A Report from the University of Vermont Transportation Research Center

Vermont Bicycle and Pedestrian Counting Program

Final Report

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Vermont Bicycle and Pedestrian Counting Program

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Disclaimer

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Executive Summary

Traffic counts are used extensively in transportation system management, planning, policy and research. Counts help us better understand spatial relationships and temporal trends in travel activity. In spite of the growing recognition of the importance of non-motorized travel, tracking of bicyclist and pedestrian travel behavior with counts lags behind comparable efforts focused on motorized travel. Count data helps agencies to better understand the non-motorized transportation activity in their jurisdictions by designing and prescribing:

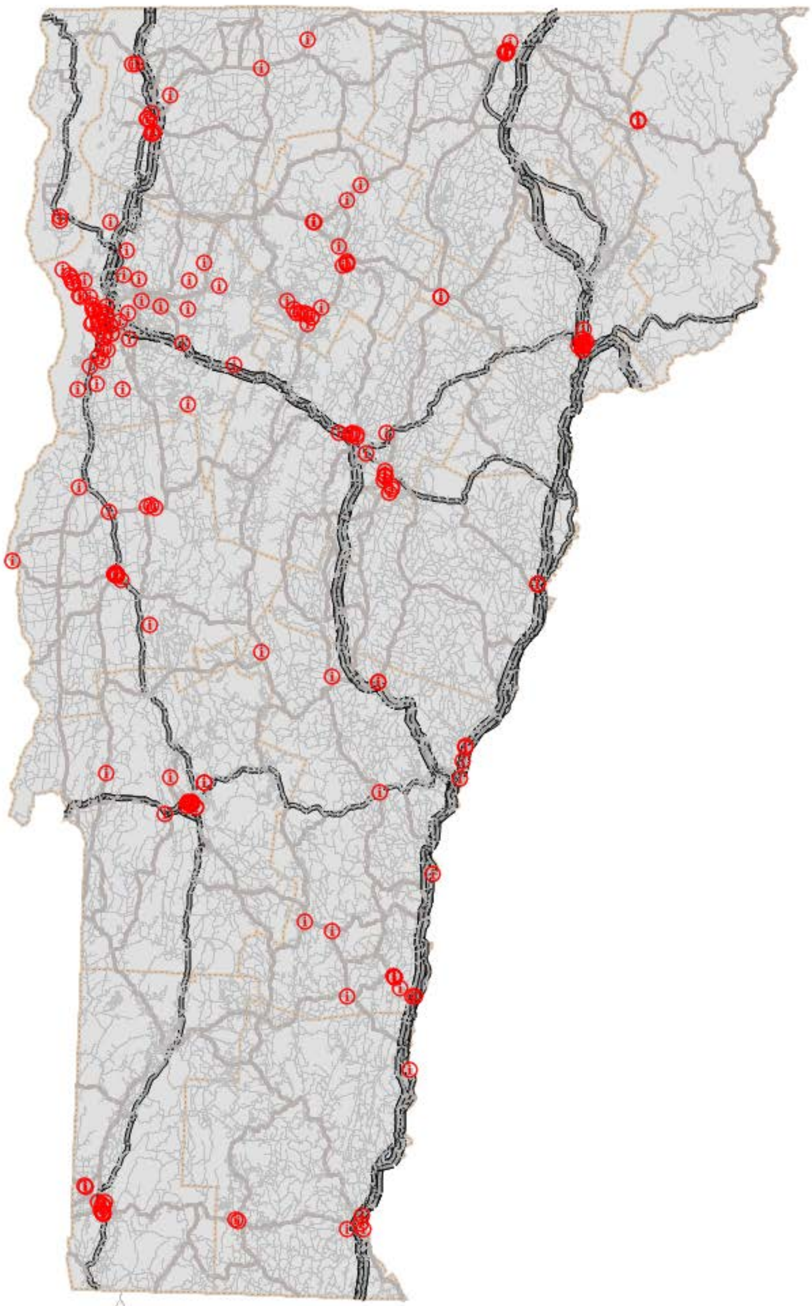
- data collection locations to count non-motorized transportation users;
- methods appropriate for counting at each location;
- data processing and management structures to assemble and quality assure data; and,
- web portals to disseminate the information to the public and other stakeholders.

