and/or bicycles was made or is planned, excluding crashes occurring within the terminal intersections of each (e.g., for Tulane Avenue and Esplanade Avenue, the study area is from S. Claiborne Avenue to S. Carrollton Avenue, but excluding crashes occurring at those intersections)
- The results were saved and exported as spreadsheets for each study area for summary of trends

The key questions investigated through analysis of the crash data were:

- How many crashes occurred in the study area in the 3 or 5-year period before the infrastructure intervention?
- How many of those crashes involved pedestrians or bicyclists?
- How many crashes resulted in serious injury or fatality (any mode)?
- With the data currently available, is it possible to derive a pedestrian and/or bicycle crash rate for this corridor, given the estimated bike/ped AADT derived from counts?

Finally, in order to advance holistic evaluation of how to measure the impact of active transportation investment and Complete Streets approaches to our transportation networks, a review of methods for conducting cost-benefit analyses for active transportation projects was also conducted, in order to identify a framework for future analysis in Louisiana. A working paper detailing findings can be found in Appendix C-4, while summary results appear below.

DISCUSSION OF RESULTS

This section summarizes findings from each of the tasks describes above which inform how Louisiana should proceed in expanding nonmotorized count data collection and refining analytic methods for project and policy evaluation.

Task 1: Literature Review

Background and Federal Guidance: Why Count?

The US Federal Highway Administration (FHWA) has clearly asserted support for walking and bicycling as part of an efficient and equitable transportation system *[5]:*

"Providing multimodal transportation options improves equitable access to jobs and essential services, encourages efficient mobility of people and goods, and contributes to a range of policy goals related to equity, health, economic development, and the environment."

More specifically, USDOT has asserted a national goal of achieving an 80% reduction in pedestrian and bicyclist fatalities and serious injuries in the next 15 years, advancing to zero pedestrian and bicyclist fatalities and serious injuries within 30 years, all while increasing the share of short trips (defined as 1 mile for pedestrians and 5 miles for bicyclists) to 30% by 2025 in order to "preserve capacity on our nation's roadways, including National Highway System Corridors" *[5]*. Achieving these goals will require significant investment in active transportation infrastructure; evaluating progress toward them will require more routine and robust nonmotorized data collection efforts.

Broadly, FHWA acknowledges that "while the state of the practice is moving forward, there is still a need to mainstream and institutionalize these efforts" *[5]*. An increasingly robust body of literature exists documenting and evaluating local and state efforts to collect and utilize pedestrian and bicycle count data, most of which has been produced in the last 15 years. Recently, several key documents provide FHWA-approved guidance regarding best practices and the current state of the practice, including an updated FHWA *Traffic Monitoring Guide* and several NCHRP reports including the *Guidebook on Pedestrian and Bicycle Volume Data Collection, Multimodal Level of Service Analysis for Urban Streets*, and *Estimating Bicycling and Walking for Planning and Project Development: A Guidebook [6 - 9]*.

However, there remains a lack of nationally standardized or peer-reviewed literature for the collection, processing, and application of such data *[10, 11]*. Moreover, the recent FHWA guidance assumes the development of nonmotorized count programs that are analogous in scope and scale to motor vehicle programs and does not specifically address the challenge of realistically developing monitoring programs large enough to develop consistent annual daily volume or miles traveled estimates *[11]*. As a result, many transportation agencies have a limited ability to effectively identify and meet active transportation infrastructure needs, and are stymied in efforts to holistically evaluate advancement toward safety goals.

The need for more and higher quality pedestrian and bicycle volume data, similar to that available for decades for motor vehicles, has been well-documented by transportation planners and researchers. The Bureau of Transportation Statistics' *Bicycle and Pedestrian Data Sources, Needs, and Gaps* summarized these and identified outstanding data needs and priorities *[12]*.

Government agencies and researchers have initiated pedestrian and bicycle count programs for a variety of reasons, including:

- To track changes in overall active transportation trends (volumes as well as behavioral) over time *[7, 13 - 15]*
- To understand spatial variation in user volumes across a geographic area and determine existing travel patterns *[13]*
- To evaluate the impacts and/or efficiency of previous investments *[7, 15, 16]*
- To plan for and prioritize future infrastructure investments *[7, 14, 17]*
- To develop more nuanced extrapolation factors for estimating volumes from short-duration counts *[7]*
- To benchmark progress toward transportation and/or public health policy goals *[10, 15]*

In addition, "projects specifically targeted for bicycle and pedestrian travel struggle to compete for funding with other highway projects because they lack information to determine current or future facility usage" *[10]*. Thus, collection of nonmotorized data also supports implementation of active transportation infrastructure interventions by providing evidence of existing facility demand. Nonmotorized volume data can also be used in transportation modeling to estimate demand across a network and/or project future demand *[7, 15]*.

Critically, it can also be used to better understand and benchmark progress toward improvements in safety outcomes by providing key information for normalizing crash rates and conducting risk/exposure analyses *[7, 10, 15, 16]*. Such evaluations can provide context for crash data at the facility or area-wide level by using estimated pedestrian or bicycle miles traveled as an exposure metric *[7]*.

Most walking and bicycling occurs on local roadways, thus, most nonmotorized volume monitoring has been conducted by local jurisdictions *[11]*. However, as the state of the practice advances, it has become clear that federal funding for transportation is becoming further contingent upon data supporting proposals, including for nonmotorized modes, making it incumbent upon state DOTs to begin to incorporate this kind of data collection into their operations. FHWA expects to add new pedestrian and bicycle performance measures to their regulations *[5]*. Multimodal volume data is likely to be among these.

The Federal Highway Administration has observed that “the best way to improve transportation networks for any mode is to collect and analyze trip data to optimize investments *[14]*. Walking and bicycling trip data for many communities are lacking. This data gap can be overcome by establishing routine collection of nonmotorized trip information.” In the last few years, US DOT has supported that claim, supporting a series of key research projects and technical documents providing at least preliminary guidance for nonmotorized data collection. These include:

- *FHWA Traffic Monitoring Guide*– the latest edition of this key document utilized by state highway agencies to guide policies, procedures, and equipment purchases, for the first time explicitly provides guidelines for nonmotorized traffic monitoring, including recommendations for data management and integration into the federal Travel Monitoring Analysis System *[6]*.

- *Transportation Research Circular E-6183: Monitoring Bicyclist and Pedestrian Travel and Behavior*– this report surveys currently deployed methods and technology as well as recent and ongoing related research findings *[13]*.

- *NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection*– this report describes count methodologies and provides recommendations for implementing a count program, including example applications *[7]*. This report, designed to complement the TMG, outlines the need and potential value of nonmotorized data collection, provides guidance on program development and data management and processing/application, and is supplemented by *NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection*, which provides detailed information on the findings from tests of a range of automated count technologies *[17]*.

- *USDOT Strategic Agenda 2016*– this recently released report, while not providing explicit guidance on data collection, highlights the overriding goals driving FHWA initiatives and investments for the next five years, in service to the USDOT 2014-2018 strategic plan and 2010 USDOT policy statement on bicycle and pedestrian accommodation *[5]*.

Existing Pedestrian and Bicycle Count Programs

This section provides an overview of statewide as well as notable local and regional nonmotorized count programs and highlights preliminary key findings which may guide Louisiana's efforts to develop multimodal data collection policy and actions. (See Appendix A: Count Program Inventory).

Statewide Programs. Relatively few state transportation agencies have engaged directly in monitoring nonmotorized traffic *[11]*. Notably, several other states including Oregon and Virginia are currently engaged in developing nonmotorized count programs, highlighting the increasing focus on this subject among state transportation officials. Strategies and specific methods vary significantly from state to state; larger states and those with more road miles will experience different challenges in developing monitoring programs *[11]*. This section highlights efforts at state DOTs to initiate or conduct statewide pedestrian and bicycle counts, including the following.

North Carolina – NCDOT's Transportation Mobility and Safety Division conducted a two-year pilot project to design and test a pedestrian and bicycle data collection protocol within a ten-count region. This effort included the installation of 12 permanent count locations, and identified an additional 22 sites for short-duration counting *[10]*.

Washington – WSDOT, which has an explicit goal of "doubling the number of bicycle and pedestrian trips by 2027" has implemented a coordinated statewide count program, depending largely on volunteer-based manual counts following the National Pedestrian and Bicycle Documentation's protocols *[15, 18]*. Local jurisdictions (including more than 30 to date) have identified count coordinators who select count locations (based on criteria established by the state including current or planned active transportation facilities, transit corridors, local stakeholder recommendations, historical count locations, and Smart Growth or mixed-use land use classifications. Washington's count program in part aims to assess pedestrian and bicyclist exposure rates by developing metrics for Pedestrian and Bicycle Miles Traveled *[6]*. Washington also uses automated counters, and is integrating data from these into vehicular traffic count databases *[11]*.

Colorado – CDOT initiated automated volume monitoring in 2009, and has collected automated data on more than 20 on-and off-street locations using infrared and inductive loop counters *[11]*. The agency is working to develop factor groups based on differing activity patterns *[7]*. Colorado has largely rejected the use of short-term manual counts, is working to integrate bicycle counts into motorized vehicle databases *[15]*. However, they have worked with local jurisdictions to incorporate their count data into the program (representing at least 63 additional count locations using infrared and inductive loops, primarily on off-street trails), and have purchased additional mobile infrared counters which may be used by local jurisdictions by request for short term counts from 1 week to 1 month. Colorado has identified traffic pattern groups for study mountain non-commute, front-range non-commute, and commute *[11]*.

Vermont – Vermont's approach to nonmotorized traffic monitoring has focused on purchasing an inventory of automated count equipment which is available for loan to local agencies around the state to collect their own data *[15]*.

Minnesota – MnDOT has supported research and count programs locally, but only recently institutionalized nonmotorized traffic monitoring through projects to develop monitoring procedures and a central data repository. These actions were taken in support of their multi-modal long range transportation plan (2050 Vision – Minnesota Go) and Complete Streets, Safe Routes to School, and Toward Zero Deaths policies. However, MnDOT has not taken on operation of permanent count locations or factor group development themselves *[11]*.

Oregon – ODOT has operated automated bicycle counters since the 1980s, but has not had a systematic count program for nonmotorized users (although the state is in the process of developing such a program). In 2012 it funded a Portland State University project to design a statewide data collection program focusing on on-street facilities and automated count methods. As of 2014, ODOT operated one inductive loop counter and was working to use traffic controller data to estimate pedestrian and bicycle volumes *[11]*.

Select Regional and Local Programs

Minneapolis – As part of the Nonmotorized Transportation Pilot Program, the Twin Cities metropolitan area has developed an extensive count program involving both manual and automated counts, and guidelines to expand this methodology statewide. The Minneapolis Department of Public Works conducted manual counts at 133 locations in 43 communities in the metro area and has installed three inductive loop counters (as of 2013). Technical assistance for the manual counts (including training programs for count managers) was provided by Transit for Livable Communities. These counts followed NPBD protocols; emphasizing evening peak counts *[15]*.

Although Minneapolis has been collecting count data, primarily on trails, for several years, prior to this project, MnDOT had only collected limited bicycle and pedestrian counts on a project-level basis only. This project included the development of adjustment factors from automated counts from six trail locations to extrapolate short term count data. Manual counts were also found to be useful for identifying specific characteristics of users *[15]*.

The project found that improved reporting methods and web-based data reporting and analytic tools are needed, and that integrating short-duration counts into vehicle monitoring databases is a challenge *[15]*. They also found that infrared counters systematically undercount users, while inductive loops were found to variably over and undercount. In addition, Lindsey et al. recommend that the state DOT collaborate with local jurisdictions to establish a network of permanent automated monitoring sites and to share equipment for short-duration monitoring in order to make data collection feasible for small jurisdictions *[15]*. Notably, the wide participation of local communities in this initiative was supported by a requirement by the Minnesota Department of Health that all state health improvement program grantees must participate in the manual counts *[15]*.

San Diego County – San Diego, California’s Seamless Travel Project (2007-2010) represents one of the most comprehensive nonmotorized data collection efforts in the country, including manual peak-period counts at 80 locations, one year of continuous counts using automated counters at five locations, as well as a travel survey to better understand user behaviors. This project, funded by Caltrans using a CDC Community Putting Prevention to Work (CPPW) Grant, was managed by the University of California Traffic Safety Center with support from Alta Planning + Design *[19]*.

California’s Blueprint for Bicycling and Walking included an explicit goal of increasing bicycling and walking by 50%, while simultaneously reducing fatality rates by 50%. Thus, one of the objectives of this study was to support the development of effective metrics for evaluating exposure rates and the impact of new facilities on safety *[19]*. Count locations were selected based on a number of factors, including the presence of existing or planned facilities, designated “Smart Growth Opportunity Areas,” and geographic and demographic variety so as to achieve a stratified sample *[7]*. For the automated counts, used to expand short-term manual counts to develop annual estimates, passive (JAMAR) and active (TrailMaster) infrared counters were deployed on off-street facilities only.

The study, intended to provide a model for future statewide count efforts, emphasized potential applications of the data for travel demand modeling and forecasting. The short and long-term count data provided nuance to these modeling efforts, finding for example that while bike lanes may be expected to result in increasing user volumes over time, they are not necessarily an effective indicator of where the greatest number of riders will be, and that employment density—rather than population density or transit use--was the most important indicator for walking *[19]*. For estimating exposure, the researchers note that standard models must be refined "with variables triggered by specific thresholds of volumes" to adjust for local patterns identified through counts *[19]*.

Arlington, VA – Arlington, Virginia has established a count program using entirely automated count methods, with the first two counters (inductive loops, piezo strips, and passive infrared) installed on trails in 2009. They have since expanded to at least 18 permanent count locations on trails, 10 permanent on-street bicycle counters, and 6 mobile infrared counters for sidewalks, plus an additional bicycle counter with a real-time count display on a key bicycle corridor. Almost all of the products used come from Eco-Counter. As a result of this program, Arlington staffers have identified seasonal patterns and overall growth in bicycling *[7]*. Notably, Arlington's count data are made available to the public at BikeArlington.com, allowing communities, researchers, and other government agencies to query and utilize the data quickly and easily. Similarly, Blacksburg, Virginia, has installed four permanent counters and has conducted at least 97 cyclical short-duration (1-week) counts from which they have derived AADPT/AADBT estimates for a variety of location/road types with different seasonal and daily usage patterns. Researchers in Blacksburg have used pneumatic tubes to count bicycle volumes on roadways and sidewalks simultaneously.

Delaware Valley RPC (Philadelphia) – Delaware Valley RPC, serving the Philadelphia region, has 12 permanent pedestrian and bicycle count locations along trails (supported by the William Penn Foundation and utilizing EcoCounter Eco-Multi equipment) as well as a short-term count program where automated counters are deployed strategically around representative locations in the region. Over 5000 locations have been incorporated into this program since 2010, representing remarkably comprehensive coverage of the metro area, and facilitating development of count factor groups and robust short-duration adjustment factors. In particular, counts have been conducted at all intersections along key downtown corridors, allowing more robust analysis of mode share and active transportation activity entering the downtown core of the city. Delaware Valley RPC's program is also notable for its robust and user-friendly online count data interface.

North Central Texas Council of Governments – North Central Texas Council of Governments (NCTCOG), serving the Dallas-Fort Worth 16-county region, has established a bicycle and pedestrian traffic monitoring program intended to collect usage data and better understand travel patterns, analyze changes, and evaluate impacts of specific projects. NCTCOG has installed 26 permanent automated counters on shared-use paths, and has also developed an inventory of portable count equipment which may be used in minimum two-week increments on paths, sidewalks, or on-street facilities. In addition to collecting their own data, NCTCOG makes their mobile equipment available for local jurisdictions to borrow to conduct their own counts. To support local data collection, NCTCOG has also developed a "Mobile Counter Site Selection Best Practices Guide" to ensure useful and accurate data-collection *[20]*.

The above listed programs represent a selection of programs identified as leaders in innovation in this field, but are by no means an exhaustive list. For a more comprehensive list of state and major local or regional count programs, see Appendix A.

Task 2: Bicycle and Pedestrian Counting Research Methods Exploration

Overview of Data Collection Methods

In broad terms, as for motor vehicles, pedestrian and bicycle counts can be conducted manually (using either human observers in the field or by collecting video data to be manually processed later) or using automated technology. They may be short in duration (ranging from one hour to several months) or permanent. At present, there are no federal or state requirements for nonmotorized traffic monitoring, and methods vary widely among states, regions, and municipalities across the nation.

Generally, pedestrians and bicyclists present a greater challenge to effectively count and model. Even in well-developed count programs, the scale of data collection is unlikely to match that implemented for motorized vehicles. The movements and travel channels of pedestrian and bicyclists tend to be less constrained and predictable *[21]*. Pedestrians and bicyclists may occupy a variety of facilities within the right of way, including shared or dedicated on-street bikeways, shared-use off-street paths, sidewalks, and roadway crossings. Different approached and technologies are needed for each of these situations.

In addition, accurately inferring estimated daily or annual volumes is more challenging for nonmotorized modes than for motor vehicle traffic because there tend to be significantly lower volumes and greater variability, as these users are more sensitive to environmental factors *[7]*. Unlike for motor vehicles, higher usage levels are often observed on lower functional class roads, which tend to have slower speeds and greater user comfort. Although technology is advancing rapidly to more efficiently capture these users, historically, the majority of nonmotorized volume and behavioral data has been collected manually (54%, not including post-processed video data), in part due to agency interest in capturing more nuanced data in addition to total volumes, such as gender and helmet use *[7]*.

There are two basic types of count locations, regardless of count method:

1. Screenline count/segment count – conducted by observing the number of users passing a mid-segment point along a facility (typically used to determine or estimate annual volumes, person miles traveled, etc.). Most technologies discussed below may be used for screenline counts, and most are able to detect direction of travel. Note that some researchers recommend use of the term "segment count" so as to avoid confusion with screen-line counts as used in transportation modeling to validate regional travel models. However, most literature uses these terms interchangeably, which is reflected in this report *[11]*.

2. Intersection counts – conducted by counting roadway crossings and/or turning movements (typically used to evaluate operations or safety evaluations, including signal timing and determining exposure rates for specific intersections)

The Traffic Monitoring Guide and NCHRP recommend that a comprehensive multimodal count program include a mix of short and long-term counts, and identify roles for both manual and automated methods. However, NCHRP Report 797 focuses on automated count methods because (a) the literature for this emerging field is relatively scant and (b) the larger number of hours of count data needed in order to produce accurate volume estimates tend to favor the use of automated technology.

Finally, there are tradeoffs among count methods and applicable technologies. Agencies must consider cost, ease of deployment and use, reliability, level of vendor support, and compatibility with data needs among other concerns (Table 1).

Manual Counts

Manual counts have dominated local data collection due to the low barrier to entry of these methods: start-up costs are low, technical expertise needed is limited, and a relatively large number of count locations can be covered quickly and cheaply. Manual counts may be used to demonstrate general overall trends, provide preliminary evidence of infrastructure impacts, and demonstrate user demand. They have also proven to be particularly effective in the context of advocacy efforts *[13]*. Smartphone or tablet applications (e.g., Bike Count and BikeAndWalk) that replace paper forms for manual counting, significantly expediting data processing time and, potentially facilitating the aggregation of crowdsourced counts for use in modeling *[13]*.

The National Bicycle and Pedestrian Documentation Project defined the first standardized technique for manual counts and has been widely utilized *[22]*. However, the results of data extrapolation using this method have demonstrated that although some extrapolation of short-duration counts is possible (e.g., using peak PM counts to estimate total volume on a given day, seasonal and regional variations hinder accuracy, and two-hour data has been found to be of limited use for statistical analysis; agencies utilizing NBPD protocols to conduct manual counts are advised against using this data to attempt to estimate AADPT/AADBT (Average Annual Daily Pedestrian/Bicycle Traffic) *[11, 13]*.

The Traffic Monitoring Guide does not provide definitive standards for manual counts, but recommends a minimum duration of 4-6 hours during peak periods (i.e., morning and evening commute times for weekdays, and mid-day for weekends or in recreational areas). If possible, twelve-hour counts are preferred, although the TMG notes that individual observers should not be asked to count for more than two consecutive hours at a time. If longer duration counts are not possible, the NBPD recommends conducting 2-hour (or more) counts on multiple days in order to reduce error rates when extrapolating the data. In particular, areas with lower anticipated pedestrian or bicycle activity levels – or land uses which generate highly irregular activity patterns – may need to be counted on multiple occasions in order to extract meaningful information about user volumes or patterns.

Manual counting – here including manual observation of recorded video-- does present two distinct advantages over most currently available automated count technologies: 1) the ability to conduct intersection counts that capture pedestrian and bicyclist turning movements, in addition to total volumes, and 2) the opportunity to capture data about user characteristics (e.g., gender, age) or behaviors (e.g., helmet use, travel orientation). If manual review of video data is employed, the ability to pause and rewind has can result in very high rates of accuracy. For this reason, it is often used to validate and test automated count data.

While some DOTs engaged in pedestrian and bicycle monitoring have encouraged local jurisdictions to undertake manual counts in order to collect user attribute data (e.g., MnDOT), others (like CDOT) have established policies to only collect and archive automated count data which is longer in duration *[11]*.

Automated Counts

Compared to manual counts, automated counts provide economies of scale and require less staff time per hour of data collected. Most technologies utilized for automated count data collection only permit screenline counts, although video imaging technology offers the promise of capturing more complex data points such as turning movements or total users crossing at more than one point within the right-of-way.

The most common automated count technologies for counting pedestrians and/or bicyclists include: Pneumatic Tubes, Infrared Counters, and Inductive Loop counters. In addition, increasing attention is being paid to applications of video-based automated data analysis, and several new technologies are emerging which may have potential count applications. For additional information about specific vendors and products, see Appendix B: Product and Vendor Inventory.

Infrared Counters. Infrared count devices (either passive IR, which senses heat of people passing through the detection field, or active IR which detects breaks in an infrared beam) may be used to count combined volumes of pedestrians and bicyclists on facilities which do not permit motor vehicle travel, but cannot distinguish between user types unless combined with other technology. They cannot be used for on-street facilities. Active infrared sensors, used in pairs, can be used to differentiate pedestrians and bicyclists by setting one unit to record only slow-moving users (less than 8 mph) and subtracting this from the total to determine modal split *[9]*.

A key limitation of infrared counters is that they tend to systematically undercount users, largely due to occlusion when users travel in groups. This effect is exacerbated on higher volume facilities *[13]*. NCHRP's research found that positioning infrared counters at a 45-degree angle to the path helps to minimize occlusion effects (i.e., people traveling side by side as they pass the sensor being counted as only one user *[7]*. Infrared devices should be placed so as to avoid areas where users are likely to linger in place. If possible, passive IR devices should be directed at a fixed surface (such as a wall), and avoid pointing toward metallic or reflective surfaces and vegetation (which can trigger false positive counts).

Pneumatic Tubes. Commonly used in motorized vehicle data collection, pneumatic tube counters may be used to collect bicycle volume data. These devices, in which one or (more typically) two tubes are stretched across a right-of-way, which record when vehicles pass over and depress the tubes. Relatively low-cost, they are the only commonly used technology for measuring bicycles only that is also portable.

Pneumatic counters can be bicycle-specific (typically with dual tubes; may be used in mixed traffic but will register only bicycles), classification counters (dual tubes that count all users but are calibrated to differentiate between vehicle types and also typically can provide speed data), and volume counters, which are a single tube which cannot differentiate vehicle types and may only be used on trails or bike facilities where no motor vehicles may travel.

Tube counters produced for motorized vehicle monitoring (classification counters) may be adapted to count bicycles by adjusting the counter software's vehicle classification scheme, providing a very low cost means by which to integrate bicycle counts into existing count programs. However, accuracy of pneumatic tubes intended for motor vehicle use tends to be lower than those developed specifically to count bicycles *[16]*. Researchers in Oregon found that Motor vehicle tube counters from MetroCount, using smaller-diameter tubes and an updated vehicle classification system and calibrated carefully, were effective at counting both motor vehicles and bicycles, however, bicycle-specific models from EcoCounter were found to have the highest accuracy at 95% *[23]*.

Pneumatic tube counters tend to undercount bicycles, but may also occasionally overcount where volume totals are higher, according to NCHRP tests *[7]*. Research generally indicates that pneumatic tubes are more accurate and effective in lower-volume traffic conditions, and when tube distances are relatively short, as accuracy decreases with distance from the count device *[16]*. Using one set of tube to count multiple travel lanes is not recommended due to an increased likelihood of occlusion errors *[16]*. Smaller diameter tubes [such as those developed specifically for bicycle monitoring] have been found to be more accurate *[16, 23]*. Even under ideal circumstances, very small or light bicyclists may be missed, and very light motorized vehicles may be misclassified as bicyclists *[23]*.

ODOT conducted a study using three different types of pneumatic tube counters for counting bicycles from five manufacturers (EcoCounter, Jamar Technologies, Inc, Time Mark, MetroCount, and Diamond Traffic Products). Two of these were bicycle-specific devices, three were motor vehicle counters with the capability to classify bicycles, and one was a volume-only motor vehicle counter. The authors tested the devices on a state highway known to have relatively high bicycle volumes, and found that undercounting was typical, with error rates ranging from 1 – 12% when users were within 10 feet of the counter, with bicycle-specific counters reporting the highest accuracy rates. Accuracy decreased with longer tube lengths or distance (especially beyond 27 feet from the counter) as well as with increases in bicycle and car traffic. No clear relationship was found between accuracy and bicycle speed, tube spacing, or tube diameter. Testing in Boulder, CO, corroborates Oregon's finding that bicycle-specific tube counters tend to produce the most accurate counts and that counts are more accurate closer to the count device *[16]*.

Inductive Loops. Inductive loops, which are installed within or on the surface of the pavement to detect bicycle activity through the disruption of their electromagnetic field by metallic objects, are also commonly used in motor vehicle monitoring and can be used to count bicycles in either restricted or shared bicycle/motor vehicle facilities. On a restricted facility (i.e., trail or sidepath), these can be combined with an infrared sensor to calculate pedestrian and bicycle traffic independently. They may also be installed in shared traffic, although accuracy has been found to be higher when separate *[7]*. Inductive loops require saw cuts to the pavement to install on existing facilities, but can be placed directly in the base course under concrete for new construction *[24]*.

Inductive loops may achieve up to 96% accuracy even in shared lanes *[13]*. However, careful calibration of the sensitivity of the device is key: sensitivity must be high enough to capture bicycles, but low enough so that motorized vehicles passing nearby are not picked up. This can be achieved by starting at the highest sensitivity setting and turning it incrementally down while observing traffic until bicycles are no longer detected *[20]*.

Placement and orientation of the loops is also key: loops (like pneumatic tubes) should be located where traffic will flow over them, not near where vehicles are likely to stop *[20]*. Moreover, double chevron, parallelogram or quadrupole loop configurations have been found to detect bicycles more effectively and with fewer false positive errors *[20, 24]*. As with infrared sensors, placing the loops at an angle will help reduce occlusion errors *[24]*.

At present, inductive sensors used to detect presence (e.g., for signal timing) are not suited to also collect count data, however, increasing demand for nonmotorized volume data has product vendors working to develop applications to facilitate this dual purpose *[7]*.

The city of Boulder has been using inductive loops to count bicyclists since 1998. A study of results found that like pneumatic tubes, the loops had a tendency to undercount users, and that several devices (particularly those in use for longer periods of time) had serious inaccuracies and were in need of software adjustment or equipment recalibration *[24]*. However, they also found that the loops were effective in accurately counting a variety of bicycle types, including bikes with trailers, carbon fiber and titanium bicycles, etc.

Table 1
Comparison of characteristics of commonly used pedestrian and bicycle count technologies

Characteristic	**Passive Infrared**	**Active Infrared**	**Pneumatic Tubes**	**Inductive Loops**	**Passive IR + Inductive Loops**	**Automated Video**	**Manual Counts**
Types of Users Counted							
All	X	X			X	X	X
Pedestrians Only					X	X	X
Bicycles only			X	X	X	X	X
Pedestrians AND Bicycles					X	X	X
Bicycles AND Autos			X	X		X	X
Characteristics Collected							
Different user types					X	X	X
Direction of Travel	X	X	X	X	X	X	X
User Characteristics						X	X
Types of Sites							
Shared-Use Trails	X	X	X	X	X	X	X
Sidewalk segments	X	X			X	X	X
Bike lane segments			X	X		X	X
Cycle track segments		X	X	X		X	X
Shared roadway segments			X	X		X	X
Roadway crossings		X	X	X		X	X
Intersections/turning movements						X	X
Count Durations							
Long Duration/Permanent	X	X		X	X		
Short Duration	X	X	X			X	X
Resources Required							
Equipment Cost*	Med	High	Med	Med	High	Med	Low
Preparation/Planning Costs	Med	Med	Med	High	High	Med	Low
Installation Costs	Low	Med	Low	High	High	Med	n/a

Emerging and Other Technologies. In addition to the commonly used tools described above, additional technologies have been found to meet nonmotorized count program goals in specific locations and contexts. Meanwhile, new technologies for data collection are emerging. These include:

- *Piezoelectric strips* – a pair of strips of material that are laid on the surface of or underground which produce an electric signal when deformed. These can be installed permanently, though some vendors have developed an easier to install, temporary version of this product that offers similar benefits to pneumatic tubes.

- *Radar sensors* – Radar sensors can be installed underground or on a post to capture pedestrians and/or bicyclists. These can be permanently or temporarily installed. This is an emerging field of technological development, so far best suited for applications similar to infrared sensor technology.

- *Thermal sensors* – Mounted above an area, these offer the promise of capturing both total counts and movements of users. These are likely to be most useful for permanent count locations, as they require external power and appropriate mount locations. More research is needed on the accuracy or limitations of this technology *[7]*.

- *Fiberoptic Sensors* – can detect changes the amount of light transmitted based on the amount of pressure applied to a fiberoptic cable. These can potentially be applied in any paved area. This has been used in Europe but so far very limited testing has been conducted and installation costs are relatively high *[7]*.

- *Laser scanners* – often used to detect presence indoors, these capture details about activity based on reflected laser pulses and could also be utilized for screenline counts in areas with no horizontal obstructions where electrical power supply is available. Limited data is available on this alternative, although NCHRP found it is likely challenging to use where precipitation is common *[7]*.

- *Acoustic (pedestrian only) or pressure (bicycle and pedestrian) pads* – these are installed in the ground to detect weight may be useful for unpaved trails or for establishing pedestrian demand where sidewalks currently do not exist, but appear to be of minimal use in typical count contexts

- *Magnetometers* – can detect (but not distinguish among) metallic objects that impact the magnetic field (e.g., bicycles or cars) and may be useful in certain trail contexts

- *Off-the-shelf products* – Sensors developed for unrelated purposes may also be employed to conduct counts, such as the use of Microsoft Kinect devices to conduct pedestrian counts. Such applications present similar challenges as video imaging, but in an “off-the-shelf” format that requires minimal technical expertise.

To date, these emerging sensor types have not yet definitively demonstrated superiority to the more traditional equipment categories described above. However, several such products (e.g., piezoelectric and radar sensors) offer comparable applicability, and may be worth considering if they become cost-competitive (at present, no significant cost advantages were identified). Thus, for the time being, a combination of inductive loop, infrared, and pneumatic tube sensors designed or at least specifically calibrated for nonmotorized vehicles are recommended for (physical) automated data collection, along with continued exploration of video-based counts (discussed below). For additional information about available count technologies, including specific vendors and products, see Appendix B.

Indirect Data Collection Methods and Data Sources

In addition to direct volume data collection, evaluating nonmotorized user demand and behavior in service to planning, policy, and safety goals may include indirect data collection methods including survey data, GPS and Bluetooth sample data, and proxy measures of demand like the use of actuated signal counts. These tools and techniques can be useful for understanding user origins and destinations, route choice, and mode share and are useful in contextualizing and applying count data, and are being used by a wide variety of jurisdictions in conjunction with direct methods of demand data collection, but cannot generally be extrapolated into overall user counts.

Survey Data. Internationally, “most decisions about bicycle infrastructure are made on the basis of household surveys and do not require count data collection to verify usefulness of nonmotorized facilities” *[21]*. In the United States, survey data is less extensive. Key data sources for evaluating active transportation trends include the American Community Survey (ACS) and the National Household Travel Survey (NHTS) and National Personal Transportation Survey, which began in 2001 and is conducted every 5 to 7 years.

The ACS provides useful information on commute trips at a fine geographic grain, however, it suffers from certain limitations: trips by bicycle or walking are often for non-work purposes; the survey asks how a commuter “usually” got to work excluding occasional active commute trips as well as multimodal trips; and at smaller levels of geography, margins of error can be large *[12]*. Utilizing the Census Transportation Planning Package can provide jurisdictions with valuable additional cross-tab data linking transportation information to demographic data *[13]*.

The NHTS provides rich data on driver characteristics, travel time, trip purpose, time of day, day of week, and school transportation, however, it is limited to a relatively small national sample which cannot be disaggregated to evaluate smaller jurisdictions except those that pay for additional add-on sampling *[13, 25]*. Notably, it can be more cost-effective for agencies to utilize the option to add on local NHTS sample expansions (which also provides the opportunity to add additional questions to the survey addressing local concerns) than to conduct an entirely separate travel survey *[25]*.

However, there are several additional limitations to this method, including variance between what people report as "typical" in a week and actual reported trips, a tendency to exclude or mis-categorize short or circular trips, and respondent error *[25]*. In addition, travel surveys (including NHTS) often permit only one mode per trip, excluding multimodal travelers, in particular "last mile" connections *[13]*. NHTS data can be used to calculate exposure rates using the number of reported active trips, or preferably, person miles traveled broken down by mode, but due to the tendency noted above to underreport nonmotorized trips, as well as small sample sizes, this application is limited *[25]*.

In addition, other resources exist for the collection of local or statewide survey data to capture information about nonmotorized travel patterns and trends. One example is the Pedestrian and Bicyclist Survey (PABS), an open source survey instrument *[26]* and inexpensive, simple survey for jurisdictions to conduct themselves for community-level monitoring *[13], [25]*.

GPS Data. GPS data can be another indirect means of capturing relevant active transportation information. Smartphone applications (e.g., Strava, Map My Ride, CycleTracks) utilize GPS data to provide route choice and frequency data for users who choose to download and deploy these apps. Although these cannot be used to substitute for absolute volume data (as "the sample data collected through this method can be used to establish minimum volumes at a location, but cannot be adjusted to estimate total pedestrian or bicycle volumes" and includes sample bias), they can provide information about relative demand on different facilities within an area (at least for a subset of the bicycling population) *[7]*. Regions which have encouraged utilization of specific apps in order to improve data availability have found success, but observed that participation tends to drop off rapidly. Such data sources can either be passively collected (providing larger sample sizes, but often constrained in their ability to differentiate travel modes), or from active monitoring (e.g., Strava), with smaller, and often biased, samples.

Bikeshare systems also typically utilize GPS data to track their equipment; for communities with bikeshare systems operating, this data can also be a valuable dataset used to assess the origins, destinations, and route choices of this user group, although as with other sample datasets, is of limited utility for assessing absolute volumes.

Bluetooth Data. Meanwhile, researchers have utilized Bluetooth sensors to capture (primarily motorized) roadway users. Every Bluetooth device has a unique ID. By deploying sensors at two or more locations within a street segment, travel time and vehicle speed can be deduced for each device recorded, allowing delineation of nonmotorized users and potentially expansion of our understanding of nonmotorized origin and destination datasets as well as travel time. This technology is also suitable for tracking users in densely crowded areas where other sensor technologies would likely fail *[13]*. However, more research is needed to develop effective methodologies for this, as current algorithms in use are likely to discard nonmotorized records as outliers *[27]*.

Similarly, Radio waves can be used to capture users by attaching Radio Frequency ID (RFID) tags to (volunteer) bicyclists or pedestrians). These signals can be picked up when users pass dedicated locations with RFID readers. Radar devices can also count users based on reflected radio wave pulses.

For all such data sources, it is important to note that only a sample of users will be included. Not all pedestrians and bicyclists will have a Bluetooth device (and some may have more than one), and even fewer will download and utilize trip tracking applications. Moreover, this sample is not likely to be statistically representative of the population, thus these are likely able only to complement, rather than replace, traditional volume data collection methods *[13, 27]*.

Actuated Signal Counts. In certain circumstances, proxy measures such as the use of existing actuated signal infrastructure may also be useful for assessing relative pedestrian or bicycle demand. ODOT recently conducted a pilot test of existing signals with pedestrian push buttons as well as inductive loop presence detectors, measuring the number of actuations at suburban signalized intersections against 24-hours of video data. They found that the pedestrian actuations could be used as a reasonable proxy for estimating pedestrian activity, though bicyclist counts were less accurate (largely because many cyclists were observed riding on the sidewalk) *[7, 21]*.

A key challenge of using such proxies is in order to be meaningful, the researcher must also be able to estimate how many pedestrians (or bicycles) cross on each actuated cycle in order to develop estimates of average daily volumes. Thus, this application is likely only to be useful in situations where there is relatively sparse nonmotorized activity, no pedestrian phases operate on recall, and detectors are positioned so that only the desired user group is likely to activate them (i.e., pedestrians who push both buttons on one corner, or bicyclists using pedestrian push buttons) *[21]*.

Planning and Structuring a Count Program

The following questions are fundamental to count program development in order to develop a statistically valid, reliable, efficient, and inclusive data collection program *[7, 10, 15]:*

1. What data has already been or is currently being collected?
2. What is the purpose of the data collection and what kinds of data are required to meet program needs?
3. What resources are available for its implementation?
4. Where, whom, and when will you count, and for what duration?
5. What methods and technologies will be used (including specific protocols for project management, data collection, and data retrieval)?
6. How will equipment be calibrated and data validated?
7. How will data be processed and managed, and what quality control measures will be in place?
8. How will findings be reported, disseminated, and utilized?

This section outlines recommended best practices step-by-step in planning a nonmotorized traffic volume data collection program, highlighting key steps and decisions which will impact program success. Much of these findings stem from guidance in the Traffic Monitoring Guide, which now includes guidance for nonmotorized users and which the literature indicates is the preferred model for state agencies engaged in nonmotorized monitoring (although as noted above, this outlines an ideal scope and processes which may be unrealistic for most transportation agencies) *[6]*. Practitioners *[11]* simplify the TMG's recommended process for institutionalizing both permanent and short-duration nonmotorized traffic monitoring as such:

Permanent Data Program:

1. Review existing permanent count program
2. Develop inventory of available permanent count locations and equipment
3. Determine traffic patterns to be monitored
4. Establish seasonal pattern groups
5. Determine the appropriate number of automated traffic count locations

6. Select specific count locations
7. Compute monthly factors
8. Develop seasonal factors

Short-Term Data Program:

1. Select count locations (random and/or non-random)
2. Select type of count (segment and/or intersection)
3. Determine duration of counts
4. Determine method of counting (automated and/or manual)
5. Determine number of short term counts
6. Evaluate counts (accuracy characteristics, variability)
7. Apply factors (occlusion, time of day, day of week, monthly, seasonal)

The 2013 TMG identifies a full review of any existing count programs and the development of an inventory of available count locations and equipment in the jurisdiction, including those conducted by other agencies. This review should include:

- evaluation of count locations and site selection criteria
- equipment or methods utilized and identified limitations or assessments of those methods
- how the data is being utilized and by whom
- identified data gaps and priorities

If existing continuous count data is available, this may be evaluated (variance by time of day, day of week, month or season, under different weather conditions, during special events, by street functional class or facility presence, by land use or demographic characteristics) to provide preliminary guidance about typical traffic patterns in various contexts *[6]*. This information will support the development of factor groups that will facilitate the development of annual volume estimates based on short-term counts. As the TMG observes (Section 4.4.1), “some data is better than no data in establishing typical traffic patterns.” In addition, this evaluation should note how any existing data has been processed and what quality control measures have been applied.

Identifying the overall purpose and specific goals of a count program is a critical early step. The overarching goal of the data collection may impact methodology, site selection, and processing needs. Identification of specific goals will guide general parameters of program scope, as well as methods. For example, a DOT-based program will need to decide to what extent it will collect data on off-system facilities. These goals may also guide which kinds of nonmotorized trips and in what proportion) the agency seeks to document, e.g., commute, recreational, and utilitarian, based on predicted or previously observed traffic patterns *[6]*.

Agency goals will also dictate methods utilized. For example, a local jurisdiction seeking to evaluate demographic and behavioral trends or identify countermeasures at a high-crash intersection may be best served by limited manual counts, while a state agency seeking to develop factor groups for systematic monitoring or determine mode share along a specific corridor would require longer-duration automated screenline counts.

Site Selection. Site selection criteria should be developed with program goals in mind. The TMG recommends first identifying seasonal traffic pattern groups to guide selection of groups of continuous count locations based on existing nonmotorized data or comparable data from regions with similar characteristics (to be refined as regionally specific data becomes available). On the other hand, "in a new data collection program where no counts have been collected in the past, the site selection process should begin before ordering equipment and should occur before establishment of factor groups" *[10]*.

If budgets are not constrained, the TMG recommends 3 – 5 continuous count locations should be installed for each factor group, but concedes that "in most cases…the number of count locations will be based on what is feasible given existing traffic monitoring budgets" (Section 4.4.4) Colorado DOT, meanwhile, has identified a recommendation of seven permanent count stations per factor group *[13]*. Oregon DOT, moreover, suggests that the number of sites needed will relate to geographic and weather differences across the state, population, and bicycle facility characteristics *[11]*.

Once the number and scope of count locations has been identified (based on available resources and program goals), specific count locations may be determined. Criteria may be different for short- and long-term count locations. The TMG outlines count location selection guidelines in Chapters 2 and 4, with key findings pertaining to nonmotorized monitoring incorporated below.

Practitioners in North Carolina outline a process and overarching principles for site selection, based on their experiences with NCDOT, where clear site selection procedures were found to be critical for justifying allocation of funds to develop a count program over time *[10]*. These principles include:

- Develop a clear, standardized site selection protocol, and incorporate this into a reference guidebook to support vertical and horizontal policy alignment
- Follow FHWA guidelines "to the extent possible on the basis of feasibility and fiscal resources."
- Engage stakeholders in site selection methodology and develop inter-agency partnerships to encourage procedural alignment and data-sharing

Ultimately, the responsible agency must define site selection criteria, which may include the following siting strategies *[7]:*

- *Random or stratified random sampling* – though true random sampling is seldom considered in pedestrian and bicycle monitoring because it is unlikely to provide an efficient use of resources, stratified sampling which identifies multiple count locations representative of specific contextual characteristics may guide site selection *[6]*
- *Representative locations* – Identification of locations that are "most representative of prevailing nonmotorized traffic patterns"–i.e., factor groups—or of different geographic areas, socioeconomic or land use characteristics, or facility types *[6]*. This may include locations in pedestrian and bicycle activity centers (downtowns, near schools or other activity generators), locations representative of typical urban, suburban, and rural locations, or other delineated groups. Notably, these should not simply be locations that are expected to have the highest volumes within that representative group. This strategy may be particularly useful in evaluating safety trends:

  > *Representative sites can be used to compare changes in the number of reported pedestrian and bicycle crashes with changes in overall pedestrian and bicycle activity levels throughout the community. This approach allows analysists to track the relative risk of pedestrian or bicycle crashes (per pedestrian crossing, per trail user, per bicyclist, etc.) ... representative counts control for exposure across the community as a whole. [7]*

- *Targeted locations*, such as existing nonmotorized facilities and/or anticipated facility construction, or "pinch point" locations like bridges or underpasses, locations where counts were previously conducted or are being conducted by other agencies, and high-crash locations. The TMG acknowledges that many agencies are well-served by focusing on locations with high anticipated nonmotorized volumes, but notes that it is important to recognize that using such locations to make generalizations about a larger area may be inappropriate *[6]*.
- *Control locations* – "to get a true understanding of the effect of a specific project on pedestrian or bicycle activity or safety, it is also necessary to count at similar locations not directly affected by the project" *[7]*

From a technical perspective, equipment purchases should follow the identification of desired count locations so that equipment specifications can be tailored to site needs (e.g., inductive loops of the appropriate size). Simultaneously, count sites should be selected based on the needs of the specific monitoring equipment expected to employed, including but not limited to the following *[6, 22]:*

- Sites where users are constrained to the area being measured (e.g., on a bridge, most bicyclists may use the sidewalk, but if bicycling on the roadway is permitted some may be missed)
- On straight, smooth, level sections of roadway or trail (not on a curve or steep grade)
- Away from potential sources of interference (e.g., water direct sunlight for infrared sensors, utility lines for inductive loop detectors)
- Ability (or need) to differentiate pedestrian and bicyclist traffic (the 2013 TMG does not differentiate its recommendations based on mode, but suggests that due to the varying challenges in capturing these user groups and divergent usage patterns, it suggests that guidance for monitoring each mode separately may be forthcoming).
- Near major access points (for shared-use trails as well as key activity generators such as schools)
- Locations where users are unlikely to linger in place

Practitioners recommend generating a list of potential site locations based on existing counts, interests of collaborating stakeholders, and logistical feasibility, then developing a tracking system for potential site locations and selection criteria that includes the following site characteristics:

- Priority
- Coordinates
- Area type
- Anticipated travel pattern/factor group
- Location ownership/jurisdiction
- Existing infrastructure
- Appropriate count type/method/duration
- Local jurisdiction contact information

Prior to selecting final count locations, a site visit to prospective count sites should be conducted to document the location for technical constraints, general baseline activity levels (i.e., the presence or absence of observed nonmotorized users and their characteristics), and other site specific factors. In addition, testing for interference from utilities or other metallic objects is strongly recommended, particularly where inductive loops are intended *[10]*.

Count Program Duration and Timing. As noted above, federal guidance recommends that a well-developed nonmotorized count program will include a mix of continuous and short-duration count locations, similar to the programs maintained by DOTs for motorized vehicle monitoring. However, the TMG recognizes that nonmotorized count programs are likely to be more limited in scope, since "most nonmotorized travel occurs off the State highway system and on lower-volume and lower-speed city streets, shared use paths, and pedestrian facilities" *[6]*.

As demonstrated by states like Washington, pedestrian and bicycle count programs may also include a mix of manual and automated count types. For the purposes of this research, this section assumes short-duration counts executed by DOTD are to be conducted using automated technology, based on prior discussion of agency goals and the limitations of manual counts identified above.

If the development of factor groups and the ability to extrapolate short-duration counts into estimated annual total volumes and/or mile traveled are program goals, permanent continuous count locations at locations representative of those predicted factor groups are essential *[6]*. Long term counts are needed to establish appropriate expansion factors for shorter term counts, and there ideally need to be enough of these to develop factors specific to a variety of contexts (factor groups) and allow you to generalize about typical user patters (e.g., primarily recreational or utilitarian) *[13]*. Moreover, short term counts are difficult to confidently apply to evaluations of change over time because short-term variations in volumes often outweigh long-term trends, although consistent counts taken at a relatively large number of locations (FHWA recommends 30-50) may be used longitudinally for this purpose *[13]*.

On the other hand, short term counts can help better understand spatial variation in terms of safety, infrastructure, etc., although statistically robust analysis would require a large number of randomly selected count locations, which is typically impractical for agencies implementing count programs *[13]*. Prior to the implementation of a permanent count site, a short-duration count (either manual or automated) should also be conducted if possible in order to confirm that data is consistent with expectations *[10]*.

There is no definitive guidance for how many short-duration count sites are needed; FHWA acknowledges that this will be based on budget and need. Rather, from the list of identified potential count locations, the TMG recommends working with relevant stakeholders to identify both permanent and short term priorities

At a minimum, research suggests short-term counts of at least seven days in order to minimize error from short-term variations with a preferred duration of two weeks, particularly in the case of inclement weather *[5, 10, 23, 28]*. These counts should generally be conducted at times of the year with high expected user volumes and minimal variability, although there may be circumstances where counts are desired at other times of the year (e.g., special events or time-sensitive project evaluations) *[10]*.

Generally, in most US climates, fall and spring months yield desirable conditions for active transportation, though long-term count data should be consulted if available to confirm periods of consistent activity *[6]*. Temperature, humidity, precipitation, and high variability have all been found to impact active transportation activity *[6, 7]*. Whenever counts are conducted, weather condition data should be recorded. The TMG recommends collecting information on:

- Whether precipitation fell during data collection
- Approximate high temperature for count duration/day
- Approximate low temperature for count duration/day

The TMG also cautions in using short-term counts conducted for special purposes (such as before-and-after facility installation) at sites not selected specifically for statistical representativeness to make inferences about larger areas or trends, as not enough research has been conducted in this field.

Equipment Selection and Installation. Once count locations and parameters have been identified, these count sites may be matched to existing equipment inventories or planned purchases. Many count programs employ more than one type of technology and method, and may utilize multiple vendors or models in order to meet different contextual needs, which can complicate data management.

NCHRP recommends the following considerations in deciding what methods and technologies to utilize *[7]:*

- Peak hour user volume
- Mix of user types
- Detection zone width
- Facility surface
- Vehicular traffic presence and flow
- Trees and vegetation present
- Sources of background interference

- Snow and debris
- Radiant temperature
- Mounting devices available/needed
- Security from theft and vandalism
- Social environment characteristics (e.g., bus stops, doorways, obstructions, bike racks)
- Adjacent land uses

In addition, agencies should consider technical considerations such as battery life, overall product life, data downloading requirements, and software options/compatibility (e.g., compatibility with FHWA TMAS) *[7]*. Some jurisdictions may be able to use existing motor vehicle count equipment, if carefully calibrated and validated to meet accuracy targets, although most practitioners recommend use of products specifically designed to capture pedestrian and bicycle activity.

Proper device installation is critical to count program success. Product vendors should provide clear guidance and, if needed, customer support tailored to the specific equipment being deployed.

Equipment Calibration and Data Validation. Regardless of technology selected, an immediate check for functionality and to calibrate the device if necessary (such as by adjusting sensitivity) should be conducted. The Initiative for Pedestrian and Bicycle Innovation at Portland State University recommends these initial validation checks should involve the manual observation of at least ten bicyclists and/or pedestrians to test basic functionality. NCHRP recommends testing a minimum of 15 minutes of data [ideally one hour or more] *[7]*. If there are few users at the time of testing, counts may be simulated by the installation team by walking or bicycling across the test area as necessary. A second test should be conducted a few days after installation *[7]*. Practitioners emphasize that that "bicycle counting… (in this instance utilizing pneumatic tubes) is a more challenging task than counting motor vehicles and should be approached with attention to detail" *[23]*.

For more involved verification/calibration efforts, manual review of video camera footage is often employed to facilitate review of longer periods *[16, 23]*. Sarah O'Brien with the University of North Carolina's Institute for Transportation Research and Education suggests collecting 24-30 hours of validation footage (8 hours with 15-minute bin intervals), including a mix of volume ranges and times (unless image quality precludes use of nighttime video). Although as some degree of error is inherent in all automated count technology, it may not be worth the time required to conduct extensive testing once baseline accuracy thresholds have been achieved *[24]*. Moreover, "commercially available automatic counters for pedestrians and bicyclists are still evolving and maturing, and error rates for various technologies and configurations are not yet well known" *[29]*. Thus, it is the responsibility of the implementing agency to set standards for accuracy that will meet the needs of their count program and any related policy goals.

As discussed above, a tendency toward systemic undercounting [largely due to occlusion] is inherent in some count technologies; these errors can be corrected with calibration equations *[7, 16]*. Overcounts are more problematic [as sources for these errors may be difficult to determine] particularly on roads with low bicycle counts, as even minor errors can significantly skew results *[23]*. Relatedly, correcting for error is particularly important in cases where absolute count values are needed in order to satisfy a regulatory condition, e.g., minimum pedestrian flow to warrant traffic signal installation *[29]*.