In Vermont, non-motorized traffic counts are collected by the UVM TRC, VTrans, and several of the state's regional planning commissions. RPCs collect counts in support of local initiatives and at the request of VTrans. The VTrans Traffic Research Unit has also collected a series of manual counts and the Agency recently purchased data from Strava, Inc., which includes data on routes used by cyclists who used the Strava app between 2014 and 2016 in Vermont. Strava's mobile app and its desktop website interface allow athletes to track, analyze, plan, and share their training rides and runs. The Strava Metro product anonymizes and aggregates all of the cycling (and running) data recorded by Strava members for the given time frame aggregated onto a GIS of the street network.

The variety of collection efforts creates a diverse set of statewide count data, but it makes compilation of a single state-wide archive challenging. The goals of this project were to create a bicycle and pedestrian count database for the state of Vermont, communicate the state of non-motorized travel statewide, and make recommendations for future data collection and management.

Count Database Development

All existing counts in Vermont were compiled into a new unified database, with four separate tables linked by a new site ID.The database contains over 200,000 hours of observation at 194 locations:



Count Locations in Vermont

The majority of count sites and durations were either on multiuse paths (72 sites with over 60,000 hours) or sidewalks along Class 1 Town Highways (43 sites with nearly 140,000 hours). Class 1 Town Highways in Vermont are predominantly located in the core of downtown districts or village centers.

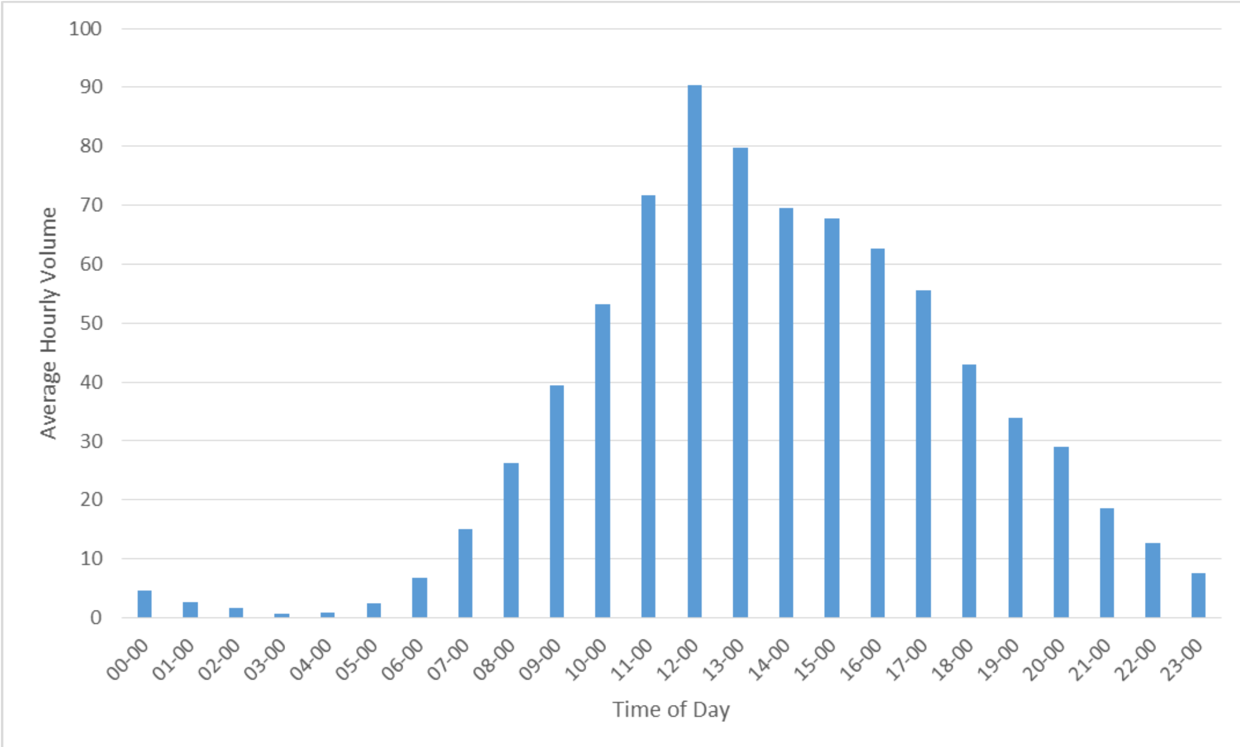
All 194 locations have a peak hourly travel (PHT), since even the manual count sites covered at least one hour. The PHT represents the largest recorded count of cyclists and pedestrian over 4 consecutive 15-minute periods. The average PHT across all 194 sites was 110, indicating that the focus of all counts to date has generally been at locations where high levels of walking and cycling are expected.