If using equipment where records are "binned" by time period (typically 15 minutes or 1 hour) you may not be able to calculate the exact number of false positives and negatives, only the overall under or overcount per time interval. In addition to occlusion, common reasons for incorrect counts include blocked sensors, user bypassing of sensor (e.g., at edge of path or deliberate avoidance), equipment malfunction or power loss, very high or low temperatures, precipitation (for optical sensors), and lighting (optical or video). Sensors deployed in mixed traffic may also be found to mis-categorize vehicle types, in which case software and sensitivity settings will need to be adjusted.

Periodic, ongoing checks of permanent count site should be conducted. NCHRP recommends visiting sites at least every three months, and verifying accuracy once per year *[7]*. Validation should also be repeated if there are any significant changes at the count location (e.g., pavement overlay replacement of sensor or change of sensor settings). In addition, count accuracy can deteriorate over time (e.g., low battery, water damage or corrosion, insect damage) and software or equipment calibration may be needed *[24]*.

Data Processing, Management, and Quality Control - As an emerging focus for agency attention and research, quality control standards for pedestrian and bicycle count data are less fully developed than for motorized vehicle data *[30]*. Data quality is essential if the findings are to be credible among transportation professionals, with the general public, and to potential funding agencies *[29]*. Researchers Turner and Lasley identify the following principles for assuring data quality *[29]*:

1. "Quality assurance starts before data are collected," at all phases and during all actions of a monitoring program.

2. “Acceptable data quality is determined by its use,” and thus may vary from agency to agency
3. “Measures can quantify different quality dimensions” including accuracy, validity, completeness, timeliness, coverage, and accessibility.

Specific standards should be developed for the routine validation of data. This includes checking data for unusually high or prolonged zero counts, and identifying whether these can be explained by unusual events or circumstances (e.g., inclement weather, holidays) or should be excluded as errors. Ideally, an automated process for detecting suspect data should be developed, based on trigger thresholds for inaccuracy for single observations (e.g., is the count more than two standard deviations above or below an 8-week average for counts/hours at the same time of the week), multiple observations (e.g., if four count periods/hours are more than one standard deviation above or below the average of 8 corresponding non-holiday counts), and/or outliers based on the dataset’s interquartile range *[7, 29, 30]*. On the other hand, to a far greater degree than for motor vehicle monitoring, manual determination of atypical data may be required to determine whether data is erroneous, or accurate but reflective of atypical conditions (e.g., special events).

Once erroneous data has been identified, it may be omitted from analysis entirely, or the data can be cleaned by adding imputed values based on comparable previous counts or regression models *[7]*.

The development of processing standards for identifying and rectifying errors and calculating summary statistics for data of various sources, collected using diverse technologies, is an ongoing need in the field *[27, 29]*. A standardized procedure for evaluating accuracy is still needed. Common performance metrics which may be used to evaluate accuracy include:

- Overall error/ average percent deviation (APD) – the overall divergence from perfect accuracy, including both over and undercounts
- Average of the Absolute Percentage Difference (AAPD)—a measure of consistency (the lower the AAPD value the easier to use a simple adjustment factor)
- Pearsons correlation coefficient R value *[31]*

Agencies conducting counts internally define criteria that define the range of acceptable data values, and set validity rules (preferably automated) to flag suspect data for review *[29]*. Some motorized vehicle traffic databases include such validity criteria, and it may be possible to adapt and use existing software to evaluate nonmotorized traffic, using modified parameters to account for greater variability in walking and bicycling traffic patterns.

As noted in the US DOT Strategic Agenda for Pedestrian and Bicycle Transportation, nonmotorized traffic volume and mode share data are "important for numerous applications," but typically not stored or collected or precisely as motorized data, and tend not to be integrated with motor vehicle data *[5]*. More comprehensive data coverage, as well as more consistent data formatting, are needed. Data can be integrated with auto traffic count data, either within the same database or as a linked database (see CDOT for example of such integration). Where possible, consistency with the TMAS data format is recommended *[7]*.

Developing databases that are modally integrated and consistent will facilitate not only the direct application of data by the collecting agency, but also inter-jurisdictional collaboration in order to address the remaining data, research, and modeling gaps within this field. Notably, data must be in 1-hour bins in order to align with TMAS standards.

Data Reporting and Dissemination. A final key consideration for count program planning is how data will be reported and disseminated within the collecting agency, across agencies and jurisdictions, and to the public. Terms used in describing data in this evolving field should be clearly defined, as those sometimes used by active transportation researchers and professionals occasionally differ from how they are used in related disciplines *[27]*.

Moreover, as there is yet no standardized methodology for estimating annual average daily traffic volumes from short term pedestrian and bicycle counts, clear explanations of all methods employed, including notations of data errors, should be included along with published data and summary statistics *[27, 32]*. FHWA's TMAS system has been updated to allow bicycle and pedestrian point data, which can be stored and shared via this platform, and the Transportation Research Board's Bicycle and Pedestrian Data Subcommittee is actively engaged in developing and refining national guidance for nonmotorized data processing and archiving methods in order to promote inter-jurisdictional sharing and collaboration. The FHWA's Jeremy Raw observes that pedestrian and bicycle submissions should be allowed beginning in 2018, with several state DOTs already participating in pilot submission of such data to ensure QA/QC protocols are effective for checking the quality and formatting of this data.

Meanwhile, protocol should be developed for the distribution of cleaned data and/or publication of summary statistics (e.g., average annual daily traffic, mean hourly traffic, mean daily peak hour traffic or percentage, etc.). Some jurisdictions have developed public interfaces for archived data, including Portland's Bike Ped Portal and Delaware Valley RPC's user-friendly database *[33, 34]*.

AADT Estimation Techniques: Factoring and Data Expansion

It is not practically feasible to collect long-term count data throughout a network. Moreover, "limited data collection resources have constrained pedestrian and bicyclist monitoring to what is realistically affordable rather than statistically reliable," and "pedestrian and bicyclist traffic has higher variability in several time dimensions than motorized traffic and thus it is more difficult to collect statistically representative samples" *[29]*. For pedestrians and bicyclists as well as motor vehicles, short-term data collection is needed to provide greater network coverage and allow flexibility and adaptation in count program implementation to achieve agency goals. In order to develop Average Annual Daily Traffic (AADT) estimates necessary for data applications ranging from mode share evaluation to exposure/risk assessment, long-term data can be analyzed to provide adjustment factors by which to extrapolate a larger number of short duration counts throughout a network *[35]*.

The Traffic Monitoring Guide (TMG) acknowledges that such practices are not currently typical, and that rather, most agencies have tended to collect short duration counts during periods assumed to represent typical activity levels, but encourages evolution of the practice toward a more standardized approach similar to that used for traditional motor vehicle traffic monitoring, utilizing a factoring process that acknowledges up to five key factors (depending on count duration and method, weather conditions, etc.) including time of day, day of week, month or season, occlusion, and weather (Section 4.5.5). The TMG also notes, however, that there is a lack of consensus about many of the specifics of this process: what type of factor adjustments, how many factor groups, how many count locations needed per factor group, etc. Future iterations of the TMG are expected to incorporate additional guidance as such consensus emerges.

Broadly, however, the process for correcting and adjusting data for suitability for broader applications involves the following basic elements *[7]:*

- Clean data to identify any errors, outliers, or anomalies
- Develop site-level data correction factors
- Use those factors to correct data
- Develop factor groups based on user volume profiles and other characteristics
- Expand short-term count data to annual volumes using extrapolation factors based on grouping

Before data can be extrapolated into annual estimates, it is first necessary to adjust for systematic errors inherent to the technology utilized. Validation for each monitoring location, particularly where multiple types of automated count technologies are integrated (e.g., infrared and loop detectors), is imperative *[15]*. For most mechanical automated count methods, the most significant source of systemic counter error is occlusion, discussed above. Validation counts (manual or video-based) conducted at and subsequent to installation can provide overall correction factors which may be applied to the full dataset. A minimum of 30 intervals (8 hours if the device bins data by 15 minute intervals, 30 hours if binned hourly) is recommended (NCHRP). The Initiative for Pedestrian and Bicycle Information recommends that initial validation and computation of correction factors may be accomplished in 1 or 2 peak hours, provided at least 100 bicyclists and/or pedestrians are observed *[30]*. Manual ground-truth data may be plotted against automated counts and a curve defined fitted to the resulting pattern. If no clear curve emerges (i.e., a “cloud” pattern), the researcher should consider recalibrating the device and repeating this process until better fit is established. NCHRP provides a table of multipliers for various technologies tested, but recommends developing site and/or device specific correction factors if possible for greater accuracy. *[7]* Experts recommend conducting full validation of all equipment at purchase, and testing of performance annually.

Once the data is generally adjusted to account for systemic error (most typically undercounts due to occlusion), the data can be further expanded to estimate over longer time periods. Several methods exist to adjust data with varying levels of reported accuracy. Unlike factoring of short-term motor vehicle data, there is not yet a standardized, reliable method for extrapolating nonmotorized user data, due to the fact that counts have a high degree of fluctuation from day to day and are more sensitive to temporal and environmental factors including facility type and quality *[7, 26]*.

The first step in adjusting short term data for expansion into annual estimates is to develop factor groups, i.e., sets of count locations that may be expected to have similar daily volume patterns and thus can be reliably linked to a permanent count station in a similar context. Factor groups can be developed using short-term count data and observation to identify patterns through visual analysis and/or statistical evaluation. For example, practitioners may evaluate the ratio of weekend to weekday traffic volume and the ratio of morning peak traffic to midday traffic to develop appropriate groupings. As more data becomes available, factor groups can be developed and refined: in addition to basic volume trends, additional criteria may be applied to refine factor groups, including land use and urban form characteristics, facility types and street functional class, and socioeconomic variables, as well as weekday/weekend traffic ratios and morning/midday hourly traffic volumes *[7, 15, 36]*.

Typical factor group classifications (Table 2) may incorporate the following basic considerations, at a minimum *[10]:*

Table 2
Typical basic factor groups for pedestrian and bicycle count data adjustment

Area Type	Travel Pattern Anticipated	Proposed Factor Group
• Urban • Rural • University	• Commute • Recreation • Mixed	• Urban Commute • Urban Recreation • Urban Mixed • Rural Commute • Rural Recreation • Rural Mixed • University Mixed

The TMG recommends establishing at least 3-5 continuous count stations for every such factor group, although as noted above, this is unlikely to be feasible for most agencies and represents an aspirational guideline. However regardless of method, at least one permanent counter is required per factor group for the study area, collecting at least one full year of data (including the days in which short-duration counts were collected) in order to develop AADT estimates *[7, 37]*. Notably, the TMG has recently updated templates for reporting and submitting nonmotorized data that allow reporting of various adjustment factors for up to five different factor groups (Section 4.5.5)

AASHTO has translated the standard method recommended for extrapolating short-duration motor vehicle counts for application to bicycle data, using 1-3 day counts factored by daily and/or monthly adjustment factors (based on available permanent count station data). The results of this method are daily factors representing the ratio of the AADT for all days to the AADT for any given day of the week *[28]*. However, researchers have found that this method does not adequately capture the degree of variability inherent to nonmotorized travel, resulting in insufficiently reliable estimates *[28, 38]*. For example, some studies have found a greater degree of count variability in later months of the year, or need to exclude or account for holidays when developing factors *[37]*. In response, additional methodologies for extrapolation have been developed to better account for seasonal, regional, and weather-specific factors *[28, 32, 38]*. Professionals in this field generally agree that just as important is that short duration counts should be a minimum of one week, and preferably two, in order to reduce the errors resulting from active transportation daily variation. Although, some researchers have utilized various regression models, application of K factors (the proportion of AADT occurring in the analysis hour, dependent on the analysis hour selected, characteristics, and location of roadway) to estimate annual average volumes from less direct data *[35]*. However, the goodness of fit of such models has not been definitively demonstrated *[37]*.

Environmental factors (e.g., temperature, precipitation, holidays, etc.) are a critical area of research for pedestrian and bicycle, as the relationship between such factors is non-linear, and strong *[37]*. Researchers have all employed variations on day-of-year scaling factors (which inherently factor in seasonal and weather variations) to develop estimates: using a full year of volume data from one location, adjustment factors for the region are developed for each day of that year which may be applied to other locations *[2, 32, 38]*. Analysis of three adjustment factor calculation methods (AASHTO, month-and-weather, and day-of-year), found that day-of-year factoring resulted in the lowest mean absolute percent error (MAPE) at 17.5%, compared to month-and-weather (24.5% MAPE), and AASHTO (30% MAPE) methods *[28]*. Research teams from Minneapolis and Montreal have found similar results indicating the efficacy of day-of-year factoring methods, provided sufficient data is available, even compared to models that explicitly include an environmental/weather factor, as these inherently account for weather issues which may be missed with other methods *[30]*.

Several state DOTs are actively working on developing regionally appropriate adjustment factors with which to expand short term data, including CDOT, MnDOT, and ODOT. Of these, Colorado’s program is the most advanced, providing a useful model for factor group development and application *[11]*. Many State DOTs already have data tools that automatically perform factoring for motor vehicle counts; with adaptation these could in some cases also be utilized to process and record nonmotorized count functions, although as noted above a greater degree of manual evaluation is likely needed to account for greater variability based on factors not typically incorporated in extrapolating motor vehicle data *[6]*.

Evaluation of Techniques for Normalizing Crash Data

In efforts to measure, understand, and improve pedestrian and bicycle safety in communities across the country, adequate methods to assess the exposure of active users to motor vehicle traffic is a “missing piece of the puzzle” for, making it hard to interpret trends and prioritize high-risk locations *[39]*. At present, there is no clear state or federal guidance for how to evaluate pedestrian and bicyclist exposure and therefore efforts to evaluate progress toward safety goals are often limited. The FAST act of 2015 established a NHTSA safety fund to reduce pedestrian and bicycle facilities, and an FHWA-funded study aimed at filling this gap by developing a standardized approach for evaluating risk of injury or fatality for pedestrians and bicycles is currently underway (Federal Grant #DFTH6116D00004, TTI Task Order #2). This project's ultimate goal is to develop a Scalable Risk Assessment Methodology (ScRAM) to address this gap by standardizing currently disparate methods of estimating exposure. This project has incorporated the preliminary findings of that study (based on a review of over 280 documents pertaining to this subject), and ongoing tracking of research outcomes to inform how to identify and prioritize high-risk locations and interpret data is recommended.

The FHWA has stipulated that state DOTs and MPOs are expected to report out on five safety management performance measures in conjunction with implementation of their Highway Safety Improvement Program, one of which is the number of nonmotorized fatalities and serious injuries. However, unlike for motor vehicle performance measures, this metric does not require normalization to account for exposure, due to the lack of widely available data and lack of standardization of approach in deriving such measures *[39]*.

Generally, the literature is in agreement that risk is "a measure of the probability of a crash to occur given exposure to potential crash events" *[39]*. In other words, the number of expected or actual crashes, classified by type or severity, divided by exposure, but definitions of where and when exactly nonmotorized users are "exposed" differ, and thus operational definitions of exposure vary widely, including pedestrian or bicycle volumes, total intersection flows, the product of bike/ped volume and motor vehicle volume or its square root, person-miles traveled, distance or number of travel lanes crossed, travel time, area population, and travel survey data such as the number of bike/walk trips made *[39]*. Which measures and methods are employed typically (and necessarily) depends on the (typically limited) data available, relative to the scale of exposure analysis and the precision or existence of data at that scale.

Broadly, exposure can be estimated based on area population, direct or modeled user volumes, and/or distance or time traveled (Table 3).

Table 3
Overview of exposure analysis components

Exposure Data Inputs	Scales of Analysis	Measures of Exposure
• Direct Counts • Model Outputs • Travel Survey Responses	• Regional (e.g., State, MSA, City) • Network (e.g., TAZ, Census Tract) • Road segment • Intersection or point	• Population • Travelers • Trips • Distance • Time

Source: Adapted from Turner et al. 2017 [39].

Common operational definitions of exposure based on those basic categories include:

- Pedestrian or bicycle volume (AADT)
- The sum of total flows (both motorized and nonmotorized) passing through an intersection
- The product of pedestrian or bicycle volume and vehicle volume
- The square root of that calculated product
- Estimated crossing distance
- Estimated travel distances
- Estimated travel time
- Number of trips made
- Area population
- Active mode share (via Census or travel survey)

The Traffic Monitoring Guide outlines adjustment factor development procedures for calculating AADT from very short duration counts, and by extension, bicycle and pedestrian miles traveled (another key metric, particularly for evaluating safety) *[6]*. This consists of:

- Calculating average peak hour count volumes

- Using continuous count data, adjusting peak hour counts to average annual weekday traffic estimates

- Calculating average annual bicyclists and pedestrians
- Multiplying user volumes by estimated road segment length to estimate bicycle or pedestrian miles traveled

However, short, peak-hour counts are not necessarily representative of typical (or even "peak") traffic for nonmotorized users, and most communities lack adequate historic data from which to confidently develop such adjustment factors *[14]*. Moreover, for pedestrians and bicycles, the length of the segment that any given count represents is often unknown. NCHRP also highlights this disconnect, noting that "one of the biggest challenges in pedestrian and bicycle crash data evaluation is evaluating the number of crashes at a location without knowing the volume of pedestrians or bicycles at those locations" *[7]*. The Highway Safety Manual (HSM) provides methods for assessing crash frequency, but, due to insufficient research and data, doesn't provide crash modification factors to assess the impacts of suggested countermeasures *[7]*.

Regardless of how exposure is defined for the purpose of any particular study, which will depend on the underlying goals of the evaluator, three primary forms of activity data may be used: travel survey data, direct counts, or modeled volume estimates. The utility of each of these data types is typically contingent on the geographic scale of evaluation and the desired coverage area. Broadly, the scale of analysis can be classified as either area-wide (ranging from statewide to network-level within a sub area such as a census tract or TAZ) or facility-specific (e.g., corridor, road segment, or intersection).

Areawide Exposure Analysis. Despite relying on similar data sources, areawide exposure measures vary widely. Although efforts to calculate exposure typically combine multiple data sources, given current data limitations, survey data tends to form the foundation of efforts to calculate area-wide exposure. The simplest measures simply normalize crash statistics for a given area by population (e.g., bicyclist fatalities per million population), although this tends to account poorly for differing rates of active travel. Travel survey data is typically used to estimate exposure at the regional or network level. Some analyses rely solely on ACS journey to work data, while others focus on NHTS data for total trips. The FHWA Nonmotorized Transportation Pilot Program calculated areawide an exposure metric using NHTS, ACS, and local count data to evaluate safety improvements over the duration of the program, while the Alliance for Bicycling and Walking's Benchmarking Report calculates areawide exposure for states and major cities. Some analyses derive estimated pedestrian and bicyclist miles of travel using travel survey trip length data, and a few developed estimates for travel time *[39]*.

Key survey data sources include:

- *American Community Survey* - this data source from the U.S. Census provides journey to work data at levels of geography down to the block group level, with 1-year estimates for geographic areas with greater than 65,000 people, 3-year estimates for areas with populations greater than 20,000, and 5-year estimates for everything else. This dataset is widely used, however, margins of error at the Census tract level or smaller are high, and data focused on commute trips may misrepresent overall walking and bicycling behavior in many areas *[40]*.

- *National Household Travel Survey data* - this survey, completed every five to seven years, can provide aggregate national mode share estimates for walking and bicycling trips, but is of limited utility at smaller geographic scales unless add-on samples are used due to the small number of survey responses per jurisdiction *[41, 42]*.

- *Regional household travel surveys* - many state, regional, and local jurisdictions periodically undertake travel surveys to answer questions not effectively addressed by the national efforts listed above. However, frequency and content of such surveys varies widely.

From survey data, exposure measures may be based on area population, the number of people walking or bicycling, the number of total trips taken, or the reported or extrapolated distance or duration of active trips may be used, depending on the study purpose, method, and location *[43]*. Such calculations are typically used for sketch planning purposes and quick estimates, rather than in-depth analysis, given the relatively low level of accuracy inherent *[39]*.

Importantly, unless robust regional travel survey data (including NHTS add-on samples) is available, the geographic scales at which such estimates are useful are limited, and do not take the specific conditions of the built environment that impact the degree of interaction between motorized and nonmotorized road users within those geographies into account. Specifically, ACS data on work trips may not provide a representation of overall walking and bicycling in an area, and for both ACS and NHTS, the number of walk and bike trips represented for nearly any region or smaller geographic area is too small for reliable analysis *[39]*. As such, most areawide exposure analyses described in the literature are suitable for sketch planning purposes only, where relatively low accuracy is acceptable.

However, some organizations have undertaken more ambitious efforts to provide comparable data among states and cities (e.g., the Alliance for Biking and Walking's Benchmarking

Report) and/or combine and index multiple data sources to calculate change following intervention (e.g., the National Complete Streets Coalition, and the FHWA Nonmotorized Transportation Pilot Program, which combines NHTS, ACS, and local count data to model community-wide safety impacts over ten years).

Additionally, although the margins of error of survey data increase with decreasing geographic scale, regression models aimed at determining factors influencing demand may also rely heavily upon survey data even at smaller levels of geography *[39]*. For example, by using regional travel survey data, combined with NHTS data, to measure exposure at the census-tract level and comparing the outputs to various demographic and neighborhood characteristics to develop estimated crash rates at a neighborhood scale *[44]*.

Facility-Level Exposure Analysis. Inputs for calculating exposure at the facility level (segment or point), on the other hand principally include either: direct measurements (i.e., counts on specific facilities), regional or network model outputs (calibrated using direct counts) for various geographic scales, or, increasingly, a combination of the two.

Broadly, exposure using direct or estimated count data defines the unit of exposure as the volume of users for a specific time period or distance traveled (e.g., segment or crossing distance), or as the product of that volume times the volume of motorized traffic to account for the interactions between modes *[39]*. At its simplest, exposure can be calculated by the number of crashes (total or for a specific mode), divided by the AADT. Both point- and segement-level exposure measurements are common, with many researchers developing crash rates for both (or an aggregation of the two for a given area) within an individual study. In addition to reporting normalized crash rates, exposure calculations can be used to assess longitudinal trends, intervention impacts, and as an input in cost-benefit analyses *[39]*.

Critically, the use of direct counts in exposure, crash rate, and/or risk calculation relies on the ability to derive estimated annual average daily traffic figures for the given facility and mode(s). As discussed above, this means (absent continuous long-term count data for the specific location) adjusting short-duration counts based on the target facility’s factor group. For motor vehicles, systematic traffic monitoring programs allow reliance on the direct measurement approach, whereas for pedestrians and bicyclists, for whom far less current and historical count data exists, a wide variety of statistical models have been developed, with distinctly differing needs for pedestrian and bicycle evaluations.

Direct demand models are among the most commonly used, using regression analysis to relate count data to physical and/or demographic characteristics of the built environment, including urban form and density, land use/activity generators, transportation system elements, socio-economic characteristics, weather, etc. Such models are relatively simple to use, allowing estimation of volumes (and thus, exposure) across a network of facilities, even if there are only direct measurements at a selection therein. Importantly, such models can also be used as an alternative approach to deriving areawide exposure by aggregating results across the desired geography *[45, 46]*. FHWA included several direct demand models to estimate pedestrian and bicycle volumes using count data in its Nonmotorized Travel Analysis Toolkit *[47]*. However, these tend not to account for behavioral characteristics, and cannot generally be transferred from one location to another *[39]*. The current research underway is expected to provide actionable recommendations for calculating exposure, both with and without facility-specific user volume data.

In addition to direct demand models, regional travel demand models based on traditional trip-generation forecasting have been employed to estimate the number of nonmotorized trips for a given area, however, the scale of spatial analysis limits their utility for these modes. Emerging research and new modeling techniques (e.g., tour-based and activity-based models) are expected to improve the utility of this common analysis activity for smaller levels of geography *[39]*. GIS-based models, specialty models (e.g., MoPeD, an open source regional model for pedestrian trip generation and flow), and network analysis models have also been employed as a component of exposure and risk analysis in select instances, while simulation-based traffic models are currently evolving rapidly with new capacities to model nonmotorized (particularly pedestrian) demand and flow. However, these still tend to require considerable input data and technical capacity to operationalize *[39]*.

Overall, “the scale for which exposure is required will determine what data source and methods are practical and feasible” *[39]*, and methods still vary considerably, with survey data calculations (alone or in combination) most commonly used for areawide analysis and direct demand estimation models for facility-specific analysis to make use of limited count data. Units of exposure vary, but are typically reported by time period or distance traveled (often multiplied by motorized traffic volumes), and regression analysis can be used to relate count data to various environmental attributes. At present, FHWA does not require calculation of pedestrian or bicycle exposure in nonmotorized safety performance, but as measures are identified and defined as best practices, expectations for incorporating risk exposure estimation for such users are likely to increase.

Task 3: Video-Based Count Detection Assessment

Current State of the Practice

Using video technology for bicycle and pedestrian counting programs is relatively new but has shown significant promise. As with counting technologies in general, video counting technology can be broken down into two distinctive categories: manual and automated. Manual video counts are conducted by a person observing video data. Automated video counts rely on video image processing technology to detect and classify the data. Both techniques have their own advantages and limitations.

Video technology can be used to perform manual observation counts simply by allowing researchers to review video data while automated video counts rely on video image processing technology to detect, classify, and record data. An obvious advantage that video observation presents over traditional manual counting is the ability to manipulate the speed at which the data is observed. In cases of high volume, the observer can slow down, pause, or even rewind data for verification and thus, increased accuracy. Due to the ability to review collected video data, any number user characteristics (e.g., gender, race, helmet use, etc.) can be more accurately accounted for given the time an observer has to review and analyze the data, particularly in high volume environments. Video observations also allow for counts of a longer duration that would otherwise be impossible or suffer in terms of accuracy due to counters tiring or becoming distracted standing in the field for hours at a time. Through video observations, an agency can keep a permanent record to be reviewed at any time for verification. A convenient side benefit that manual video observations provide is a way to analyze the variance between manual counts and automated counting equipment to test accuracy.

The primary limitation of manual video observation is the same as with any manual count. Manual counts using video footage can achieve near-perfect accuracy, assuming a trained and fastidious reviewer (with the highest accuracy rates achieved through employing two reviewers for each dataset). Apart from human error, video observations (manual or automated) are susceptible to the problems of traditional automated counting devices (e.g., theft, vandalism, malfunctions, etc.). Additionally, weather and lighting can greatly inhibit counting via video observation while other forms of automated counting do not suffer in this way (though environmental constraints can be largely mitigated through careful site selection and use of high-definition video). While manual video observations can be the most accurate form of counting if performed properly in the best of conditions, there is a higher price to pay in the form of the additional labor hours required to meticulously view and document the data with as little error as possible. Thus, this method is only suitable for short-duration counts and/or as a means to supplement and validate data collected through other means (i.e., as an expedient alternative to stationing manual observers in the field).

Automated video counting technology, on the other hand, can eliminate many of the labor costs associated with manual counting. Through the use of a camera and computerized algorithms, automated video counting systems can collect and catalog data instantaneously, without the need of a human researcher aside from setup and maintenance.

Although some early studies demonstrated the potential utility of using video technology for bicycle and pedestrian counting, development of reliable, accurate methods for deployment in programs is relatively new *[48]*. The technology has come a long way in the past couple of decades, but even as far back as the year 2000, a video count system that could detect, track, and classify objects was created, though its accuracy rate for counting bicycles was only 70% *[49]*. That process of detecting movement and singling out an object, tracking the object frame-by-frame, and then classifying it by type (e.g., pedestrian, bicycle, vehicle, etc.) is broadly referred to in the literature as image processing, which is the basis of any automated video counting system.

Most of the work in automated video counting since has essentially been an effort to improve upon one or more of those three basic steps of image processing. There have been many technical studies that attempt to perfect complicated algorithms to improve overall accuracy, but the process almost always consists of those three basic steps--detection, tracking, and classification—even if they are referred to by slightly different terms *[50 - 57]*.

Research has increased significantly in the past five years with algorithms becoming more sophisticated. A study designed to measure pedestrian counts, direction, and walking speed concluded that “computer vision techniques have the potential to collect microscopic data on road users at a degree of automation and accuracy that cannot be feasibly achieved by manual or semi-automated techniques” *[55]*. Similarly, other researchers determined that “accurate automated cyclist counts and tracking can be performed with CV techniques and may expand the possibilities for cyclist data collection significantly... both geographically (different locations) and temporally (for longer periods of time)” *[56]*. More recent attempts to improve computer vision algorithms typically targeted specific problem areas of the technology, including classification difficulties and counting in complicated environments.

Classification has always been the trickiest step in the process. The reason it is challenging for machines to distinguish between bicycles and pedestrians is that “a bicyclist is an intricate combination of a bicycle and a person” *[51]*. More recently, researchers have developed an improved system for video counting of bicycles by implementing a combination of classification techniques, determining that combined approaches proved more accurate than using a single classification technique *[57]*. New automated video counting systems have sought to improve algorithms in certain problematic areas, including high-density environments, complicated scenes like intersections, and occlusion resulting from lighting and weather *[58, 59]*.

Video count technology promises to aid in conducting automated counts at intersections, where more traditional counting methods, like loop detectors and pneumatic tubes, are not as effective *[60]*. Automated video technology's ability to perform counts across a screenline or at intersections, as well as in mixed traffic scenarios is a key advantage. On the other hand, while some more traditional automated technologies may not be affected by lighting and weather, these factors can greatly affect the accuracy of automated video counts, as they can with manual video observations as well. Use of thermal cameras may mitigate these limitations *[61]*. Cameras may be deployed in a variety of contexts and manners to meet the objective of the counts. For manual count purposes, portable camera units may be set up anywhere that provides a clear view of the intersection or screen-line targeted for analysis. For automated counts, additional deployment criteria will need to be identified based on the analytic software's specifications (e.g., specific height, parameters of field of vision, lighting, etc.).

In recent years, cameras in general have become more affordable, more portable, and easier to install. While opportunities exist to use devices that are already in place, like security and surveillance cameras, these were typically not installed with this purpose in mind, and the location, viewing angle, power source, or other factors may inhibit the utility of such units for these purposes. Preliminary research indicates that many of these limitations, however, can be overcome through adaptation of algorithms used in tracking movements, albeit to varying degrees of accuracy *[62 - 67]*. Since existing cameras (traffic cameras, police cameras, red light cameras, security cameras, etc.) are typically installed on a long-term basis, agencies responsible for their implementation should be encouraged to consider factoring other potential data uses such as pedestrian and bicycle counting into their placement and installation protocols *[66]*.

In addition to developing video-count solutions in-house using new or existing cameras and customized or open-source algorithms developed and/or managed by agency personnel, a variety of software and hardware companies currently provide products which meet these needs, ranging from full-service vendors who provide specialized hardware and process the data using proprietary (typically offered as a monthly subscription fee), providing agencies with a variety of summary data points, to companies which provide software to analyze existing video feeds and may or may not provide accompanying hardware or analytic support (See Appendix B for additional information). Most products are currently designed to count only pedestrians or only bicycles, while others can count both simultaneously (either aggregated or disaggregated), and a few vendors (e.g., Numina) are currently working to develop fully multi-modal solutions. As noted above, this is an emerging field in rapid and constant flux. However, for virtually all vendors and products currently on the market, a custom project design must be negotiated between the vendor and customer based on the site(s) selected, the type of data needed (e.g., screenline counts, travel modes, turning movements, pedestrian paths, etc.), and the duration of analysis.

LTRC Support Study Summary Findings

Full methodological details and results for LTRC's support study activities focused on a pilot application of camera-based automated counting. may be found in LTRC Final Report: ITS Support for Pedestrians and Bicyclists Count: Developing a Statewide Multimodal Count Program *[4]*. Overall, accuracy rates across the five sample study locations ranged between 29 – 91% for detection of pedestrians, and between 0 – 60% for cyclists (Table 4). This result was fairly poor but can be attributed to a number of reasons, such as occlusion, lighting condition and viewpoint angle of the camera.

Table 4

Accuracy rates of pedestrian and cyclist detection at pilot automated video detection sites

		PEDESTRIANS			CYCLISTS		
Site	Number of frames	Manually Counted	HOG Algorithm	Accuracy Rate	Manually Counted	HOG Algorithm	Accuracy Rate
1	54	40	30	75%	14	0	0
2	480	856	541	63%	62	37	60%
3	365	582	171	29%	15	0	0
4	221	305	277	91%	0	0	N/A
5	278	495	374	76%	9	2	22%

Data Source: Julius Codjoe, LTRC

The viewpoint angle was a major factor affecting the accuracy of the results. A consistent angle for mounting cameras is required for better accuracy. Another contributing factor for low accuracy rates is the rich background. This study was performed in the real environment, such as a busy street, parking lot, and so on. It is possible for objects such as trees and poles to be detected as human beings. However, this did not appear to be a factor for this study as the algorithm undercounted both pedestrians and cyclists.

Occlusion can also affect the accuracy rates of detection. When there are several people passing by the camera at the same time, some of them may not be detected or several of them may be detected as just one person if they are very close to each other. This is because low number of features could be detected in this case. Table 4 shows that occlusion could be a problem with this study as it can be seen that higher number of pedestrians in a frame resulted in poorer accuracy rates.

Lighting condition can also cause inaccuracy of detection. If the light is not bright enough, the pedestrian in the scene is not clear enough to be detected. In the future, the research team hope to add a tracking element to count the number of pedestrians and cyclists. Tracking and counting will improve the performance of the algorithm.

While the overall accuracy rate of the HOG algorithm in detecting pedestrians and cyclists were poor, the research team investigated the effect of the density of pedestrians/cyclists in each frame to the accuracy rate. Generally, the higher the number of pedestrians in a frame, the poorer the accuracy rate. All of the investigated sites had low cyclist density, so no comparable trend was derived for this user group.

LTRC Support Study Conclusions

The overall conclusion to be drawn from the literature and results is that automated data collection via video and image processing technology has grown to be an effective and feasible method for counting pedestrians and cyclists. While the collection of studies on newer technologies is not as robust as that of traditional ones, there is enough evidence to justify and guide the use of automated video count technology. To date, most researchers have developed unique algorithms and products in service to their agency or research goals rather than strictly replicating other methods to improve existing algorithm and deploy on a wide scale. Further research into using existing cameras, rather than new cameras, for collecting video data would be most beneficial as leveraging these sources could prove a huge benefit in terms of time and cost. Perfecting this method of automated data collection would greatly expand an already exciting technology growing in capacity. The implications of having a tested and efficient automated video-based count program will allow planners to add this method of data collection when deciding on research methods for count programs, and policymakers can trust the results in their decision-making.

This particular study aimed at developing such a system for pedestrian and cyclist detection. However, the limited study time meant that the research team focused on the detection part of the algorithm. A fully developed algorithm will be capable of detecting, tracking, and counting accurately. This study involved breaking video footage into subsequent frames and then utilizing the part-based method suggested by Felzenszwalb et al. for detecting the objects in the frames. The method relied heavily on exploiting the technique of HOG as well as a latent SVM classifier. The results of the pedestrian detection ranged between 29-91% and that of the cyclist detection spanned between 0-60%. The results showcase a method which is efficient in terms of development within a limited time frame, despite having compromised accuracy. In the future, the research team plans to enrich the models in order to improve the accuracy rate. This feat would involve training the algorithm with a dataset considering various instances of true positives or various viewpoints of pedestrians and cyclists, as well as false positives such as background trees, buildings, etc. In addition, the research team would like to add pedestrian-tracking and cyclist-tracking to the algorithm for counting. Tracking can also improve the accuracy rate significantly since from the tested data, the same object or person can be detected at some frames while not at other frames while being continuously extracted from the footage. Tracking would improve the results by capturing and storing the location of the object over successive frames.

Task 4: Identify Funding Sources

Funding for active transportation projects and programs, including those focused on data collection, monitoring, and/or evaluation, can come from a variety of federal, state and local government sources as well as the private sector. Choosing among these resources depends on the type of projects and availability of the funds. Importantly, the availability of data as resulting from investment in monitoring pedestrian and bicycle activity can enhance a jurisdiction's ability to secure funding infrastructure improvements by providing evidence of need, supporting forecasting of potential impacts, etc. This section outlines potential funding sources for which data collection and monitoring may be an eligible activity, and provides summary information about cost estimates for statewide count efforts from two states and one city/region.

Estimating Program Costs

Importantly, there exists no universal standard for how much funding is needed to support statewide pedestrian and bicycle monitoring. Programs can be scaled to fit available resources, and typically grow incrementally over time. Rather, this section describes the general types of costs that jurisdictions interested in collecting count data may expect, and provides examples from states currently engaged in these activities. Broadly speaking, a count program can expect to incur the following categories of costs:

- *Capital costs* - equipment and installation: automated count equipment
    - Long-duration or permanent counters range in cost from about $2,000 to $7,000 per unit (infrared sensors on the lower end of the range, and sensors which are capable of counting pedestrians and bicycles separately at the higher end).

    - Temporary/mobile count units commonly in use range from $1,000 to $4,000 per unit, depending on sensor range, data intervals required, etc.
    - Installation - installation costs (other than staff time) are typically only required for permanent count units requiring engineering expertise (e.g., inductive loops). Many transportation agencies have in-house capacity to complete installation or can partner with another governmental entity that has this capacity; if outside contractors are required, installation costs of $1,000 - $2,000 per unit may be anticipated (though per unit costs may decrease with scale).
- *Operational costs* - Maintenance, supplies, vendor/subscription costs
    - Maintenance - Over time, wear and tear of count equipment can be expected. Units should be durable for all kinds of weather and to minimize vandalism, however, intermittent costs for replacement of major components, cleaning, etc. should be considered.
    - Supplies - including routine costs for replacement batteries, tubes, installation hardware, etc. These costs will vary based on how heavily individual count units are used
    - Vendor/subscription costs - this may range from fees associated with automatic data transmission (e.g., EcoCounter, $400/unit per year modem cost), web platforms for analyzing data (may be included), to full-service data solutions (e.g., Numina’s $100/month cost data subscription).
- *Personnel costs* - Practitioners recommend an established program should dedicate at least the equivalent of one full-time staff person to bike/ped data collection (States, MPOs, and larger cities); time may be split among team members with different roles (e.g., program coordination, installation/maintenance, and data analysis). Smaller programs should dedicate staff time as needed to conduct periodic maintenance, data retrieval, and reporting tasks.

Ultimately, the scale and scope of monitoring activities must be tied to the agency’s goals, and will be constrained by available resources. At a municipal level, one or two strategically placed permanent counters, plus a set of mobile units capable of counting nonmotorized traffic on a typical street configuration, may be accomplished with a one-time budget allocation of $20,000 - $25,000 for equipment, plus a few hours of staff time per month to install, maintain, and monitor counts. For a jurisdiction wishing to conduct a one-time comprehensive analysis of demand and behavior at the top 20 pedestrian and bicycle crash intersections, for example, a program focused on a vendor-based count product may be of greater overall utility.

On the other hand, a state DOT wishing to systematically monitor active transportation trends, develop regionally- and factor-specific adjustment groups, and evaluate crash rates on specific facilities may require 20+ continuous count stations, an inventory of different short-duration count units suitable for multiple facility contexts, and dedicated, full-time staff responsible for installing and maintaining equipment and managing/utilizing the data. The following examples illustrate two instances of the latter scenario, as well as one example of effective state collaboration in a local/regional multimodal count program.

Minnesota - Minnesota's active transportation monitoring program has evolved out of a series of research projects working with Greg Lindsey funded by MnDOT, totaling over $300,000 from 2011-2017. These projects involved pilot use of various count units, standardizing procedures for manual counting, and institutionalizing use of the data. Thereafter, MnDOT invested $250,000 in automated count equipment and installation. MnDOT also coordinated with FHWA to pilot integration of active transportation data into the Traffic Monitoring and Analysis (TMAS) system, utilizing a $30,000 grant to support staff time.

Today, MnDOT funds a full-time bicycle and pedestrian data coordinator position, within the Office of Transit, who collaborates with multiple departments within MnDOT, as well as local partners, to fund and install count equipment. Excluding capital purchases, the annual cost of this program is approximately $70,000. Meanwhile, MnDOT maintains a log of projected capital expenses for their inventory of counters for the next 10 years, including replacement batteries, an annual maintenance estimate, and a 5% inflation factor, anticipating a total cost of approximately $320,000 from 2016-2026.

Colorado - CDOT began developing their motorized traffic counting program eight years ago with a private grant from Kaiser Permanente Foundation. Since then, CDOT has placed 20+ permanent counters and deploys approximately 60 short-duration counters each year. Now, the state's program is funded with SPR (state planning and research) federal funds. CDOT has also encouraged and provided technical support to local agencies to implement counting programs throughout the state, including Boulder County, the City of Boulder, the City of Fort Collins, Colorado State University in Fort Collins, Windsor Parks and Rec, The North Front Range MPO, the City of Denver, and the City of Colorado Springs, all of which have some form of counting program that they implement and manage. A requested summary of program expenses was not provided.

Oregon - Oregon funds pedestrian and bicycle programs, including data collection, in part through their state transportation budget (supported by state gas taxes and associated fees). Oregon is currently in the process of developing a statewide count program housed within ODOT, but in the interim, has supported multi-modal count programs at the local level, including a collaboration with Bend, Oregon (City of Bend Growth Management program and Bend MPO), notable for the way in which their motor vehicle count program was completely reorganized in 2016 to fully incorporate pedestrian and bicycle traffic as part of traffic monitoring overall, rather than as a separate, specialized program.

Bend leveraged local transportation planning funds allocated to their vehicle count program to purchase and install permanent count equipment at five locations (with bike/ped equipment from EcoCounter), and to pay for a contractor to conduct short-duration tube counts. These funds served as the local match for a grant from ODOT's Traffic Records Coordination Committee using federal Section 405 funds, and from ODOT's Research Division to purchase temporary counters. In total, Bend estimates their program costs (for monitoring all modes) as follows:

- 5 permanent count locations (all modes): $70,000 equipment, $30,000 installation
- 15 temporary bike/ped counters: $70,000 equipment, $10,000 for contractor to deploy (1-2 week counts), plus $15,000 local match in staff time
- Motor vehicle 24-hour tube counts, 40 sites per year: $15,000
- Maintenance and service contract for permanent counters: $5,000
- Total Capital Costs: $170,000; Total Operating Costs $45,000 per year

Federal Funding Sources

A variety of federal transportation programs support, or can potentially support, bicycle and pedestrian projects. Programs under which data collection activities for active transport projects are explicitly eligible include but are not limited to: Federal Transit Administration Capital Funds (FTA), Associated Transit Improvement set asides (ATI), Highway Safety Improvement Program (HSIP), National Highway Performance Program (NHPP), Surface Transportation Block Grant Program (STBG), Transportation Alternatives Set-Asides (TA), Recreational Trails Program (RTP), Safe Routes to School Programs/Activities (SRTS), Statewide Planning and Research (SPR) or Metropolitan Planning funds (PLAN), and Federal Lands and Tribal Transportation Programs (FLTTP). In addition, other programs may be able to support data collection and monitoring indirectly, such as those that fund pedestrian and bicycle coordinator positions, planning activities, and safety assessments (Table 5).

Table 5

Potential FHWA funding opportunities for pedestrians and bicycle data collection

Activity or Project Type	TIGER	TIFIA	FTA	ATI	CMAQ	HSIP	NHPP	STBG	TA	RTP	SRTS	PLAN	NHTSA	402 NHTSA	405 FLTTP
Bicycle plans			X					X	X		X	X			X
Coordinator positions (State or local)					X			X	X		X				
Counting equipment			X	X		X	X	X	X	X	X	X			X
Data collection and monitoring for pedestrians and/or bicyclists			X	X		X	X	X	X	X	X	X			X
Pedestrian plans			X					X	X		X	X			X
Road Safety Assessment for pedestrians and bicyclists						X		X	X			X			X
Safety education positions								X	X		X		X		
Safety program technical assessment (for peds/bicyclists)								X	X		X	X	X		
Training					X	X	X	X	X	X	X	X	X		

Adapted from: "Pedestrian and Bicycle Funding Opportunities: Department of Transportation Transit, Highway, and Safety Funds" available at https://www.fhwa.dot.gov/environment/bicycle_pedestrian/funding/funding_opportunities.cfm

For some of these federal funding programs, specific requirements must be met and eligibility may be determined on a case-by-case basis. In many cases, data collection and evaluation may be included an eligible activity as a component of a larger project, supporting efforts to institutionalize active transportation monitoring by integrating such activities into routine performance measurement and evaluation protocols, and allowing for incremental expansion of data availability across the state. For example, California's Office of Planning, Environment, and Realty has awarded "Bicycle-Pedestrian Count Technology Pilot" grants to MPOs, who have in turn coordinated with local agencies for their staff time, expertise, and equipment to collect the data. In this endeavor, California has utilized FHWA PL funding to support bike/ped counting, requiring that data collection activities be tied directly to a planning project.

Transportation Alternative Set-Aside funds are a common funding source for pedestrian and bicycle infrastructure. To be eligible to receive this funding, a project must be identified in the Statewide Transportation Improvement Plan (STIP) and consistent with Statewide Transportation Plan and the Metropolitan Transportation Plan. Generally, state DOTs administer TA grant within the states, except urbanized areas with population over 200,000 where will be funded through Metropolitan Organization's (MPO) grant process. MPOs distribute TA funding through running a competitive grant program. Therefore, communities, advocates, and planners must effectively integrate biking and walking projects into the MPO funding process and project selection criteria to access these funds. In addition, state DOTs have the authority to transfer up to 50% of TA funding to the other Federal Highway-Aid Programs such as STP and STPP *[68]*.

The Highway Safety Improvement Program (HSIP), a data-driven program aimed at increasing safety and reducing traffic fatalities and injuries, is another popular resource for supporting nonmotorized data collection and evaluation. HSIP projects must address issues identified in the Strategic Highway Safety Program in order to be approved for the funding. States should regularly evaluate and track the performance of the project to ensure about the reduction in number of fatalities and injuries *[69]*.

Section 402 (State and Community Highway Safety Grant Program) funds, which fund non-infrastructure activities focused on safety, may also be applicable for research and analysis activities *[70]*.

State, Local, and Private Sources

Importantly, virtually all federal funding sources require a local match for a percentage of the project total. Communities may also support pedestrian and bicycle monitoring through state-funded revenue sources (e.g., state bicycle-pedestrian grant programs where they exist, multi-modal funds), or through local general funds, bond issues, and tax increment financing programs. For smaller communities, practitioners emphasize that most highway funds routed through state DOTs which support rural areas can be used to support for pedestrian and bicycle-related work.

In addition, providing equitable, healthy transportation options in any project add value to a community and attract private or nonprofit investment including developers, hospitals, and universities. In particular, ongoing and special-studies university partnerships to support data collection and analysis are common, and several communities have successfully accessed philanthropic funds for capital expenses related to count programs. In particular, organizations interested in the health benefits of active transportation have proven to be important benefactors in many communities; for example, Colorado’s statewide count program was initially supported with funding from Kaiser Permanente.

Meanwhile, developers may be asked to conduct counts on streets impacted by proposed developments as a part permitting processes (as well as, in some locations, to fund active transportation infrastructure improvements themselves). Additionally, institutions like universities and hospitals with large footprints (and generally, significant pedestrian activity) should be encouraged to incorporate active user volume data collection in site master plans and as a part of any major development activities.

Best Practices

Practitioners recommend that, regardless of the agency type, at least one staff person should be dedicated (full or part-time, depending on program scope) to leading data collection and analysis activities. This may or may not be the same person or team as leads motor vehicle count collection, given the differences in program scale, objectives, and methodology required. If a pedestrian/bicycle program exists, that staff person typically takes on the role of count coordinator. However, some jurisdictions have simply expanded the activities of existing travel monitoring personnel to include nonmotorized data collection. For example, the Delaware Valley Regional Planning Commission has allocated one-half of one of their travel monitoring team’s field personnel’s time to nonmotorized data, as well as one member of their planning staff at ¼ time. Ensuring that existing personnel (and/or contractors) engaged in motor vehicle counts have the training and capacity to also work with equipment that is designed and/or calibrated specifically for active modes (in the case of contractors, by requiring multimodal capability as a criterion for bid selection) is critical to ensuring an efficient, integrated data collection process.

Moreover, practitioners encourage, where feasible, integration of multimodal data collection and analysis requirements into policy and permitting processes. For example, San Mateo County, CA, requires private developers to conduct multimodal counts as part of development traffic impact studies. The county then incorporates this data into their count databases to enhance their overall body of data and facilitate evaluation activity. State DOTs can also require active transportation data collection as a condition of receiving grant funding, and/or as part of the permitting process for development impacting state roadways.

Importantly, dialogue with practitioners around the country reveals that even where coordinated statewide count programs housed within DOTs do not yet exist, state-level leadership is often instrumental in developing capacity for multimodal data collection at all levels. This begins with acknowledging the full range of federal resources which may potentially be tapped for pedestrian and bicycle data collection activities (according to FHWA), supporting multiple phases of planning and program development to standardize approaches to data collection (often using research funds and university partners to pilot methods and develop and disseminate resources), and providing staff support for local partnerships, coordination, and capacity building.

In states where DOT-led count programs do exist, leading the initiation and/or growth of a network or permanent count stations, as is routine for motor vehicle data collection, has been a key role, as this data forms the foundation of any number of subsequent analytic activities and tends to be the most expensive component (initially) of any program. States (as well as cities) are encouraged to seek out opportunities for philanthropic partnerships where available, but may also adopt a phased approach, building out the network of count locations over time.

Task 5: Case Studies

This section summarizes findings from the primary data collection and analysis activities associated with each of the three case study locations, and outline a framework for cost benefit analysis of active transportation projects, and summarize recommendations for both project and area level exposure estimates and other data applications, based on the research currently available.

Tulane Avenue

Tulane Avenue in New Orleans, defined for the purposes of this study as the segment between S. Carrollton Avenue and S. Claiborne Avenue, is a four-lane state-owned roadway (US Route 61/90) which recently underwent reconstruction and reconfiguration (completed in 2017) which included the addition of dedicated bicycle lanes in each direction. Land uses along this corridor are largely commercial, including a major medical complex, major municipal offices (e.g., Orleans Parish Criminal District Court), as well as retail, restaurants, hotels, and multifamily housing. DOTD traffic counts estimated an Average Annual Daily Traffic (AADT) of 19,228 as of 2016 near the intersection with S. Broad Avenue.

Count Data. The count equipment was installed on Tulane Avenue (approximate address 2614 Tulane Avenue, between S. Broad Avenue and S. Dorgenois St, Figures 1 and 2) on June 11, 2017, and remained installed until July 17, excluding a five-day period when the pneumatic tube counters were removed due to the threat of a hurricane and anticipated street flooding.

Figure 1
Tulane Avenue count equipment configuration, inbound

Figure 2
Tulane Avenue count equipment configuration, outbound (bicycle lane obstructed by parked vehicle)

At this site, the team experienced periodic short-term disruptions to the pneumatic tube counters due to damage and/or displacement from heavy vehicle traffic operating within the dedicated bike lane. In addition, it was observed that standard installation procedures as recommended by the equipment manufacturer were insufficient to keep the tubes in place, in part apparently due to the relatively soft asphalt of this recently re-paved roadway (Figure 3). Site visits were conducted every three days to check the equipment and conduct maintenance, and the data has been cleaned to exclude time periods where one or both of the units was not operational (imputed values added where applicable). However, there may be some temporary data disruptions which were not detected through visual and tabular review of the hourly data (e.g., if only part of the hour was impacted).