69 of the 194 sites also have an average daily travel (ADT), which is the average of any full calendar days of counts:

Summary of ADT, PHT, and PDT at Sites with an ADT

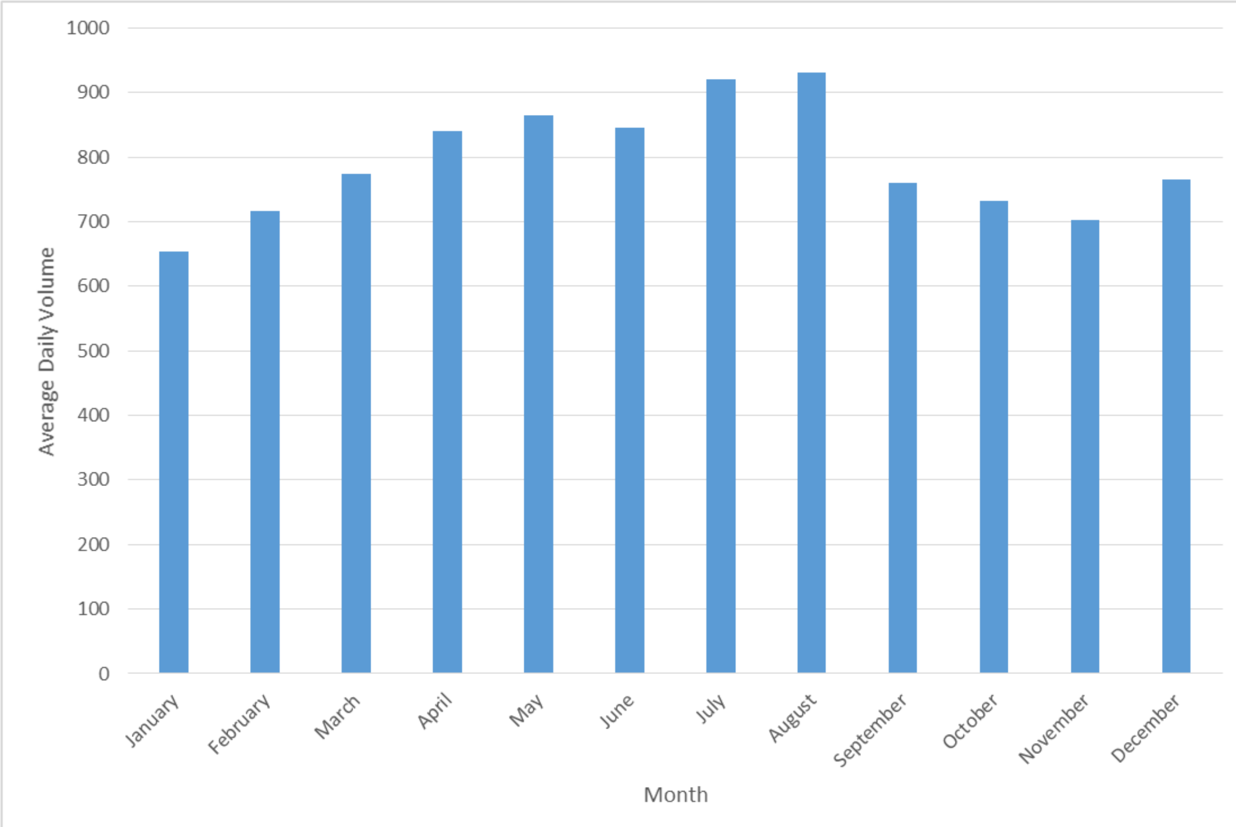
	Minimum	Maximum	Mean
Average Daily Travel	4	1,864	312
Peak Hourly Travel	0	899	182
Peak Daily Travel	4	4,966	781
Duration (hours)	24	73,165	2,962