Figure 3
Pneumatic tube dislocation in asphalt, Tulane Avenue, June 2017

In total, an average of 495 pedestrians and 174 bicyclists were recorded per day during the observation period, with a high of 788 pedestrians on June 15 and a low of 229 Pedestrians on July 16, and a high of 284 bicyclists on July 6 and a low of 80 bicyclists on July 4 (although, as noted above, low values may in some cases reflect short-term data disruptions) (Figure 4).

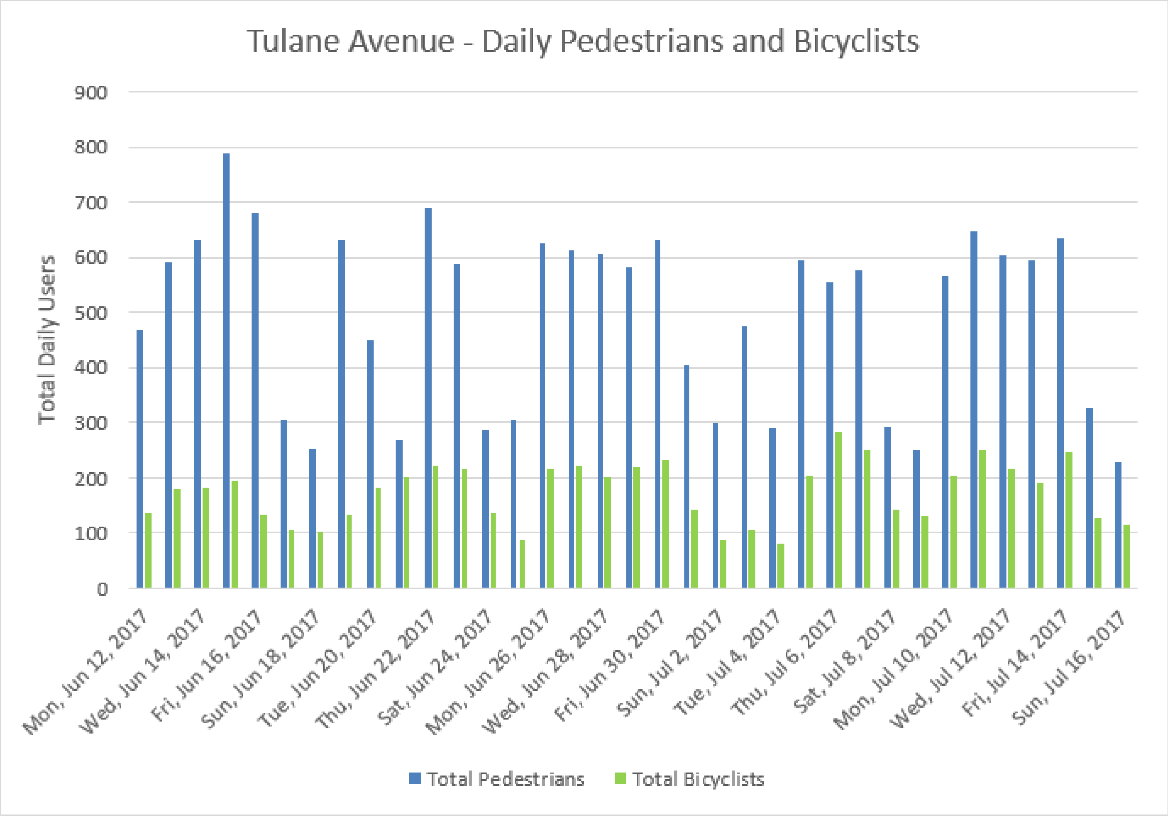

Figure 4
Tulane Avenue recorded daily pedestrians and bicyclists

Weather recorded during the observation period was typically hot, with an average daily high of 87 degrees and an average low temperature of 78 degrees. A total of 5.31 in. of rain fell in New Orleans during this period, with precipitation reported on 12 days (Table 6).

Table 6
Daily user volumes and weather conditions, Tulane Avenue

Date	Pedestrians	Bicyclists	High Temperature	Low Temperature	Precipitation (in.)
Mon, Jun 12, 2017	470	138	82	75	1.12
Tue, Jun 13, 2017	591	181	86	75	0
Wed, Jun 14, 2017	631	182	88	77	0.09
Thu, Jun 15, 2017	788	195	88	77	0
Fri, Jun 16, 2017	681	133	91	77	0
Sat, Jun 17, 2017	307	*105*	86	75	0
Sun, Jun 18, 2017	254	*103*	88	81	0.29
Mon, Jun 19, 2017	632	*135*	90	75	0
Tue, Jun 20, 2017	449	*183*	79	73	1.5
Wed, Jun 21, 2017	269	*200*	82	78	0.22
Thu, Jun 22, 2017	689	*223*	88	80	0
Fri, Jun 23, 2017	588	*216*	90	81	0
Sat, Jun 24, 2017	288	*136*	89	80	0.2
Sun, Jun 25, 2017	305	87	84	79	1.32
Mon, Jun 26, 2017	624	217	86	75	0
Tue, Jun 27, 2017	614	222	84		0
Wed, Jun 28, 2017	608	201	86	75	0
Thu, Jun 29, 2017	583	220	84	75	0.08
Fri, Jun 30, 2017	632	231	90	79	0
Sat, Jul 1, 2017	403	144	91	81	0
Sun, Jul 2, 2017	298	86	90	81	0
Mon, Jul 3, 2017	475	106	91	79	0
Tue, Jul 4, 2017	289	80			0
Wed, Jul 5, 2017	593	203	91	82	0
Thu, Jul 6, 2017	555	284	89	80	0
Fri, Jul 7, 2017	576	251	90	75	0
Sat, Jul 8, 2017	292	142	84	76	0
Sun, Jul 9, 2017	249	131	88	84	0
Mon, Jul 10, 2017	567	204	91	73	0.15
Tue, Jul 11, 2017	647	249	87	77	0.11
Wed, Jul 12, 2017	603	215	90	77	0.19
Thu, Jul 13, 2017	594	193	84	77	0.04
Fri, Jul 14, 2017	633	248	89	78	0
Sat, Jul 15, 2017	328	127	88	77	0
Sun, Jul 16, 2017	229	116	88	82	0

*Imputed Values

In order to impute missing hourly and daily values and determine goodness of fit with the Jefferson Davis Trail long-term dataset, the data was evaluated by daily usage patterns (see Appendix C-1 for additional detail about adjustment methodology). The data indicate that as a percentage of the daily total, bicycle and pedestrian traffic are relatively steady throughout the day, with no evident AM or PM commute peak period, but a spike in pedestrian activity in the early afternoon, and notably, with users remaining observed throughout the evening and overnight (Figure 5). Note that data are visualized as a percent of each mode's total for comparison purposes, although as Table 6 indicates above, there is considerably more pedestrian activity at this location than bicycle activity.

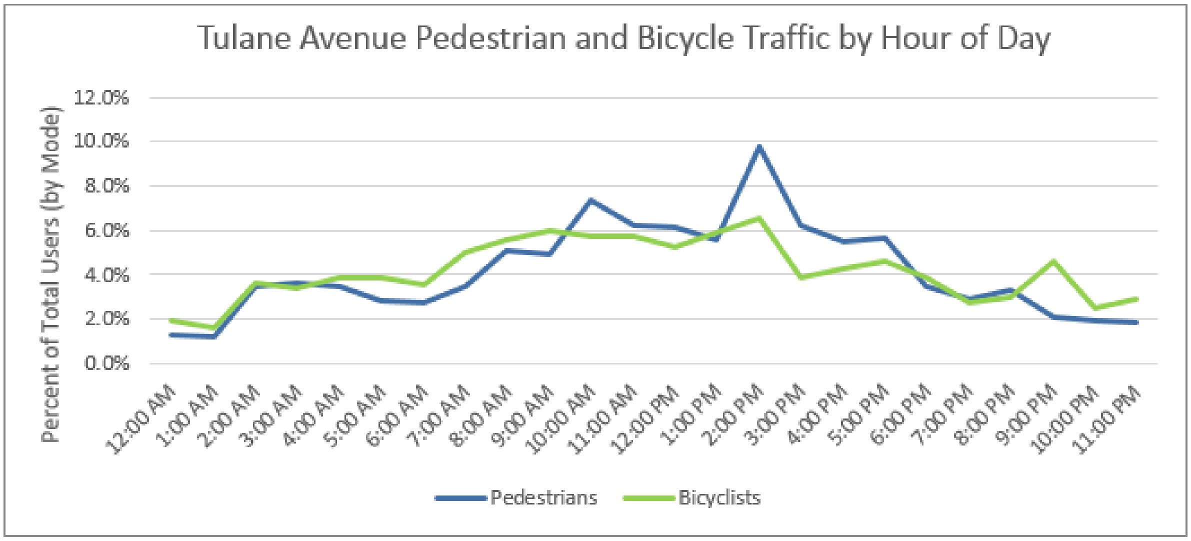

Figure 5
Tulane Avenue pedestrian and bicycle traffic by hour of day

Next, the data were broken down by day of the week and averages for each day of the week developed (with which values were imputed for five days where both tube counters were not operating, and three days where one tube counter was not operating). Daily usage patterns clearly differ again from the Jeff Davis Trail dataset, with a sharp dropoff in pedestrian and bicyclist activity on weekend days (Figure 6).

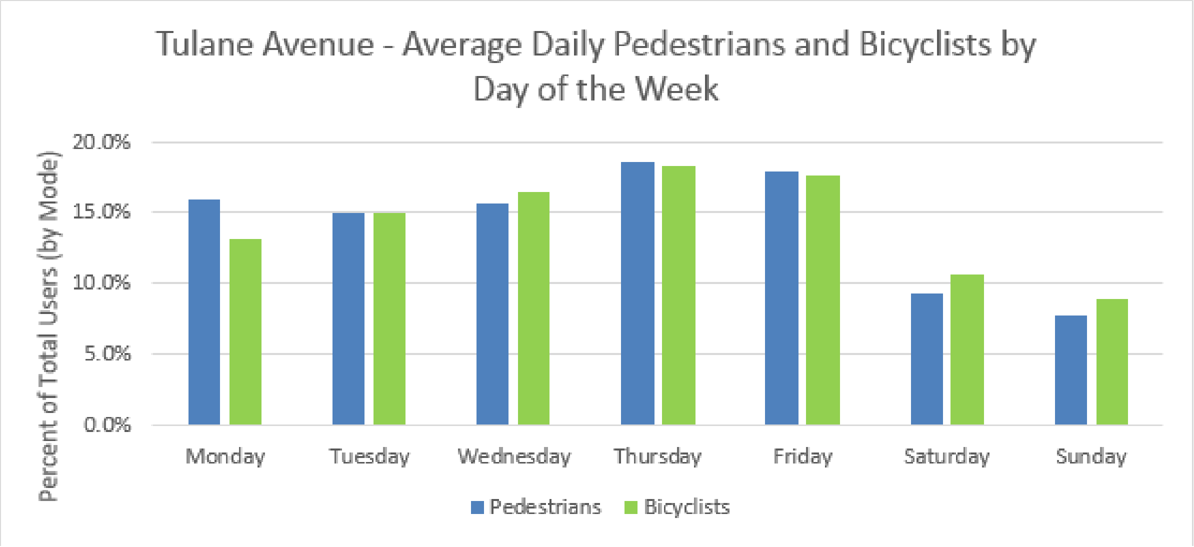

Figure 6
Tulane Avenue average daily pedestrians and bicyclists by day of the week

In order to correct for sensor and context errors (e.g., undercounts from occlusion as well as user behaviors which impact the ability of the equipment to capture all active transportation activity in this corridor, such as bicyclists riding on the sidewalk), four hours of manual validation data were collected and evaluated at the 15-minute increment level (the smallest increment in which the data can be retrieved) to determine the degree to which the sensors are accurately reflecting activity in the right-of-way. Table 7 summarizes the findings for each unit and mode. Although all four sensors were found to be operating at a very high degree of net accuracy (total users recorded/total users observed = 96% for pedestrians, with the remainder likely due to occlusion, and 100% for bicycles), true sensor accuracy was considerably lower due to a relatively large percentage of bicyclists operating outside of the bike lane, either in another travel lane (typically due to obstructions in the bike lane by other vehicles), or on the sidewalk (which also impacts the accuracy of the pedestrian counts). From this validation count, correction factors were derived, based on the net counter effectiveness (reflecting the fact that sidewalk bicyclists mitigate the impacts of occlusion based errors to some degree) to adjust for the systemic undercount.

Table 7

Manual validation summary findings and correction factors - Tulane Avenue

	Pedestrians			**Bicyclists**		
	Total	Unit 1	Unit 2	Total	Unit 1	Unit 2
Sensor Net Accuracy	96.0%	94.9%	96.9%	100.0%	100.0%	100.0%
True Sensor Accuracy - In Situ	86.6%	84.3%	88.3%	82.0%	77.8%	84.9%
Net Counter Effectiveness	91.4%	90.4%	92.2%	82.0%	77.8%	84.9%
Correction Factor	**1.09**	**1.11**	**1.08**	**1.10**	**1.11**	**1.09**

From the daily and hourly usage patterns, as well as land-use context, it is clear that this site does not align closely with the existing long-range data set used to develop expansion factors for short-term counts. However, seasonal (monthly) trends are likely to be sufficiently similar that we may use these adjustment factors to provide an initial estimate of AADT, by imputing values for the remaining days of each of the two months of evaluation (June and July) based on average daily recorded totals by day of the week, and then applying monthly expansion factors from the Jeff Davis Trail (Table 8).

Utilizing this method, estimated average monthly, annual, and daily traffic totals are derived. For comparison, existing estimates from the Pedestrian and Bicycle Resource Initiative's 2017 Greater New Orleans Pedestrian and Bicycle Count Report, which derive estimated annual average daily traffic totals based on National Pedestrian and Documentation Project methodology for expanding short-duration manual counts, are also included. Notably, those counts are conducted during assumed AM and PM "peak" hours, which as the 24-hour data show, do not accurately reflect usage patterns in this corridor. The difference between EDT derived from June versus July data illustrates the divergence of this dataset from the dataset from which the adjustment factors were derived.

Table 8
Tulane Avenue - seasonal adjustment and estimated AADT

SEASONAL ADJUSTMENT - JUNE COUNTS		
	Pedestrians	Bicyclists
Total - June (uncorrected)	15,427	5,105
Average Daily - June (uncorrected)	514	170
CORRECTION FACTOR		
Net Counter Effectiveness	91.4%	82.0%
Site-Specific Correction Factor	**1.09**	**1.10**
Total - June(Corrected	16,754	5,616
Average Daily - June (Corrected)	558	187
EXPANSION FACTOR		
Estimated % Traffic in June	**7.22%**	**7.08%**
Seasonal Adjustment Factor	**1.15**	**1.18**
Estimated Average Monthly Traffic	19,340	6,612
Estimated Annual Total Traffic	232,082	79,340
Estimated Annual Average Daily Traffic	**636**	**217**
PBRI Estimated Daily Traffic, 2017	*508*	*168*
SEASONAL ADJUSTMENT - JULY COUNTS		
	Pedestrians	Bicyclists
Total - July (uncorrected)	14,583	5,464
Average Daily - July (uncorrected)	470	176
CORRECTION FACTOR		
Net Counter Effectiveness	91.4%	82.0%
Site-Specific Correction Factor	**1.09**	**1.10**
Total July (Corrected	15,838	6,011
Average Daily - July (corrected)	511	194
EXPANSION FACTOR		
Estimated % Traffic in July	**6.26%**	**6.90%**
Seasonal Adjustment Factor	**1.33**	**1.21**
Estimated Average Monthly Traffic	21,087	7,263
Estimated Annual Total Traffic	253,050	87,152
Estimated Annual Average Daily Traffic	**693**	**239**
PBRI Estimated Daily Traffic, 2017	*508*	*168*

Crash Data. Crash data provided by DOTD were also compiled for the study area (defined here as the segment of the corridor that underwent redesign from 2015-2017, bounded by S. Claiborne Avenue and S. Carrollton Avenue, but excluding crashes occurring within those intersections, see “Methodology” section for detail).

A total of seven years of crash data were reviewed, five of which were collected prior to the roadway reconstruction project, and two of which were during the construction period. The data indicate a trend of at least one (and as many as eight) pedestrian and bicycle crashes each year, including some fatal and severe crashes involving these users (Table 9, Figures 7 and 8).

Table 9
Tulane Avenue summary crash statistics, 2010-2016

Tulane Avenue Summary Crash Statistics, 2010-2016							
	2010	**2011**	**2012**	**2013**	**2014**	**2015***	**2016***
Total Crashes	**164**	**141**	**176**	**171**	**208**	**218**	**150**
Pedestrian-Involved Crashes	7	6	6	6	2	8	3
Bicyclist-Involved Crashes	1	4	4	1	3	3	6
Fatal Injury Crashes	**0**	**0**	**1**	**0**	**1**	**0**	**2**
Pedestrian-Involved Crashes	0	0	0	0	0	0	1
Bicyclist-Involved Crashes	0	0	0	0	0	0	0
Severe Injury Crashes	**0**	**1**	**2**	**3**	**2**	**2**	**6**
Pedestrian-Involved Crashes	0	0	1	1	0	0	0
Bicyclist-Involved Crashes	0	0	0	0	0	0	1
Moderate Injury Crashes	**21**	**14**	**13**	**15**	**13**	**15**	**12**
Pedestrian-Involved Crashes	5	4	3	1	1	4	1
Bicyclist-Involved Crashes	1	0	2	0	2	2	3
Minor Injury Crashes	**28**	**39**	**35**	**49**	**51**	**48**	**27**
Pedestrian-Involved Crashes	1	2	2	4	1	1	1
Bicyclist-Involved Crashes	0	2	2	1	1	1	1
No Injury Crashes	**115**	**87**	**125**	**104**	**141**	**153**	**103**
Pedestrian-Involved Crashes	1	0	0	0	0	3	0
Bicyclist-Involved Crashes	0	2	0	0	0	0	1
** Under Construction*							

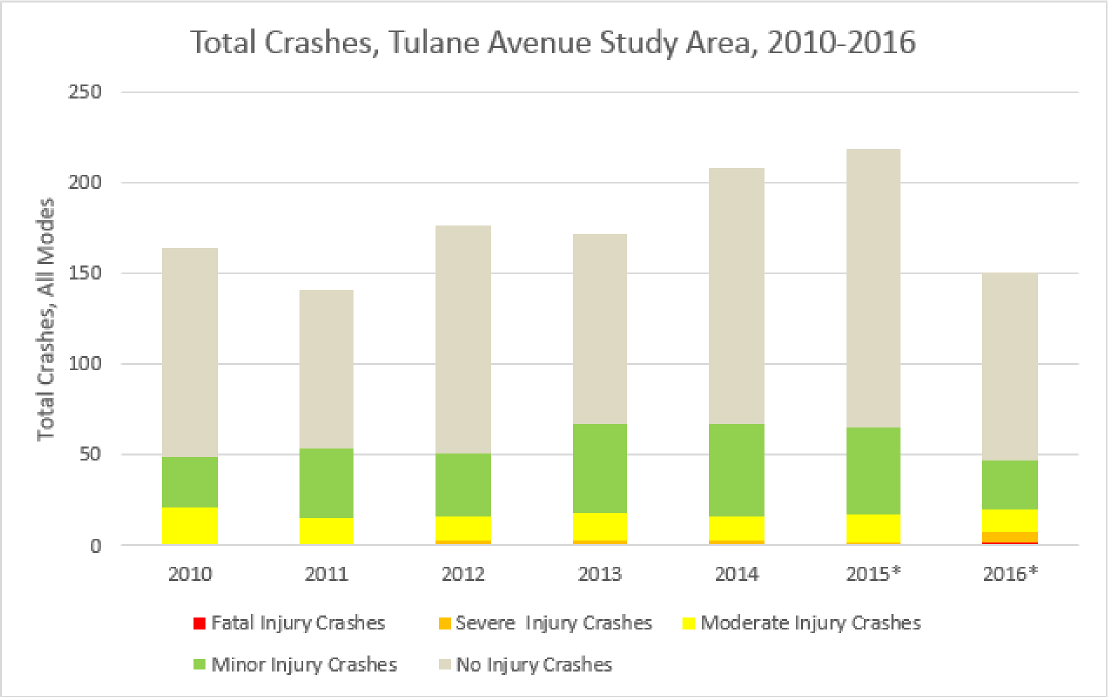

Figure 7
Total crashes, Tulane Avenue study area, 2010-2016

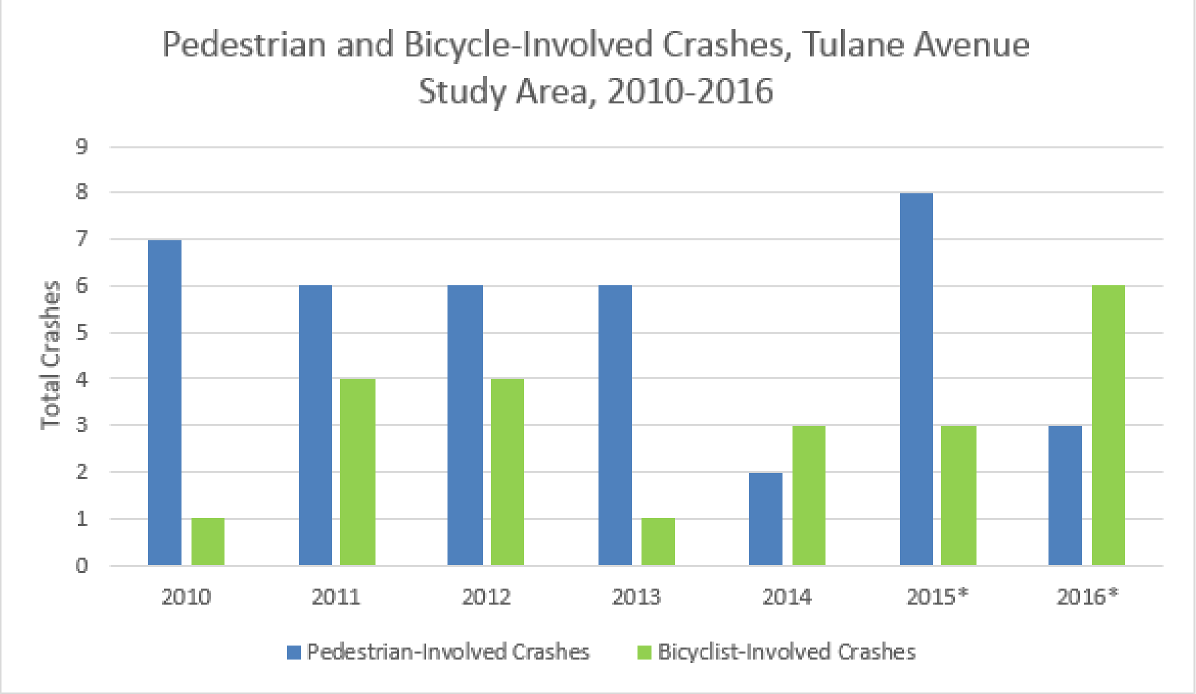

Figure 8
Pedestrian and bicycle-involved crashes, Tulane Avenue study area, 2010-2016

Pedestrian and bicycle-involved crashes are distributed throughout the corridor, with clusters at the major intersections of Jefferson Davis Parkway and S. Broad St. (Figure 9).

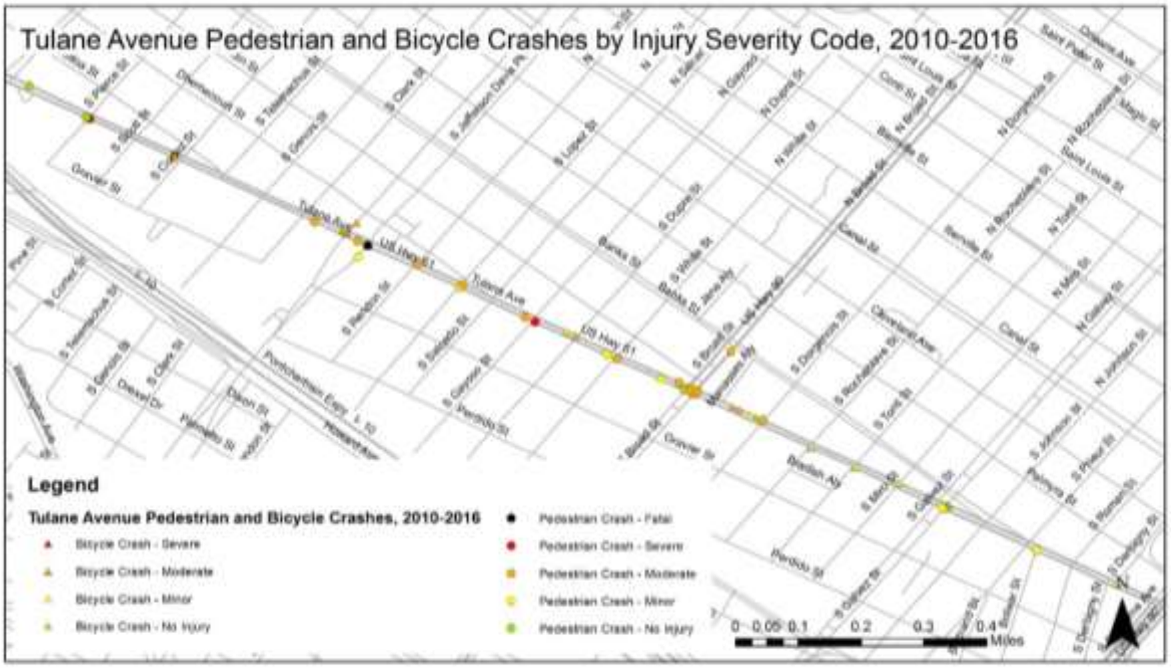

Figure 9
Tulane Avenue pedestrian and bicycle crashes by injury severity code, 2010-2016

During the five-year period prior to the beginning of reconstruction, there were an average of 172 crashes per year in this 1.8-mile road segment (all modes), of which an average of 2 per year resulted in fatal or serious injuries, and including an average 2.6 bicycle-involved crashes and 5.4 pedestrian crashes per year.