The average hourly volume of cyclists and pedestrians in Vermont provides an indication of travel throughout the average day:



Average hourly volumes from all automated infrared count sites in Vermont

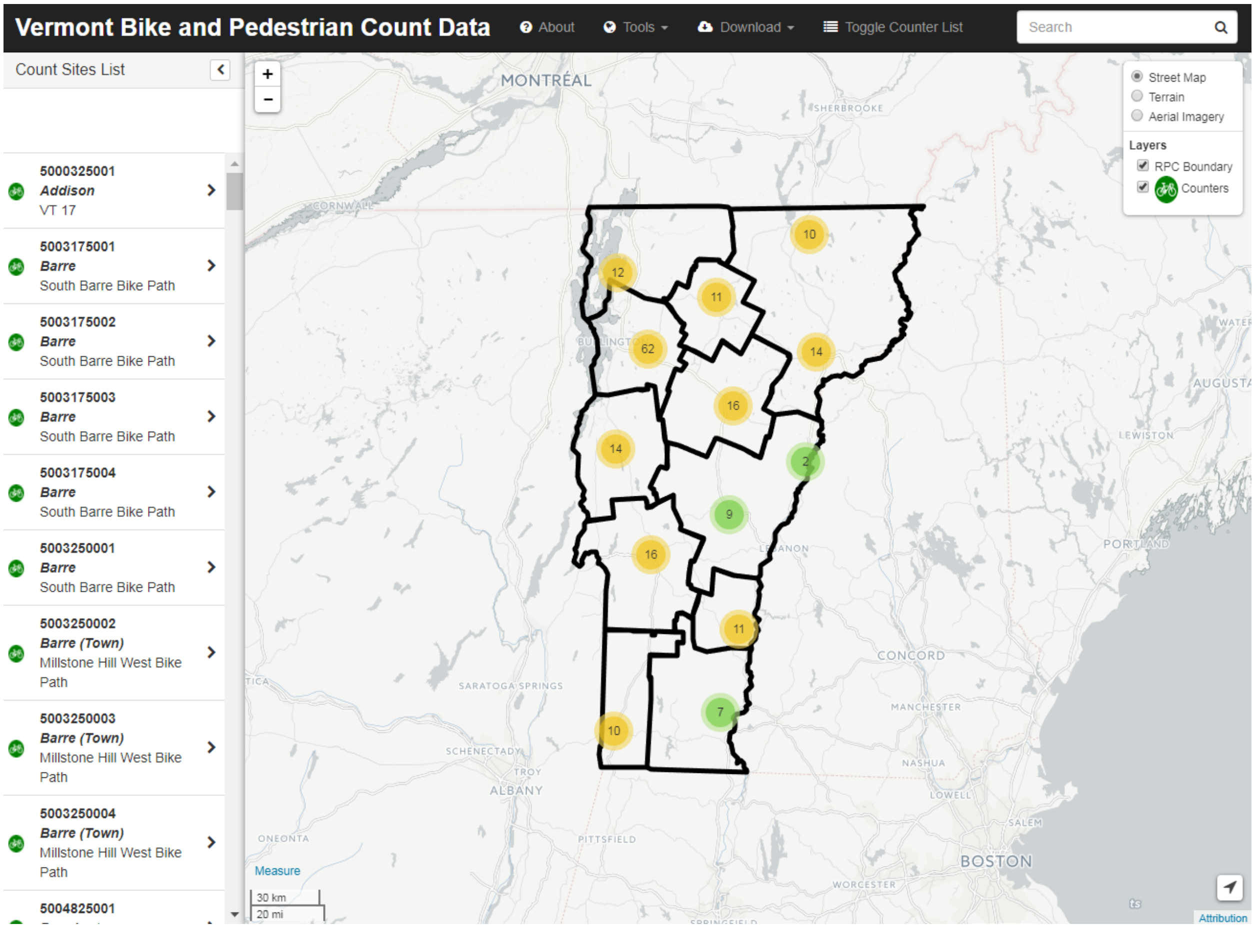
Average daily volumes at the automated infrared sites provide an indication of the seasonal fluctuations:



Average daily volumes by month from all automated infrared count sites in Vermont

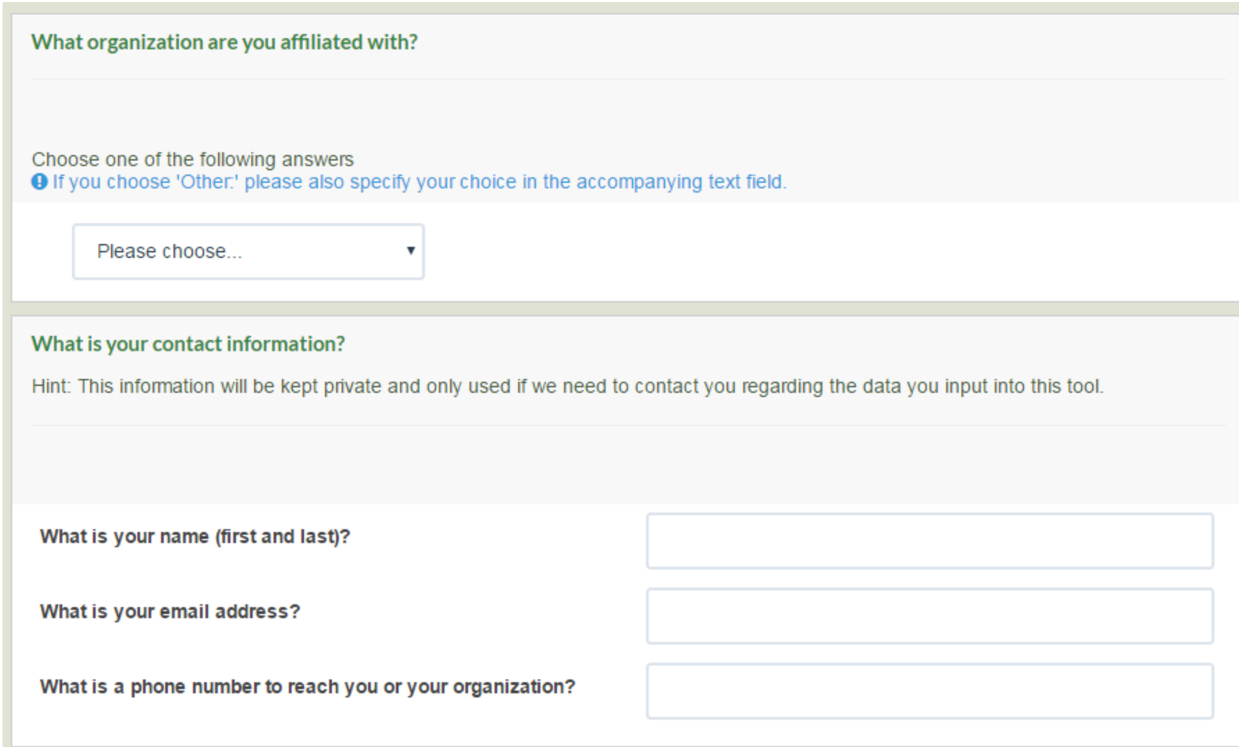
Web Portal and Data Input Tool Development

A web portal was developed with an html index script that enlists map tiles from OpenStreetMap and CartoDB (now CARTO), and aerial imagery from USGS to view and interact with the Site Data in a GIS web environment. The tool includes a number of useful features for viewing and accessing data:



Vermont Bike and Pedestrian Count Data web portal map view of count locations.

In order to achieve organized and uniformly-formatted data input from many different resources, controlling the input data accepted by the Agency was critical. The team investigated options for controlling data input. LimeSurvey met all of the criteria and was designed and administered from UVM's secure and redundant servers. The first page of the data input tool prompts the user to identify their affiliation and provide contact information:



What organization are you affiliated with?

Choose one of the following answers
If you choose 'Other:' please also specify your choice in the accompanying text field.

Please choose...

What is your contact information?

Hint: This information will be kept private and only used if we need to contact you regarding the data you input into this tool.

What is your name (first and last)?

What is your email address?

What is a phone number to reach you or your organization?

The Data Input Information section of the data input tool prompts the user for their affiliation and contact information.

Gap Analysis and Selection of New Count Sites

Screenline counts are observations of traffic, in this case bicyclist and pedestrian traffic, that cross a single imaginary line tangential to the facility on which individuals are traveling. In order to gain an improved understanding of non-motorized travel activity, a robust set of count locations is needed. A spatiotemporal / categorical gap analysis and semi-random site selection process were employed in order to improve the robustness of the set of count locations in Vermont.

A tabulation of the total mileage of each roadway class was assumed to inform the ideal, representative temporal and spatial distribution of counts by class:

Tabulation Existing Count Sites and Statewide Mileage by Class

Class	Existing Count Sites: Percent of Total Sites	Existing Count Sites: Percent of Total Duration	Statewide: Total Length (mi.)	Statewide: Percent of Total
US Highway	6%	1%	619	3%
State Highway	9%	<1%	1771	9%
Class 1 Town Highway	22%	66%	141	1%
Class 2 Town Highway	12%	1%	2750	15%
Class 3 Town Highway	11%	2%	8427	45%
Class 4 Town Highway	0%	0%	1606	9%
Private	2%	<1%	2795	15%
National/State Forest Highway	0%	0%	316	2%
Multiuse Paths	37%	29%	237	1%

To remove bias from the process of selecting new sites in each class, a stratified random sampling technique was used. A total of 20 new sites were selected in this way, and 1 of them was identified for automated infrared counting if it already had infrastructure that would allow that method to be used.

Comparison of Automated Infrared Counts and Video Manual Counts

A video manual review count at the Colchester Avenue test site was conducted to better understand the potential inaccuracies in automated infrared counts. The presence of clustered groups of pedestrians resulted in undercounting by automated infrared. Correction factors varied between 1.00 and 2.00, with an average across all 27 hours of 1.17.

Comparison of Strava Metro Data and Count Summary Data

The average comparison ratio between the Strava Metro Data and the count summary data is 0.8%, indicating that only approximately 0.8% of the non-motorized traffic stream is represented by users of the Strava app. This ratio is significantly lower than comparable values reported by Strava for other regions in the U.S., but is not surprising because most of the average daily counts from the Strava Metro data were lower than 1.0 on Vermont's roads. The average comparison ratios for sites by facility type are:

- Sidewalks or foot bridges – 0.6%,
- Multiuse paths and trails – 0.4%
- Roadways with no dedicated walking or cycling infrastructure – 1.5%.