Because all crash data available are from the period prior to roadway redesign, it is not possible at this time to evaluate how the reconfiguration of this roadway has impacted user safety outcomes. However, short term manual count data collected at this location since 2013 indicates an observed 34% increase in bicycle activity on this corridor (as well as a 39% decrease in pedestrian activity) between 2013 and 2017. This case study provides valuable (albeit not pre-intervention) data from which to continue to measure changes in observed active user trends, so as to have a basis from which to analyze any future changes in crash statistics for all modes. Future research may endeavor to extrapolate the manual count data, given the hourly usage patterns demonstrated during this data collection effort. In addition, this case study demonstrates the need to develop permanent count stations (and corresponding expansion factors) for additional facility contexts, in this case an urban commercial arterial with mixed/utilitarian usage patterns.

Esplanade Avenue

Esplanade Avenue, also in New Orleans, defined for the purposes of this study as the segment between N. Carrollton Avenue/Wisner Blvd and N. Claiborne Avenue, is a local street which was converted in 2013 from a four-lane divided roadway to a two-lane divided roadway with dedicated bicycle lanes in each direction. Land uses along this corridor are a mix of residential and small commercial, with pockets of neighborhood commercial uses and both public and private schools. No recent motor vehicle AADT estimates exist directly within this segment, however, a count conducted by New Orleans Regional Planning Commission in 2016 a few blocks from the study area terminus at N. Villere indicates approximately 13,000 vehicles per day.

Count Data. The count equipment was installed on Esplanade Avenue (approximately 2914 Esplanade Avenue, between N. Gayoso St. and N. Dupre St., Figures 10 and 11) on August 18, 2017, and was removed on September 27, 2017. This segment of the corridor features sidewalks, a parking lane, a six-ft. dedicated bike lane, and a motor vehicle travel lane in each direction. One of the sensor units was discovered to be functioning improperly due to a damaged tube for the first 20 days of installation, necessitating the extension of data collection. For the purposes of this data analysis, all available data was used in the assessment of hourly and day of week trends and used to facilitate imputation of missing data as needed. Generally, data reported reflect pedestrian data from August 19 through September 26, while bicycle data reflects data collected in September only.

Figure 10
Esplanade Avenue count equipment configuration, inbound

Figure 11
Esplanade Avenue count equipment configuration, outbound

In total, an average of 264 pedestrians and 467 bicyclists were recorded per day (including imputed values for one pneumatic tube unit for 7 days, for the other unit for 2 days, and both units for two additional days), with a high of 372 pedestrians on September 1 and a low of 182 pedestrians on August 29, and a high of 635 bicycles on September 23 and low of 352 bicycles on September 20 (Figure 12).

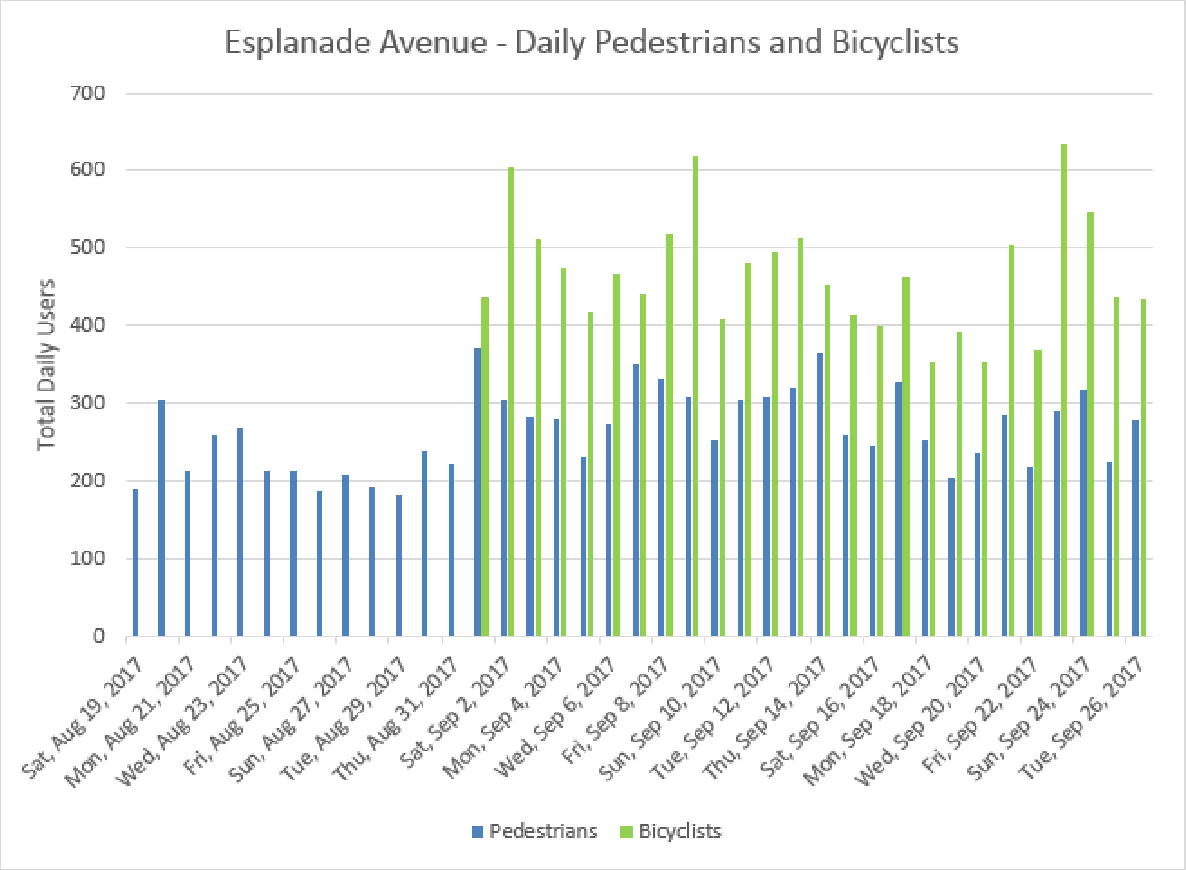

Figure 12
Esplanade Avenue recorded daily pedestrians and bicyclists

Weather recorded during the observation period was warm, with an average daily high of 87 degrees and an average low temperature of 73 degrees. A total of 1.09 in. of rain fell in New Orleans during this period, with precipitation reported on 5 days (Table 10).

Table 10
Daily user volumes and weather conditions, Esplanade Avenue

Date	Pedestrians	Bicyclists	High Temperature	Low Temperature	Precipitation (in.)
Sat, Aug 19, 2017	189		93	81	0
Sun, Aug 20, 2017	304		93	84	0
Mon, Aug 21, 2017	213		91	78	0
Tue, Aug 22, 2017	260		90	78	0
Wed, Aug 23, 2017	269		90	79	0
Thu, Aug 24, 2017	212		89	78	0
Fri, Aug 25, 2017	213		90	78	0
Sat, Aug 26, 2017	187		91	81	0
Sun, Aug 27, 2017	208		86	73	0.04
Mon, Aug 28, 2017	191		82	74	0.17
Tue, Aug 29, 2017	182		80	75	0.8
Wed, Aug 30, 2017	239		87	79	0.03
Thu, Aug 31, 2017	222		88	77	0.05
Fri, Sep 1, 2017	372	*435*	88	73	0
Sat, Sep 2, 2017	303	*603*	87	77	0
Sun, Sep 3, 2017	283	*511*	88	82	0
Mon, Sep 4, 2017	279	*474*			
Tue, Sep 5, 2017	232	*417*	89	75	0
Wed, Sep 6, 2017	274	*468*	80	66	0
Thu, Sep 7, 2017	349	*442*	81	63	0
Fri, Sep 8, 2017	331	519	82	64	0
Sat, Sep 9, 2017	309	618	84	70	0
Sun, Sep 10, 2017	252	409	82	73	0
Mon, Sep 11, 2017	303	480	82	66	0
Tue, Sep 12, 2017	309	*494*	82	62	0
Wed, Sep 13, 2017	320	*513*	82	63	0
Thu, Sep 14, 2017	365	452	86	63	0
Fri, Sep 15, 2017	260	412	89	73	0
Sat, Sep 16, 2017	246	399	87	79	0
Sun, Sep 17, 2017	327	463	89	82	0
Mon, Sep 18, 2017	252	353	90	72	0
Tue, Sep 19, 2017	204	393	90	73	0
Wed, Sep 20, 2017	236	352	89	73	0
Thu, Sep 21, 2017	285	505	90	72	0
Fri, Sep 22, 2017	217	369	89	71	0
Sat, Sep 23, 2017	289	635	88	79	0
Sun, Sep 24, 2017	317	545	88	79	0
Mon, Sep 25, 2017	225	*436*	84	71	0
Tue, Sep 26, 2017	278	*435*	88	71	0

**includes partially imputed data*

In order to impute missing hourly and daily values and determine goodness of fit with the Jefferson Davis Trail long-term dataset with a full month of data, the data was evaluated by daily usage patterns. The data indicate that as a percentage of the daily total, bicycle and pedestrian traffic are similar to established patterns at the Jeff Davis Trail dataset, with mild AM or moderate PM commute peak periods, with a general rising trend throughout the afternoon for bicyclists and a mid-day lull for pedestrians (Figure 13). Note that data are visualized as a percent of each mode's total for comparison purposes, although as Table 10 indicates above, there is generally more bicycle activity at this location than pedestrian activity.

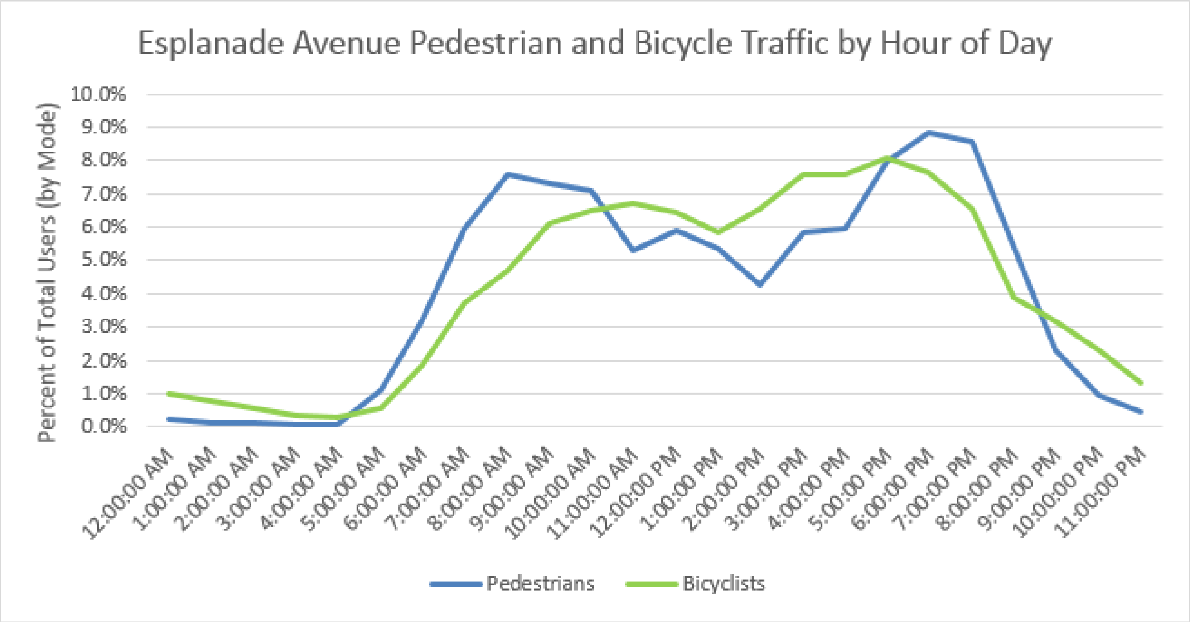

Figure 13
Esplanade Avenue pedestrian and bicycle traffic by hour of day

Next, the data were broken down by day of the week and averages for each day of the week developed (for the purposes of expansion for AADT estimates, the dataset was limited to days in September). Similar to the Jeff Davis Trail dataset, activity is relatively steady across both weekdays and weekends, with a moderate increase in activity on Saturdays (Figure 14).

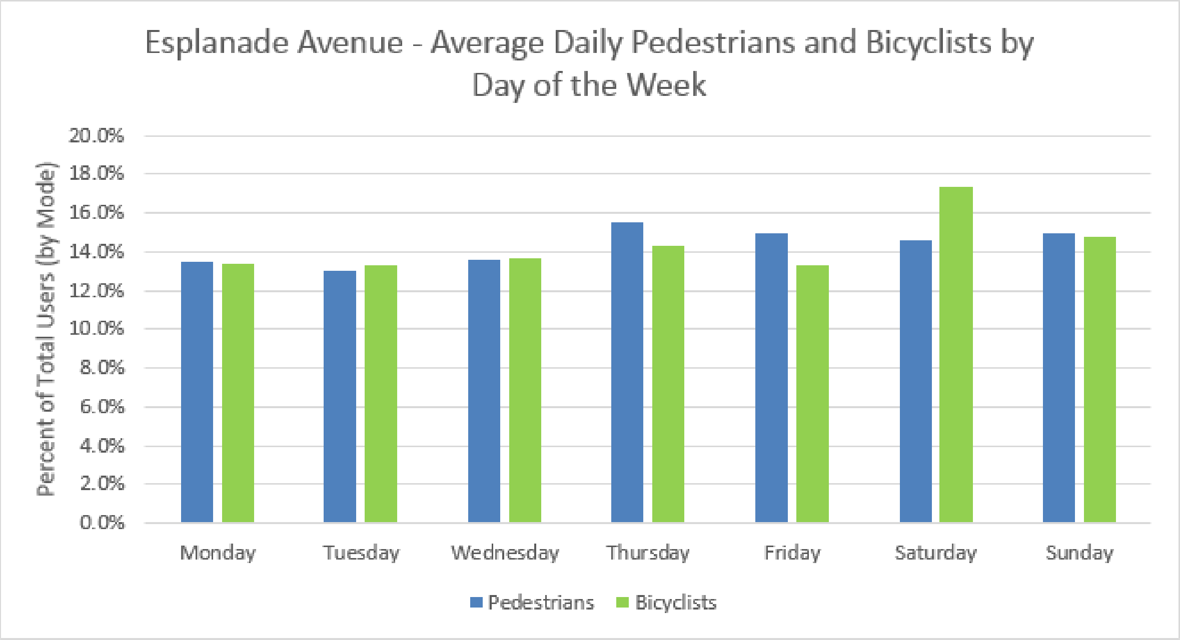

Figure 14
Esplanade Avenue average daily pedestrians and bicyclists by day of the week

In order to correct for sensor and context errors, four hours of manual validation data were collected and evaluated at the 15-minute increment level (the smallest increment in which the data can be retrieved) to determine the degree to which the sensors are accurately reflecting activity in the right-of-way. Table 11 summarizes the findings for each unit and mode.

All sensors were found to be operating within an acceptable range of net error (with nearly all undercounts likely due to occlusion), and there were no context-related systemic issues for pedestrians (all pedestrians were observed utilizing the sidewalk within the sensor’s range, and no bicyclists were observed riding on the sidewalk). However, it was observed that at this location, several bicyclists appeared to deliberately avoid the tubes, shifting into the motor vehicle lane as they approached the installation site. This behavioral error decreased the overall effectiveness of the count method. From this validation count, correction factors were derived, based on the net counter effectiveness to adjust for systemic undercounts for both modes.

Table 11
Manual validation summary findings and correction factors - Esplanade Avenue

	Pedestrians			**Bicyclists**		
	Total	Unit 1	Unit 2	Total	Unit 1	Unit 2
Sensor Net Accuracy	91.5%	92.9%	88.2%	97.5%	96.8%	98.3%
Overall Sensor Accuracy - In Situ	91.5%	92.9%	88.2%	92.9%	92.4%	93.4%
Net Counter Effectiveness	91.5%	92.9%	88.2%	92.9%	92.4%	93.4%
Correction Factor	**1.09**	**1.08**	**1.13**	**1.08**	**1.08**	**1.07**

From the daily and hourly usage patterns, as well as land-use context and geographic location in the Mid-City neighborhood, this count location appears to be a more suitable candidate for extrapolating short-duration counts to derive an estimated average annual daily traffic (AADT) figure from the Jeff Davis Trail dataset. Table 12 applies both correction and seasonal expansion factors to estimate average monthly, annual, and daily traffic totals.

For comparison, existing estimates from the Pedestrian and Bicycle Resource Initiative's 2017 Greater New Orleans Pedestrian and Bicycle Count Report, which derive estimated annual average daily traffic totals based on National Pedestrian and Documentation Project methodology for expanding short-duration manual counts (collected one block away from the monitoring site, and notably near a business use with robust pedestrian activity, which likely explains the discrepancy in apparent volumes as commercial uses are a key driver in pedestrian activity), are also included.

Table 12

Esplanade Avenue - seasonal adjustment and estimated AADT

SEASONAL ADJUSTMENT - SEPTEMBER		
	Pedestrians	Bicyclists
Total - September (uncorrected)	8,571	14,039
Average Daily - September (uncorrected)	286	468
CORRECTION FACTOR		
Overall Net Accuracy	91.5%	92.9
Site-Specific Correction Factor	**1.09**	**1.08**
Total September (Corrected	9,365	15,162
Average Daily - September (corrected)	312	505
EXPANSION FACTOR		
Estimated % Traffic in September	7.46%	8.45%
Seasonal Adjustment Factor	***1.12***	***0.99***
Estimated Average Monthly Traffic	10,455	14,949
Estimated Annual Total Traffic	125,455	179,391
Estimated Annual Average Daily Traffic	**344**	**491**
PBRI EDT, 2017	*845*	*607*

Crash Data. Crash data provided by DOTD were also compiled for the study area (defined here as the segment of the corridor that underwent redesign from 2010-2016, bounded by N. Carrollton Avenue and N. Claiborne Avenue, but excluding crashes occurring within those intersections, see “Methodology” section for detail).

A total of seven years of crash data were reviewed, three of which were collected prior to the roadway reconstruction project, and three of which following completion of the road diet that resulted in the addition of a dedicated bikeway, as well as the installation of curb ramps and crosswalks within the corridor. The data indicate a trend of at least one (and as many as nine) pedestrian and bicycle crashes each year, two of which were fatal or severe (Table 13).

Table 13
Esplanade Avenue summary crash statistics, 2010-2016

Esplanade Avenue Crash Statistics, 2010-2016							
	2010	**2011**	**2012**	**2013***	**2014**	**2015**	**2016**
Total Crashes	**82**	**85**	**95**	**85**	**83**	**81**	**110**
Pedestrian-Involved Crashes	1	2	2	2	2	2	2
Bicyclist-Involved Crashes	1	2	3	6	4	4	9
Fatal Injury Crashes	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Peds	0	0	0	0	0	0	0
Bikes	0	0	0	0	0	0	0
Severe Injury Crashes	**0**	**1**	**0**	**0**	**1**	**0**	**2**
Peds	0	0	0	0	0	0	0
Bikes	0	0	0	0	0	0	2
Moderate Injury Crashes	**7**	**4**	**12**	**9**	**10**	**9**	**14**
Peds	0	0	1	0	1	1	1
Bikes	0	2	1	2	1	1	3
Minor Injury Crashes	**25**	**14**	**12**	**19**	**13**	**22**	**29**
Peds	1	1	1	2	0	1	1
Bikes	1	0	1	4	2	2	3
No Injury Crashes	**50**	**66**	**71**	**57**	**59**	**50**	**65**
Peds	0	1	0	0	1	0	0
Bikes	0	0	1	0	1	1	1
** Under Construction*							

Despite the lack of serious injuries or fatalities along this corridor during the study period, this corridor has been routinely identified as a high-frequency crash corridor for bicyclists, although the bulk of these crashes occurred in the portion of the corridor unaffected by the road diet project, from N. Claiborne Avenue to N. Peters Street *[71]*. Overall, crashes in the corridor appear to have held relatively steady from 2010 to 2015, and then spiked notably in 2016 (Figure 15).

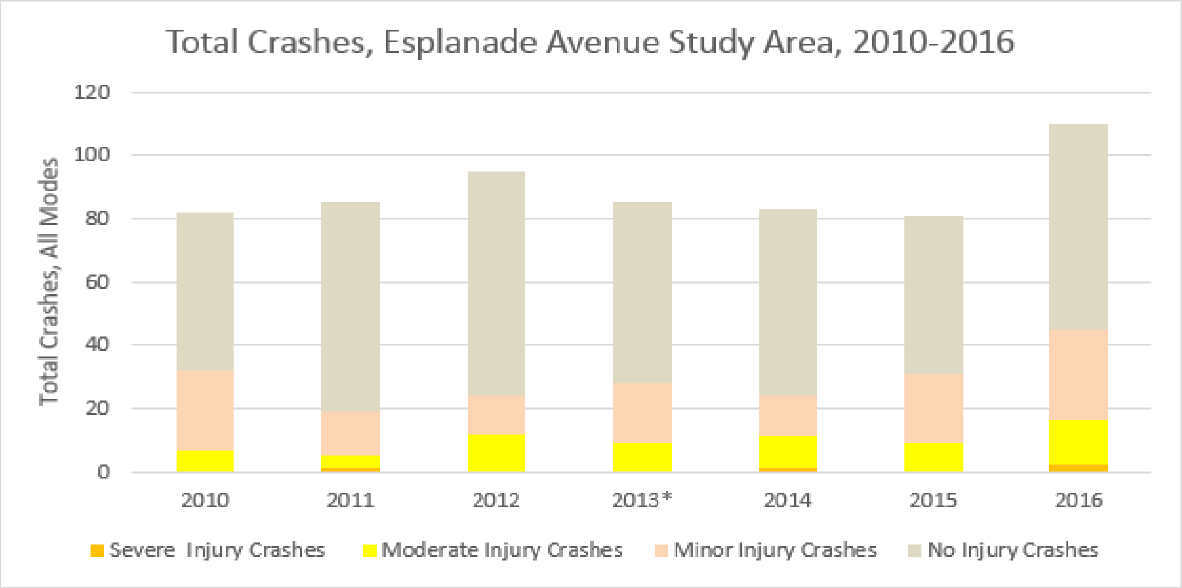

Figure 15
Total crashes, Esplanade Avenue study area, 2010-2016

Moreover, if the crash data is broken down into three year bins reflecting pre- and post-intervention intervals, it would appear that while pedestrian-involved crashes have held approximately steady (20% increase), bicycle crashes have nearly tripled (183% increase) compared to pre-intervention conditions (Figure 16). Figure 17 indicates the approximate locations of all pedestrian and bicycle crashes within the study area from 2010 to 2016.

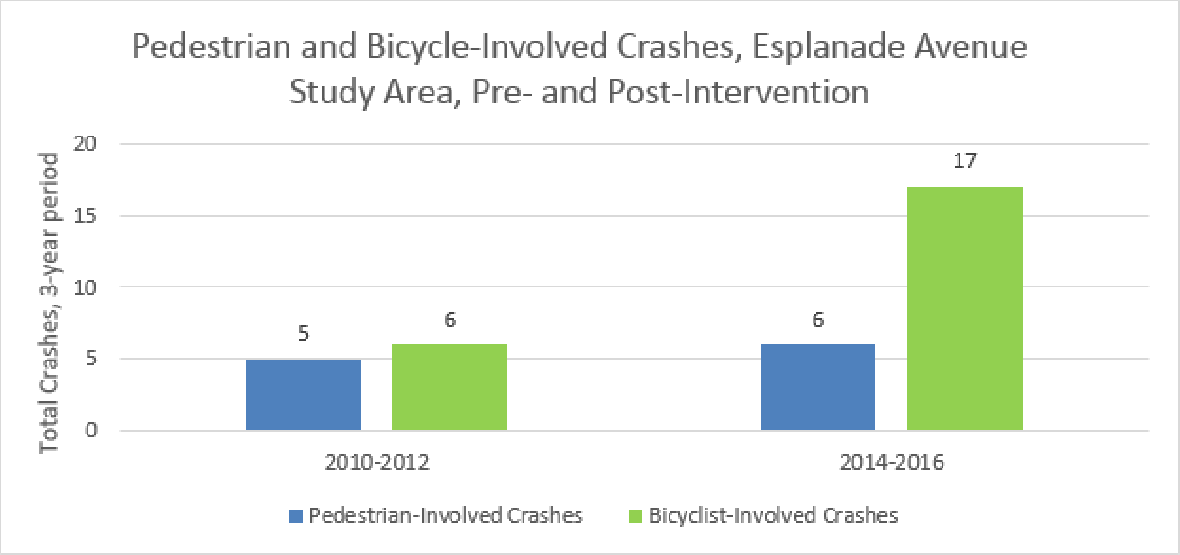

Figure 16
Pedestrian and bicycle-involved crashes, Esplanade Avenue study area, pre- and post-intervention

This apparent spike illustrates the critical need for improved metrics for measuring exposure to risk. It is imperative to note that many factors impact the number of crashes recorded in the database, including but not limited to the percentage of crashes which are not reported to police in the first place, and increasing or decreasing motor vehicle volumes (for which relevant data is not available), as well as changes in active transportation demand. In addition, the total number of crashes represented in this data set are too small to facilitate statistical analysis through regression to establish whether the change is significant.