Conclusions and Recommendations

The overarching goal of this project was to lay the foundation for a comprehensive non-motorized count program for the state of Vermont. To date, on data has been collected without a standard protocol or repository in place. This guidance and its affiliated tools will help the Agency better implement the non-motorized count program statewide.

The key outcomes of this work included:

- Creation of a new data input tool that standardized the data formats and response options based on national protocols
- Creation of a new database with a linked Site ID to prevent data duplication and loss
- Creation of a new web portal to view the existing count data in site summary form or to download raw data.
- Recommendations for 20 new count sites to generate a more representative count database, as counting to date has been focused on sidewalks and multiuse paths where high non-motorized volumes are expected.
- Automated infrared counts can be multiplied by a correction factor of 1.16 to account for occlusion, but this factor is affected by the social context of the pedestrian activity at the site – occlusion is more prevalent when pedestrians travel together in large groups.
- Strava Metro Data only accounts for about 0.8% of Vermont's daily non-motorized travel, but can be a useful source of complete-screenline data when sidewalk or on-network multiuse path counts need to be supplemented with roadway volumes.

We encourage the use of this guidance and the web portal as the primary methodology to collect and report data on non-motorized transportation across the state. This will ensure uniformly formatted data for integration into a singular data repository accessible to the public.

The primary data resources that are integral to this project require the continued efforts of various entities to collect the non-motorized count data across the state. Therefore, we strongly encourage continued support of the regional planning commissions to count non-motorized users as part of the Transportation Planning Initiative. We also encourage other individuals, including other representatives from municipalities, agencies, and advocacy groups, to report any data they collect to the portal.

1 Introduction

Traffic counts are used extensively in transportation system management, planning, policy and research. Counts help us better understand spatial relationships and temporal trends in travel activity. In recent years, many transportation planning agencies have started counting bicyclists and pedestrians using our public infrastructure for the same purposes. Vermont has been a leader with VTrans, several regional planning agencies and the university all active in counting non-motorized travel.

In spite of the growing recognition of the importance of non-motorized travel, tracking of bicyclist and pedestrian travel behavior with counts lags behind comparable efforts focused on motorized travel. The Bureau of Transportation Statistics (BTS) has identified the systematic, methodologically consistent collection of non-motorized travel data as a priority for improving infrastructure and safety analysis (BTS, 2000). Obstacles to calculating bicycle and pedestrian miles of travel (BPMT) include the expense and technical challenges of collecting bicyclist and pedestrian (BP) counts (Hocherman et al., 1988; Green-Roesel et al., 2007). Because pedestrian movement is less restricted than vehicle movement and because pedestrians may move in closely overlapping groups, the counting process is more difficult to automate than it is for vehicles (Hocherman et al., 1988). Newer pneumatic and infrared equipment work well in some settings, but are not well suited to all outdoor environments (Green-Roesel et al., 2007). Consequently, BP counts remain more dependent on expensive manual data collection and continuous count data is scarce. In addition, BP counts have tended to focus on more highly traveled paths in more bike- and pedestrian-friendly towns and locations, leaving significant spatial gaps in BP datasets (Zhang et al., 2010). Temporal and spatial shortcomings of non-motorized travel counts such as these present challenges to transportation planners. Planners often assume negligible or even no non-motorized traffic in outlying or rural areas due to the lack of data (Hammond and Elliott, 2011).

Calculating travel volumes, assessing safety and evaluating trends in non-motorized travel are only a few of the potential uses of statewide bicycle and pedestrian counts. Focused questions from the public, regional planning commissions (RPCs), and other state agencies about non-motorized travel can inform policies to encourage travel that is both conducive to greenhouse gas reductions and improved health outcomes. Analysis of specific travel corridors can justify and inform the optimal siting and design of new bicycle and pedestrian infrastructure. Most importantly, statewide understanding of bicycle and pedestrian travel can be a critical component to VTrans' commitment to safety on its roadways.