However, existing PBRI data indicates that indeed, bicycling and walking have risen markedly since data collection on the corridor began in 2010: a 123% increase in pedestrian activity between 2010 and 2017, and a 250% increase in bicycle activity. Moreover, in 2015 (prior to the completion of the Lafitte Greenway, a shared-use path which runs parallel to Esplanade Avenue), an even higher number of bicyclists were observed by PBRI, and a 346% increase compared to 2010 volumes was reported. As described elsewhere in this document, short-duration manual counts are subject to volatility due to many variables, but in either case, it is clear that the volume of bicyclists has risen considerably during this period. Based on the PBRI manual count data, it is likely that safety outcomes have actually improved relative to the number of active users traveling within the study area, however, additional data (more years of pre- and post-intervention data to determine whether the 2016 total was anomalous or indicative of an upward trend, as well as additional analysis to attempt to expand the manual counts into AADT estimates) is necessary before conclusions may be confidently drawn.

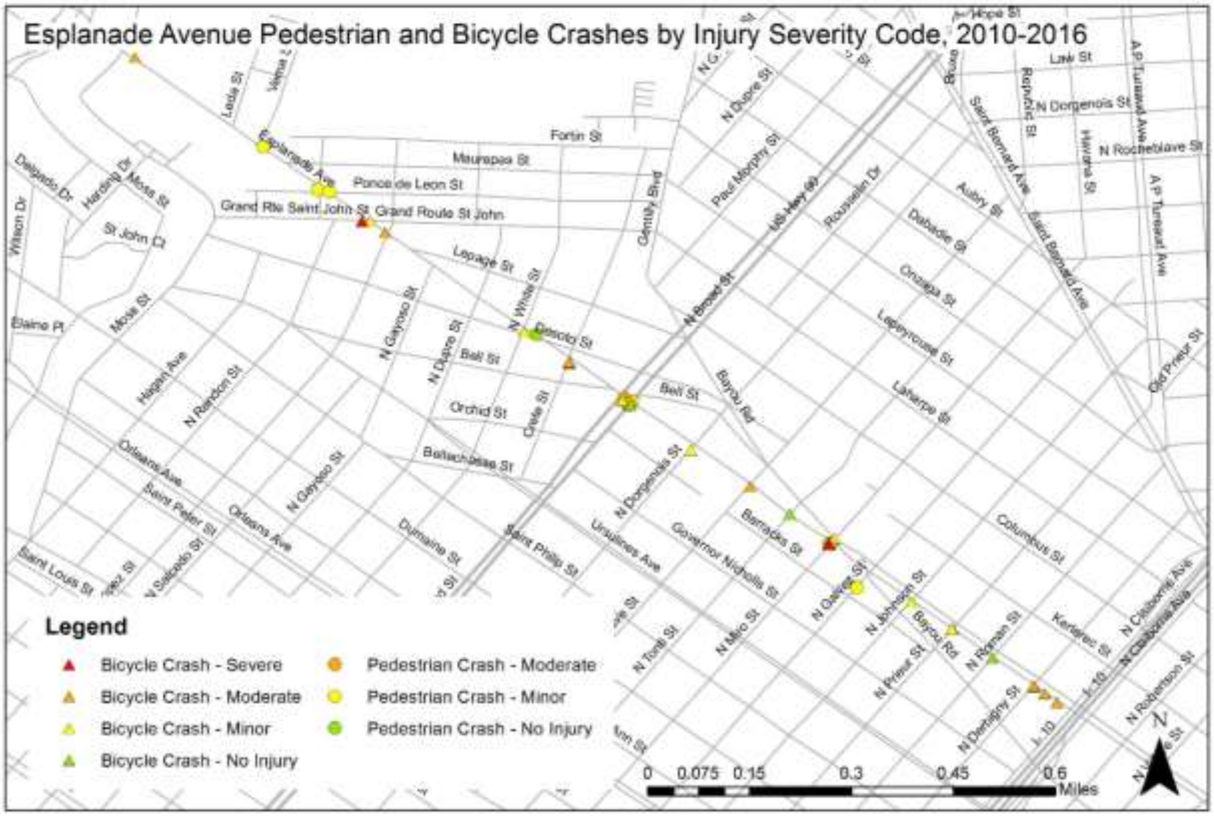

Figure 17
Esplanade Avenue pedestrian and bicycle crashes by injury severity code, 2010-2016

Government Street

Government Street in Baton Rouge, defined for the purposes of this study as the 3.8-mile segment between Eddie Robinson Drive and Lobdell Avenue, is a four-lane state-owned roadway (LA 73) which is slated for reconstruction and reconfiguration (construction is currently underway) to include the addition of dedicated bicycle lanes in each direction along selected portions of the corridor. Land uses along this corridor mixed, with stretches of primarily residential uses and clusters of neighborhood commercial and automobile-oriented commercial uses and two schools. DOTD traffic counts estimated an Average Annual Daily Traffic (AADT) of 15,435 as of 2014 at the count location nearest the data collection point at S. Eugene Street.

Count Data. The count equipment was installed on Government Street in Baton Rouge (approximately 2337 Government St, between Drehr Avenue and Evergreen Drive, Figure 18) on October 4, 2017, and removed on November 8, 2017. This segment of the corridor features sidewalks and two travel lanes in each direction, with no dedicated bikeway. Given the nature of this street section, pavement material, and the high volumes and speeds of mixed traffic (including truck and bus traffic), it was necessary to extend the pneumatic tubes all the way to the centerline of the roadway in each direction, and to secure the tubes using an alternate method to the manufacturer's recommendation (mastic tape, rather than pavement nails and loop fasteners, the latter being easier to remove and reinstall at multiple locations without damage, prolonging the life of the tubes). In addition, the tubes were installed at less than the recommended 15% tension, in order to provide greater resilience to the motor vehicle traffic. Initial checks to ensure that these alterations to installation protocol did not impact sensor reliability indicated that performance was not impacted.

Figure 18
Government Street count sensor configuration, inbound and outbound

Based on manual validation counts and visual inspection of the data for consistent patterns, all four sensors appeared to function normally until October 23, when one of the units, for reasons unknown, began to record dramatically higher bicycle counts that do not match observed conditions, prior trends, or align in magnitude with count data collected by CRPC on corridors more commonly used by bicyclists nearby. For the purposes of this data analysis, bicycle data after that point was excluded from this analysis, and no attempt to impute daily values was made at this location, although several imputations were made to correct pedestrian data for specific hours on six days when unusually high counts indicated error (typically caused by pedestrians loitering in the area and repeatedly triggering the sensor).

In total, an average of 91 pedestrians and 40 bicyclists were recorded per day, with a high of 173 pedestrians on October 31 and a low of 56 pedestrians on October 7, and a high of 98 bicycles on October 20 and low of 12 bicycles on October 8 (Figure 19).

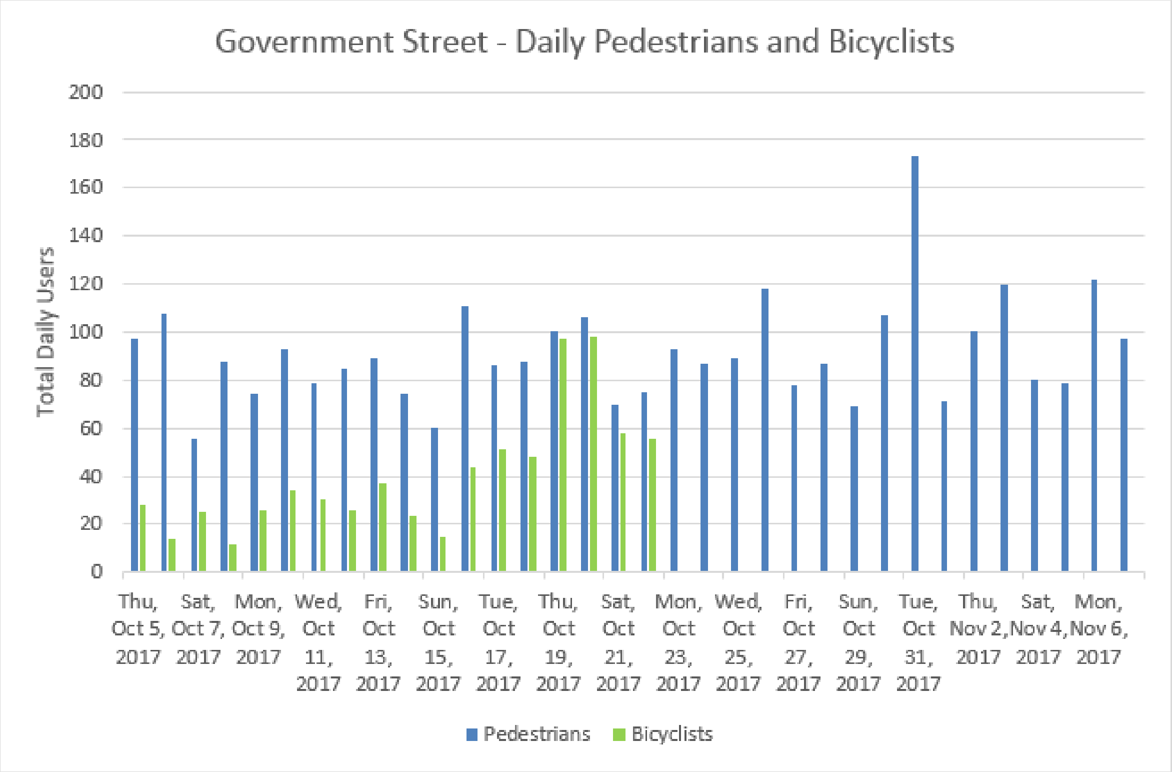

Figure 19
Government Street recorded daily pedestrians and bicyclists

Weather recorded during the observation period was highly variable, with an average daily high of 81 degrees and an average low temperature of 60 degrees (dipping as low as 36 degrees in late October). A total of 5.31 in. of rain fell in Baton Rouge during this period, with precipitation reported on 10 days (Table 14).

Table 14
Daily user volumes and weather conditions, Government Street

	Pedestrians	Bicyclists	High Temperature	Low Temperature	Precipitation (in.)
Thu, Oct 5, 2017	97	28	87	64	0
Fri, Oct 6, 2017	*108*	14	90	63	0
Sat, Oct 7, 2017	56	25	86	72	0.27
Sun, Oct 8, 2017	88	12	90	72	0
Mon, Oct 9, 2017	74	26	88	74	0.01
Tue, Oct 10, 2017	93	34	89	75	1.86
Wed, Oct 11, 2017	*79*	30	88	70	0
Thu, Oct 12, 2017	85	26	89	67	0
Fri, Oct 13, 2017	89	37	90	65	0
Sat, Oct 14, 2017	74	24	91	69	0
Sun, Oct 15, 2017	60	15	89	69	0.16
Mon, Oct 16, 2017	111	44	75	54	0.18
Tue, Oct 17, 2017	86	51	78	48	0
Wed, Oct 18, 2017	88	48	82	53	0
Thu, Oct 19, 2017	*101*	97	84	55	0
Fri, Oct 20, 2017	106	98	81	61	0
Sat, Oct 21, 2017	70	58	86	69	0.22
Sun, Oct 22, 2017	75	56	77	60	0.4
Mon, Oct 23, 2017	*93*		74	53	0
Tue, Oct 24, 2017	87		73	53	0
Wed, Oct 25, 2017	89		68	44	0
Thu, Oct 26, 2017	118		78	44	0
Fri, Oct 27, 2017	78		82	50	0.33
Sat, Oct 28, 2017	87		59	41	0.12
Sun, Oct 29, 2017	69		62	36	0
Mon, Oct 30, 2017	*107*		75	41	0
Tue, Oct 31, 2017	173		78	49	0
Wed, Nov 1, 2017	71		69	60	1.76
Thu, Nov 2, 2017	100		84	68	0
Fri, Nov 3, 2017	120		85	67	0
Sat, Nov 4, 2017	80		84	65	0
Sun, Nov 5, 2017	79		84	65	0
Mon, Nov 6, 2017	*122*		85	69	0
Tue, Nov 7, 2017	97		84	68	0

*includes partially imputed data

Next, the data was evaluated by daily usage patterns. The low absolute user volumes make it difficult to conclusively identify daily patterns, however, the data indicate that this corridor experiences greater bicycle traffic during morning commute hours, and greater pedestrian traffic in the afternoon and evening (Figure 20).

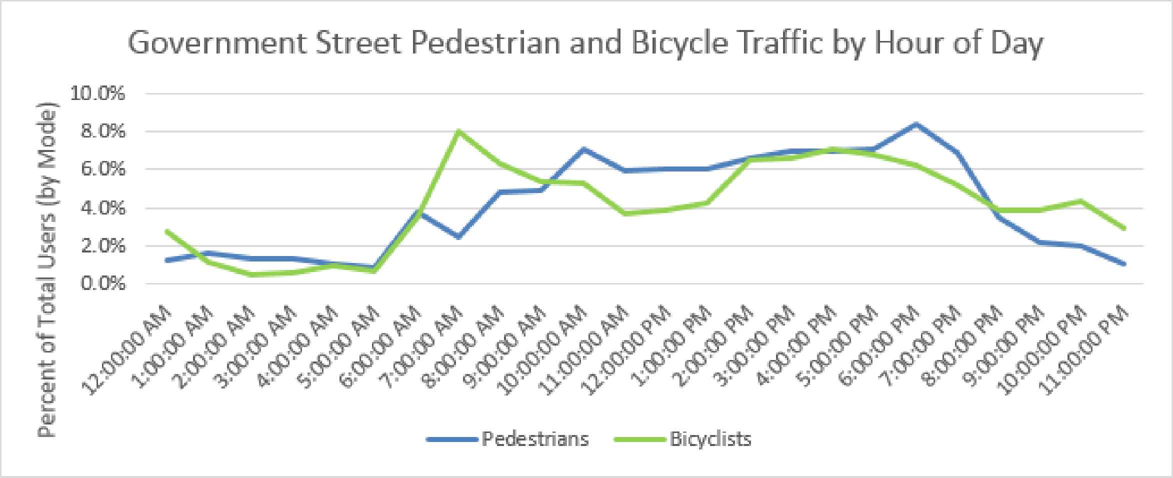

Figure 20
Government Street pedestrian and bicycle traffic by hour of day

Next, the data were broken down by day of the week and averages for each day of the week developed. Generally, user volumes were found to be proportionally higher on weekdays than weekends for both modes (Figure 21).

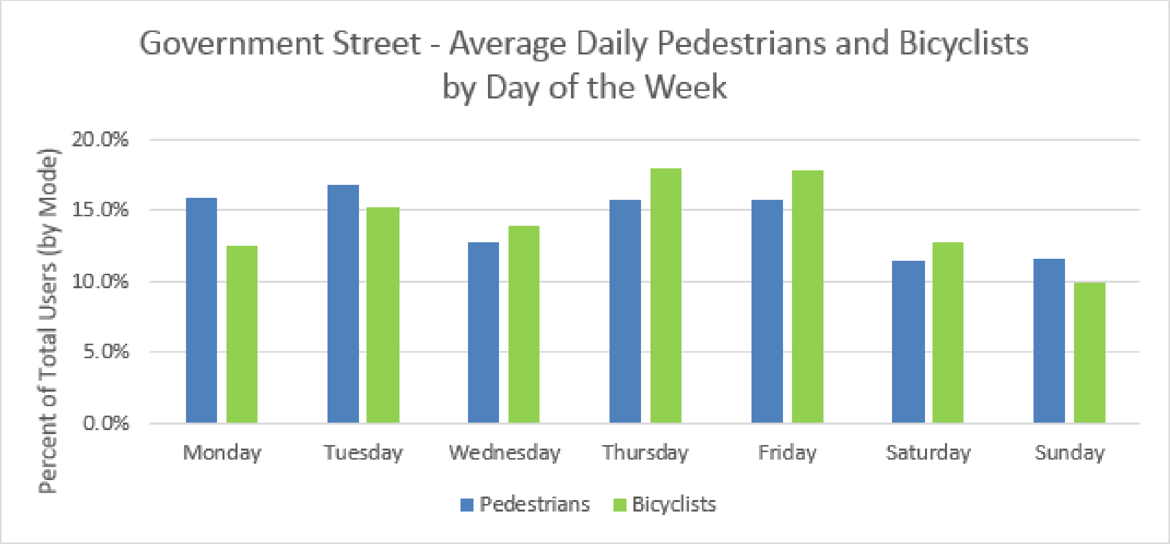

Figure 21
Government Street Pedestrian and Bicycle Traffic by Hour of Day

In order to correct for sensor and context errors, four hours of manual validation data were collected and evaluated at the 15-minute increment level (the smallest increment in which the data can be retrieved), and subsequently, an additional 15 hours of video data were evaluated at the 1-hour interval, to determine the degree to which the sensors are accurately reflecting activity in the right-of-way. Table 15 summarizes the findings for each unit and mode, and provides corrected average daily user estimates to reflect that there are likely slightly fewer pedestrians overall per day than recorded, and more than twice as many bicyclists.

Table 15
Manual validation summary findings and correction factors - Government Street

	Pedestrians			**Bicyclists**		
	Total	Unit 1	Unit 2	Total	Unit 1	Unit 2
Sensor Net Accuracy	102.9%	100.0%	106.5%	100.0%	100.0%	100.0%
Overall Sensor Accuracy - In Situ	82.4%	75.7%	90.3%	46.2%	43.8%	50.0%
Net Counter Effectiveness	102.9%	100.0%	106.5%	46.2%	43.8%	50.0%
Correction Factor	**0.97**	**1.00**	**0.94**	**2.17**	**2.29**	**2.00**
Average Daily Users - Corrected	*88*			*87*		

As anticipated, accuracy was significantly impacted by the tendency of bicyclists to ride on the sidewalk, rather than on the roadway, reflecting that the high traffic volumes and speeds and lack of dedicated space on the corridor discourage bicycle activity. As a result, a net overcount of pedestrians is reflected, with misclassified bicyclists surpassing the number of occlusion errors. Meanwhile, although during the manual validation the tube sensors were found to be highly accurate in counting bicyclists observed (albeit with a very small sample size of only 12 roadway cyclists), more than half of all bicyclists observed were traveling on the sidewalk, seriously restricting the overall efficacy of this method of data collection for this context. Correction factors are derived based on these findings, although caution should be used in their application given the limited validation sample size and other uncertainties associated with this data.

Given these constraints, and the lack of any available long-term count data from which to derive appropriate seasonal adjustment factors, it is not appropriate to apply any additional expansion factors to these data, however, it is hoped they will provide a useful baseline for future comparison following the completion of the road diet project. In addition to future re-installation of the available configuration of count equipment, future analysis employing emergent count methods (e.g., automated video counting) is recommended to more accurately capture current usage patterns and user behaviors in this corridor, and those similar to it.

Crash Data. Crash data provided by DOTD were also compiled for the study area (including data from 2012-2016 and defined here as the segment of the corridor that is undergoing redesign bounded by Eddie Robinson Drive and Lobdell Avenue, but excluding crashes occurring within those intersections, see “Methodology” section for detail).

A total of five years of crash data were reviewed. Government Street is notable for its high total number of crash incidents (which, in part, motivated the current plan to reconfigure the right-of-way to include, in addition to bicycle facilities, a dedicated left turn lane for most of the study area’s length). The data indicate that a total of 15 pedestrian and 11 bicycle crashes have occurred along or crossing this corridor within the study area, none of which were fatal, but including two severe-injury crashes involving pedestrians. (Table 16, Figures 22-24).

Table 16
Government Street Summary Crash Statistics, 2012-2016

Government St Crash Statistics, 2012-2016					
	2012	**2013**	**2014**	**2015**	**2016**
Total Crashes	**405**	**397**	**367**	**406**	**457**
Pedestrian-Involved Crashes	2	5	3	2	3
Bicyclist-Involved Crashes	2	0	5	1	3
Severe Injury Crashes	**2**	**1**	**0**	**3**	**0**
Peds	0	1	0	1	0
Bikes	0	0	0	0	0
Moderate Injury Crashes	**11**	**10**	**15**	**15**	**22**
Peds	0	2	2	0	3
Bikes	0	0	1	0	0
Minor Injury Crashes	**76**	**68**	**70**	**66**	**86**
Peds	1	2	0	1	0
Bikes	1	0	2	0	3
No Injury Crashes	**316**	**318**	**282**	**322**	**349**
Peds	1	0	1	0	0
Bikes	1	0	2	1	0
**no fatalities during this study period*					

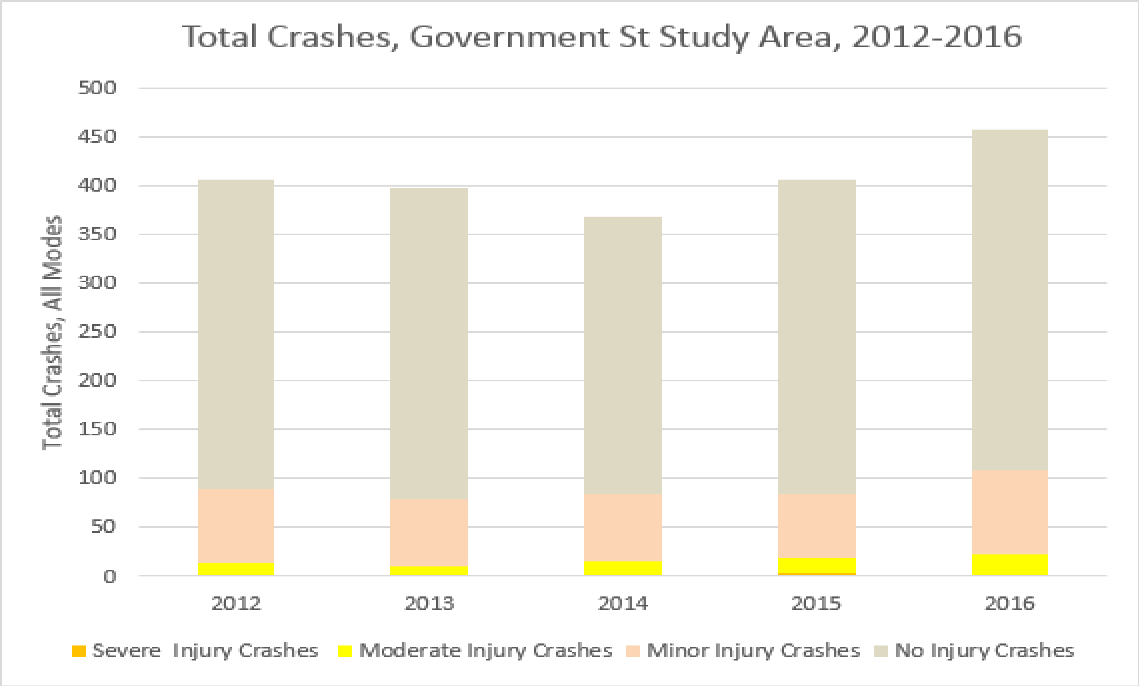

Figure 22
Total crashes, Government Street study area, 2012-2016

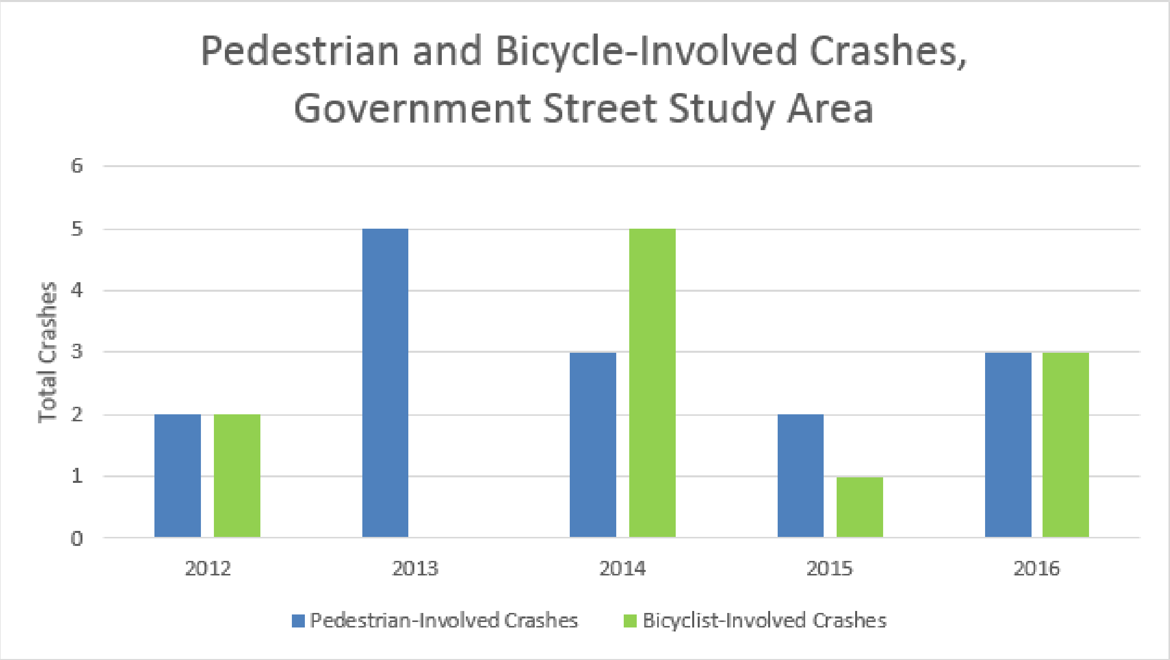

Figure 23
Pedestrian and bicycle-involved crashes, Government Street study area

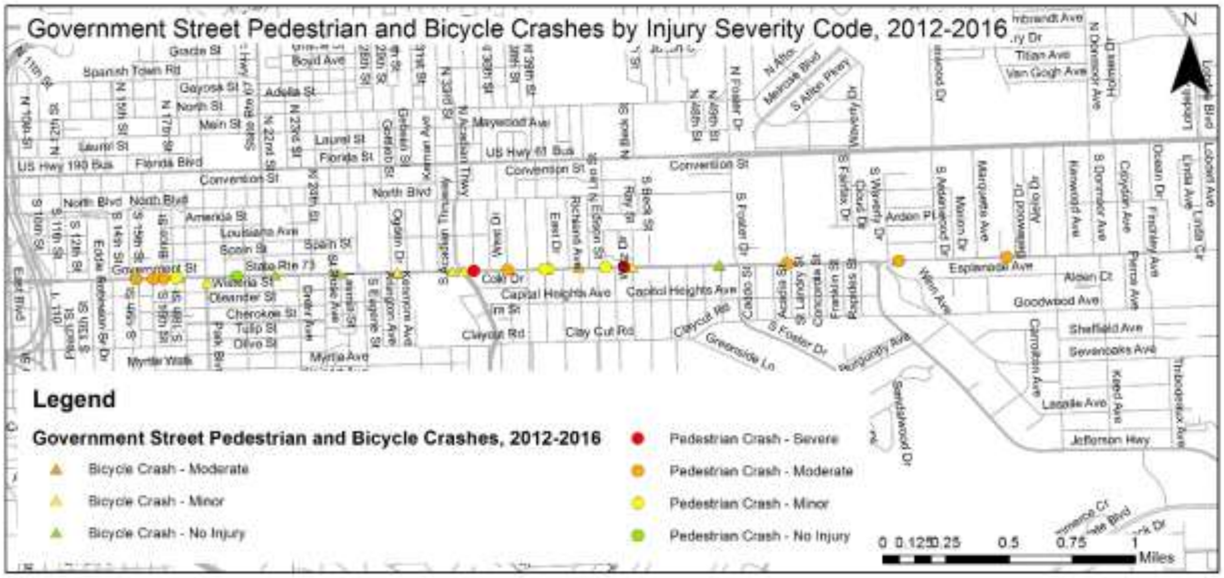

Figure 24
Government Street Pedestrian and Bicycle Crashes by Injury Severity Code, 2012-2016

As illustrated by the Esplanade Avenue case study, it is critical to contextualize changes in crash totals following an intervention which is directly or indirectly intended to result in increased volumes of pedestrians and bicyclists. In the case of Government Street, relatively few active users appear to traverse the corridor on foot or by bicycle, and yet, crashes intermittently result. Understanding how active transportation demand changes following this intervention will help prevent misinterpretation of any potential increase in raw crash frequency, if it should occur, in the years to come.

Data Applications: Safety Analysis

A key objective of this study is to advance efforts to evaluate the impact of complete streets-oriented infrastructure interventions on safety outcomes. As new pedestrian and bicycle infrastructure has been developed, observation (as well as seven years of data from the New Orleans area) suggests that the volume of people walking and bicycling on Louisiana roadways has increased substantially in some areas. Meanwhile, the number of pedestrian and bicycle crashes has also increased, and the state frequently ranks among the top ten worst for pedestrian and bicycle fatality rates. Utilizing pedestrian and bicycle count data to estimate exposure and risk for nonmotorized users, normalize crash rates, and track progress toward improved safety is foundational aim of this research.

At present, there is no clear state or federal guidance for how to evaluate pedestrian and bicyclist exposure and therefore efforts to evaluate progress toward safety goals are often limited. An FHWA-funded study aimed at filling this gap is currently underway (Federal Grant #DFTH6116D00004, TTI Task Order #2). The components included here represent a preliminary foundation and identification of anticipated data needs for future evaluation incorporating the findings and recommendations of that study, based on the existing literature, and identify best practices for integrating nonmotorized count data into safety analysis and policy implementation and benchmarking. To the limited extent that it is presently available, count data may be used to pilot improvements to analytic methodologies employed. As the body of count data (particularly, year-round continuous counts) expands, Louisiana's ability to comprehensively evaluate exposure and quantify safety impacts will be correspondingly improved.

In order to evaluate the safety impacts of an intervention, it is essential to isolate the effects of that intervention, accounting for any other treatments or enforcement activities, changes in all modes of traffic volume, or other underlying trends through regression analysis.

Two basic study designs may be employed, depending on the nature of the intervention, the availability of data (especially before and after volume data, but also detailed facility data, and crash data):

- *Before and After studies* - note that these may not account for some biases unless a reference or comparison group is utilized, and if crash frequency is low, statistical significance may be difficult or impossible to evaluate

- *Cross sectional studies* - requires a relatively similar group of locations, some of which received an intervention and some that did not. This is the preferred method when lacking sufficient volume and crash data.

An important limitation for pedestrian and bicycle safety evaluation is that in order to get statistically significant sample sizes, many years of data may be needed. Typically, three years of data are considered sufficient to perform safety analyses for motor vehicles along a given road segment. For pedestrians and bicycles, that evaluation period may yield insufficient data due to relatively low crash frequency. As the case study summaries above imply, it is difficult to conduct "before and after" evaluations if you do not have methodologically comparable data from both before—and after—the intervention. On the other hand, in the interest of timeliness, it is also not desirable to wait three or more years following project completion to begin analysis.

Aggregating data from multiple locations (i.e., cross-sectional studies) can mitigate this difficulty, while also contributing to the body of research from which Crash Modification

Factors (CMFs) may be derived. CMFs are typically used to estimate the number of crashes prevented by a given intervention. However, there are still relatively few CMFs specific to pedestrian and bicycle treatments. Resources for CMFs include PEDSAFE, BIKESAFE, the Highway Safety Manual, the CMF Clearinghouse, and various NCHRP reports.

However, even in lieu of a broad set of analysis locations and/or many years of comparable data, there is still considerable value in conducting data collection and evaluation activities as a routine component of project delivery. Even if robust statistical analysis is not possible (at least for now), collection of the following data points provides the ability to, at a minimum, describe apparent trends, identify potential areas of concern, and apply lessons learned to the planning, prioritization, and implementation of future projects:

- A minimum of one week of high-quality (i.e., error free or minimal error) continuous count data (preferably two weeks, during spring or fall, and absent extreme weather conditions) from a reasonably representative location within the study corridor, corrected for systemic error
- Relevant 365-day count data from a comparable location (i.e., in the same region and factor group), from which to extrapolate counts and derive AADT
- Post-intervention count data of similar duration and quality. If no relevant permanent count data is available, post-intervention counts should be conducted during the same time of the year, to facilitate direct comparison/minimize impacts of external variables
- Updated motor vehicle AADT estimates for the same segment, both before and after the intervention (preferably, conducted in coordination with bike/ped counts)
- Crash data for all modes for a minimum of three years prior to the intervention, as well as any crash data available post-intervention
- Documentation of any major changes in land use, corridor operations (e.g., changes to signalization, red light photo enforcement), area population, or other factors which may impact user volumes or safety outcomes

Data Applications: Cost-Benefit Analysis

Active transportation investments can result in benefits for safety, as discussed above, overall mobility of a community, congestion reduction, improved public health, economic revitalization, and more *[72]*. Evaluating the benefits of these investments relative to their costs improves our ability to prioritize projects and maximize positive impacts *[73, 74]*. Generally, cost-benefit analysis tends to be of greatest utility when measuring the potential performance of a project relative to the status quo prior to implementation, rather than retroactively or after preferred alternatives have been selected, as in the case study examples available to this project *[75]*. Thus, this section describes methods identified in the literature and outlines a proposed process for analysis, but does not attempt to fully calculate the return on investment of these specific facilities.

Holistically evaluating the full impacts of a proposed decision allows for identification of the most effective use for limited funds, however, ascribing monetary value to the impacts resulting from active transportation investment is challenging; variables may be difficult to isolate, difficult to quantify, and impacts may be distributed over time at different scales. Although there is not a consistent CBA framework to understand the merits of active transportation projects, researchers have developed roughly similar approaches to address these challenges, building from standard methods for evaluating potential motor vehicle investments and attempting to address the limitations of such approaches for active transportation applications *[75 - 78]*.

Costs associated with active transportation investment include initial installation and materials costs, maintenance costs, and operational costs (where applicable, e.g., the costs of signal operation). In some cases, such costs are easily identifiable. However, when active transportation improvements are integral components in a larger project (as is quite frequently the case under a complete streets policy approach), it can be difficult to separate out the individual elements which constitute the active transportation investment. Costs pertaining to user travel time, corridor LOS, vehicle traffic impacts, equipment and fuel costs, and other individual or societal outcomes may also be considered *[77 - 79]*.

Benefits of active transportation projects, moreover, can be very difficult to translate into monetary values. Generally, these may be categorized as benefits to individuals resulting from improved active travel conditions (e.g., health, mobility, safety) and benefits to society resulting from increased active travel activity (environmental, economic, equity), as well as land use impacts. Methods to evaluate these benefits, where direct monetization is not achievable, include revealed or stated preference studies, contingent valuation surveys, conjoint analysis, and conjoint analysis *[76 - 78]*. Based on the current state of the practice, the following framework (Table 17) for cost-benefit analysis for active transportation investment in Louisiana is proposed. Additional details about the proposed method and referenced tools and calculations may be found in Appendix C-4.

Table 17

Cost-benefit analysis framework for active transportation investment

1: Description of the project	
What is the purpose/intended outcome of the project?	
Potential goals include but are not limited to: increased physical activity, crash/injury reduction, improved access to jobs, schools, recreation, etc.	
2: Define the reference case	**Method**
What outcomes are anticipated absent the proposed intervention?	Identify various types of existing facilities and their physical characteristics.
3: Define Scope of Analysis	
Including spatial locations, time horizon (years), population, demand, mode share rate, etc.	
Factor	***Estimation***
Time period	30-50 years
Demand	Cost-Demand-Benefit Analysis Tool *[76]*
Mode share rate	Stated preferences survey
Crash rate	Bureau of Transportation Statistics
Discount rate	Depends on the build year
4: Define alternative cases	**Methods**
Describe proposed investment and/or alternative scenarios	Alternative scenarios should account for and prioritize identified safety needs, equity considerations, etc. Include details about proposed facility attributes and cost components
5: List and monetize cost factors for each scenario	**Methods**
Construction cost Maintenance Operation and promotion User costs	See Appendix C-4 for model cost component breakdown tables and worksheets

1: Description of the project	
6. Naming and quantifying benefits	**Methods**
List positive effects of investment and scope of effects	Cost-Demand-Benefit Analysis Tool [76] or Revealed preferences survey or Annual mobility equation (Appendix C-4))
Accessibility	
Health	Annual health benefit formula (Appendix C-4) or Cost-Demand-Benefit Analysis Tool or $635 per capita for 2012, adjusted for inflation [74, 76]
Safety	HEAT online tool, VSL & average value of one injury from US DOT [77]
Equity	Stated preference survey or $0.35 per passenger mile [77]
Congestion reduction	Data from TTI including VOT and fuel cost or $.20 per urban-peak vehicle mile and $0.50 per mile for urban off-peak driving
Parking savings	$1-4 (average local fee)
6. Transfer all values to present value	**Methods**
The purpose of calculating PV is to make different alternatives comparable	With a riskless discount rate; defined based on implementation and terminal year
7. Determine NPV, BCR, NBCR, ROI	**Methods**
In order to rank alternative scenarios based on various economic performance methods	Using equations in Appendix C-4, Table 13
8. Sensitivity analysis	**Methods**
Play with some parameters to shed light on the significance of each independent variable under various optimistic and conservative assumptions	“What-if analysis” tool in CBA Example Spreadsheet (Appendix C-4)
9. Final decision making	**Methods**
Use CBA as a basis to make the best choice	Based on budget constraints and ranking of scenarios

Count data for active modes supports cost-benefit analysis for projects (planned, or completed) in multiple ways. First, as discussed above, count data may be used at the facility level to normalize crash totals, which is a key component of most cost-benefit analyses. Second, many CBA analyses rely on survey data to understand facility user perceptions and estimate behavioral change. Count data may be substituted to either directly quantify changes in use of a given facility (though, importantly, may not account for the difference between modal shifts and route choice substitutions, among other limitations), or, if sufficient multimodal data exists for a given facility type, community, and/or factor group, may be used to predict the impact of a proposed change on each impacted mode. Finally, many of the models used (including those reference and suggested in the framework above) rely on the development of an estimate of person-miles traveled. Count data is a key foundation for developing such estimates.

Data Applications: Data QA/QC and Management

Finally, quality assurance/quality control (QA/QC) is essential to any traffic monitoring activity. As discussed above, a variety of factors can impact the quality of data, and the existing procedures for QA/QC for motor vehicles cannot be directly transferred to nonmotorized datasets due to the lower average volumes and much greater variability of pedestrian and bicycle activity. Standard processes for eliminating data that is not with, for example, two standard deviations of the mean, would likely result in the deletion of many hours or days of accurate, perfectly valid activity reflecting local conditions on a given facility. The following basic steps should be conducted with nonmotorized count data:

1. Chart and visually inspect data
2. Determine criteria for assessing outliers
3. Utilize professional judgement and context knowledge/research to make decisions about which data to include and exclude from the dataset.
4. Document all editing decisions and retain a copy of the raw dataset

Data collected for the case study sites above have also been utilized as samples to demonstrate preliminary QA/QC checks (Appendix C-3), and stored in accordance with the recently developed TMAS template for nonmotorized count data. Importantly, as statewide count data expands, protocols should be refined and become more stringent as data availability from which to determine appropriate criteria for a range of situations expands, and be codified and disseminated to all agencies involved in monitoring activities.

CONCLUSIONS

First and foremost, there is no “one size fits all” approach to pedestrian and bicycle monitoring; local or agency needs, intended data uses, and resource constraints must all be considered in the design of a count program. Tradeoffs exist between accuracy and cost, and no single technology can be expected to meet all an agency’s needs.

However, the US Federal Highway Administration (FHWA) has clearly asserted support for walking and bicycling as part of an efficient and equitable transportation system and developed guidance to support nonmotorized data collection. Thus far, no state (or region) has fully implemented a bike/ped monitoring program of the scope described in the TMG, although most DOTs engaged in statewide monitoring (e.g., Colorado, Vermont, Minnesota, North Carolina) are tending to follow its guidance (modified to meet local needs and resource constraints). This guidance is largely modeled on motorized vehicle monitoring, including the development of a set of permanent automated monitoring sites on which context-specific adjustment factors for a larger, rotating array of short-term monitoring sites can be developed. The lack of this foundational data is a major inhibiting factor in advanced analysis of count data currently being collected in Louisiana, and represents perhaps the most important opportunity for DOT leadership to advance the state of the practice and facilitate project impact evaluation.

Although several promising new technologies are in development or available for (pilot) deployment, the most commonly utilized and well-developed technologies for automated counting of pedestrians and bicycles include:

- Infrared counters (permanent or temporary counts on sidewalks or multi-use trails/sidepaths; counts all users but does not differentiate modes)
- Pneumatic tubes (temporary bicycle or mixed auto/bicycle counts on dedicated bikeways or shared roadways)
- Inductive Loops (permanent bicycle or mixed auto/bicycle counts on dedicated bikeways or shared roadways)

The majority of robust count programs, operated at any level of government, tend to use EcoCounter brand products due to accessibility of data, remote data retrieval functionality, and robust performance record of this industry leader. For continuous/permanent count station development, these products appear to offer the best long-term value. For short-duration counting, this company’s products are generally not the least expensive, but have been designed to be user-friendly and durable, which has made them similarly popular. On the other hand, jurisdictions new to nonmotorized volume monitoring appear more likely to experiment with emerging products and less-tested vendors, particularly those who offer turn-key solutions and less up-front investment for a set quantity of data. Ultimately, technology and vendor selection must be made in accordance with individual agency resources and goals.

Regardless of the specific vendor selected, each of these technologies is an effective and versatile solution for specific types of counts and contexts, but each has limitations. For example, pneumatic tubes calibrated specifically for bicycles are a relatively inexpensive, easy-to-install solution for a variety of road configurations, but if motor vehicle traffic volumes (especially heavy vehicles) are high and bicycles travel in mixed or even dedicated, but not buffered or protected, bikeways, tubes will require frequent maintenance and replacement. Conversely, infrared sensors can be installed on any sidewalk and are an excellent, low-maintenance solution for gathering data about pedestrians and/or bicycles on trails or at “pinch-points” that funnel users past a particular location, but will struggle to accurately capture activity on wide, busy sidewalks where users travel side by side.

Finally, all three of these technologies are likely to be of limited efficiency if counts are desired at intersections or at locations where existing pedestrian and/or bicycle infrastructure is poor: in order to capture full, comprehensive mode share figures for a temporary count on Government Street, for example, four separate sets of pneumatic tubes plus two infrared sensors would be required. On most of Florida Boulevard, as another example, it would simply be impossible to adequately capture nonmotorized activity using these devices. For such scenarios and other, video-based count technologies offer the greatest promise for understanding demand for bicycling and walking—as well as a host of more nuanced behavioral data—in the places we need it most.

Off-the-shelf products to support video-based monitoring are limited, however, this is a rapidly developing field of study and much of the literature cites automated video counts as a potentially transformative technology due to its versatility (screenline or intersection counts; multiple user and facility types; ease of validation). Technologies in use and the state of the practice are evolving concurrently: new equipment should not be discounted simply because extensive validation has not been conducted or published (however, none of “emerging” technologies reviewed other than video processing appear to promise significant cost or data quality advantages except in specific, less common location contexts).

States with developed count programs tend to use multiple methods: automated and manual, permanent and short term, various vendors and technologies which evolve over time, and secondary supplemental data streams including survey data, GPS data (e.g., Strava), etc. to aid interpretation and application of count data. All automated count equipment has inherent error; adjusting for this error and validating data requires well-defined protocols and standards established by agency and routine maintenance. Tradeoffs exist between accuracy and cost, but good customer support from vendors and resistance to vandalism are key considerations for automated count equipment. If counts are conducted in remote locations or over wide geographic area, GSM data uploading is recommended.

Importantly, nonmotorized traffic is inherently more variable than motorized traffic and thus more data is required in order to make inferences or conduct statistical analyses of count and/or crash data. Unlike for motor vehicle monitoring, short-term automated counts, regardless of method, should be conducted for a minimum of 7 days (14 preferred) during periods of reasonably good weather (for Louisiana, fall and spring months are recommended) in order to account for greater inherent variability of nonmotorized users. Due to these sensitivities and needs, housing active transportation monitoring activities fully within motor vehicle monitoring programs is uncommon, although the resources and expertise of the latter should be leveraged in program implementation to the greatest extent possible.

As noted above, permanent or long-term count locations are invaluable for understanding how short-duration counts fit into overall annual trends for a given jurisdiction, climate, and/or built environment context. Adjusting short-duration data requires a minimum of one full year of clean data; multiple years of data will allow continual refinement of adjustment factors as well as a critical barometer of overall trends. Permanent count locations, which once calibrated should need infrequent maintenance, may be incorporated into motor vehicle monitoring programs more easily than short-duration counts.

Finally, there remains a key role for manual count collection, whether conducted by observers in the field or by remote viewing of video footage. Manual counts may follow a variety of methodologies, protocols, and parameters depending on the objective of the count: to calibrate or validate an automated sensor, to collect demographic or behavioral data not captured by sensors, to align with previously collected data, and more. The duration of a manual count will depend on both the objective and the context: generally, the less bicycle and/or pedestrian activity at the count location, the more hours of data will be needed to validate a sensor or to have a general sense of user volumes or patterns in the area. In such cases, video-assisted manual counts, which allow accelerated viewing, are likely to be the preferred solution.

Interjurisdictional outreach and partnerships are needed to sustain successful nonmotorized traffic monitoring: most infrastructure interventions, project evaluations, safety studies etc. will be conducted on local streets. State engagement in existing data collection efforts and development of guidance for future local/regional data collection can ensure compatible data sets and collaboration and efficient use of resources (e.g., shared portable count devices).

No set standard for data validation/quality assurance exists; agencies should define criteria and establish data management protocols and reporting standards. Data management protocols and software configurations currently in use for motor vehicle monitoring programs may serve as a model, but must be adapted (e.g., valid data may have greater acceptable range of deviation).

Finally, the case study evaluations highlight the need for routine multimodal data collection as part of complete streets project planning and delivery, particularly (but not exclusively) for major corridor projects where improved pedestrian/bicycle safety and access is an explicit goal. Evaluation of project outcomes, and forecasting of potential future project impacts, is severely constrained if adequate, compatible, and timely pre- and post-intervention data for a variety of sites is not available. Funding for data collection efforts can come from a variety of sources, and programs can be scaled to match resources available.

RECOMMENDATIONS

Recommendations for actions to be taken by DOTD to advance efforts to understand active transportation demand, track complete streets policy implementation, and evaluate safety impacts include:

- Initiate and fund the implementation of a preliminary set of permanent count locations in different geographic locations and on different facility types, at locations (to be determined in partnership with local agencies and stakeholders) generally thought to be representative of a particular "factor group," and begin collecting data.

- Review agency policies and funding criteria to ensure that opportunities for supporting local and MPO-led data collection are clearly identified and that such activities are encouraged.

- Develop and disseminate resources summarizing active transportation monitoring best practices (including but not limited to the accompanying Guide) to promote coordinated data collection approaches and facilitate effective data sharing

- Develop capacity and expertise among traffic monitoring staff and any outside contractors employed in pedestrian and bicycle counting methods and unique considerations for these modes

- Provide guidance for and subsequently request or require bicycle and pedestrian volume data as a component of grant applications and permit requests, where appropriate

Recommendations for potential additional research needed in order to build upon this research and advance implementation of statewide data collection and the application of resultant datasets include:

- Concurrent with the implementation of an initial set of continuous permanent count units, support a second phase of this project which develops roadway factor groups and expansion factors for adjusting short-term multimodal counts. Development of AADT estimates and/or miles traveled calculations for pedestrians and bicycles requires long-term, automated counting, including the following components:

1. Update and expand research conducted through LTRC Project 16-4SA to identify current best practices in development of regionally specific and context-sensitive adjustment factors for nonmotorized count data and exposure calculation methodology (in particular, including new guidance resulting from FHWA’s in-development Scalable Risk Assessment Methodology)

2. Identify preliminary factor groups representative of Louisiana roadways and conduct short-term counts to verify anticipated traffic patterns. Developing region-specific extrapolation factors is critical to conducting advanced analysis of data; this must be developed based on permanent counters installed in sufficient quantity to identify factor groups. These factors should be climate and context (land use typology, facility, demographic) specific.

3. Identify initial long-term count locations for each anticipated factor group and implement long-term automated data collection methodologies, including calibration and validation of data over the course of one year

4. Refine methodology for developing expansion factors for short term data across the roadway network

5. Pending expanded data availability resulting from above as well as anticipated FHWA guidance (Scalable Risk Assessment Methodology expected late 2018), continue refinement of exposure and safety analysis framework and approach and establish baseline data for Louisiana

- Conduct additional case study analysis, specifically focusing on addressing data gaps for built environments not well-served by traditional count technology, using one or more emerging technologies/vendors to assess feasibility and cost-effectiveness relative to the need for such data

- Continue to advance development of internally-led automated video-image count methods to improve detection accuracy rates and advance tracking and classification algorithms

- Continue analysis of complete streets intervention outcomes with post-intervention data, particularly state-involved projects (e.g., Tulane, Government)

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AADBT	Average Annual Daily Bicycle Traffic
AADPT	Average Annual Daily Pedestrian Traffic
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACS	American Community Survey
AAPD	Average of the Absolute Percentage Difference
APD	Average percent deviation
ATI	Associated Transit Improvement set-asides
BIKESAFE	Bicycle Safety Guide and Countermeasure Selection System
CBA	Cost-Benefit Analysis
CDC	Center for Disease Control
CDOT	Colorado Department of Transportation
CMAQ	Congestion Mitigation Air Quality
CMF	Crash Modification Factor
CPPW	Community Putting Prevention to Work
CRPC	Capital Region Planning Commission
DOTD	Louisiana Department of Transportation and Development
EDT	Estimated Daily Traffic
FAST	Fixing America’s Surface Transportation
FHWA	Federal Highway Administration
ft.	foot (feet)
FTA	Federal Transit Administration
FLTTP	Federal Lands and Tribal Transportation Programs
GPS	Global Positioning System
GSM	Global System for Mobiles
HOG	Histogram of Oriented Gradient
HSIP	Highway Safety Improvement Program
in.	inch(es)
IR	Infrared
ITS	Intelligent Transportation Systems
LACSAC	Louisiana Complete Streets Advisory Council
LTRC	Louisiana Transportation Research Center
LOS	Level Of Service
LSU	Louisiana State University

MAPE	Mean Absolute Percent Error
MnDOT	Minnesota Department of Transportation
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
N.	North
NBPD	National Bicycle and Pedestrian Documentation Project
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NCTCOG	North Central Texas Council of Governments
NHPP	National Highway Performance Program
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
ODOT	Oregon Department of Transportation
PABS	Pedestrian and Bicyclist Survey
PBRI	Pedestrian Bicycle Resource Initiative
PEDSAFE	Pedestrian Safety Guide and Countermeasure Selection System
PLAN	Metropolitan Planning Funds
RFID	Radio Frequency Identification
STBG	Surface Transportation Block Grant Program
STIP	Statewide Transportation Improvement Program
TA	Transportation Alternatives Set-Asides
TAZ	Traffic Analysis Zone
TIFIA	Transportation Infrastructure Finance and Innovation Act
TIGER	Transportation Investment Generating Economic Recovery
TMG	Traffic Monitoring Guide
TMAS	Traffic Monitoring and Analysis
QA/QC	Quality Assurance/Quality Control
RPC	Regional Planning Commission
ROI	Return on Investment
RTP	Recreational Trails Program
ROW	Right-of-Way
S.	South
ScRAM	Scalable Risk Assessment Methodology
SPR	State Planning and Research
SRTS	Safe Routes to School
STP	Surface Transportation Program
STPP	Surface Transportation Policy Partnership

SVM	Support Vector Machine
UNO	University of New Orleans
UNOTI	University of New Orleans Transportation Institute

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APPENDIX

The following appendixes are available online at http://www.ltrc.lsu.edu/publications.html under Final Report 599.

Appendix A	Count Program and Pedestrian/Bicycle Plan Inventory
Appendix B	Product and Vendor Inventory
Appendix C	Additional Case Study Technical Material
Appendix D	Pedestrian and Bicycle Count Data Collection and Use: A Guide for Louisiana
Appendix E	Extended Bibliography

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