All of these potential uses of bicycle and pedestrian counts will benefit from the compilation of all count data statewide into a single, searchable GIS-based database. Whether searching for trends in non-motorized travel over time, or supporting an equitable spatial distribution of infrastructure funding, it will be critical for users to know that all of the data that has been collected in Vermont is included, and for that data to be easily accessible.

The UVM TRC has worked with the Chittenden County Regional Planning Commission (CCRPC) to build a spatially and temporally robust data set of bicycle and pedestrian counts in Chittenden County, and to develop better estimation models where count data is lacking. Extensive research analyses have allowed a better understanding of the factors of the built environment which contribute to BP activity locally (Lu and Sullivan, 2011). Varying these factors has required the collection of counts from rural roads that lack exclusive walking or biking infrastructure but nonetheless were found to have non-motorized traffic volume. The unique challenge of collecting BP counts in these rural locations has resulted in a new protocol, which includes the use of a closed-circuit video camera and digital video recorder. This new protocol has proven successful throughout the rural settings in Chittenden County.

At the same time, the importance of seasonality and weather on BP counts is better understood from year-round BP counts using Eco-Counter pyro-electric sensors. These unique sensors make it possible to collect continuous counts in areas where facilities are shared by cyclists and pedestrians, like shared-use paths and also on sidewalks. From these year-round counts, the effects of changing seasons and daily weather have been established and quantified, so that year-round estimates can be made elsewhere based on short-term counts. From this new robust dataset, the team presented and compared annual BPMT estimates for Chittenden County calculated using seasonally specific, day-of-week adjustment factors (Dowds and Sullivan, 2011).

In Vermont, non-motorized traffic counts are collected by the UVM TRC, VTrans, and several of the state's regional planning commissions. RPCs collect counts in support of local initiatives and at the request of VTrans. The VTrans Traffic Research Unit has also collected a series of manual counts. Counts collected by the RPCs are catalogued and archived in support of the state's Bicycle and Pedestrian Policy Plan (VTrans, 2008). The Bicycle and Pedestrian Policy Plan explicitly calls for the tracking of usage of BP infrastructure to measure performance of these facilities. Through May 2011, the Agency had archived 130 BP counts statewide (outside of Chittenden

County) and the CCRPC has catalogued over 400 BP counts during the same time period (2000 to 2010). The Agency has also recently purchased data from Strava, Inc. which includes data on routes used by cyclists who used the Strava app between 2014 and 2016 in Vermont. While limited in terms of representativeness, this user-based data may be a useful complement to the count data collected in the field.

The variety of collection efforts creates a diverse set of statewide count data, but it makes compilation of a single state-wide archive challenging. The goals of this project were to create a bicycle and pedestrian count database for the state of Vermont, communicate the state of non-motorized travel statewide, and make recommendations for future data collection and management. The specific objectives of this project were to:

1. review best practices in non-motorized count data management and count planning;
2. gather all existing counts into a single database and create or implement a bike and pedestrian count data web portal;
3. validate the existing count data and the methods of collection;
4. identify gaps in the statewide data set;
5. develop a continued counting plan to be implemented by VTrans.

2 Best Practices in Count Data Management

2.1 Count Data Programs

The current state of practice for bicyclist and pedestrian counting programs across the country varies tremendously depending on local or regional initiative. Without a federal mandate like that which exists for vehicle counting, the impetus for implementing non-motorized count programs is based primarily on a more localized desire to account for bicyclist and pedestrian travel in short and long-term planning activities, infrastructure improvements, or policy-making. Therefore many states, metropolitan planning organizations, and city municipalities have created their own counting programs catered to their particular needs. Efforts by these jurisdictions are guided by generic protocols from resources like the NCHRP Guidebook on Pedestrian and Bicycle Volume Data Collection and National Bicycle and Pedestrian Documentation Project (NBPD), but actually implemented and managed more locally. In some cases the count programs are volunteer-driven, manual count oriented like Washington State DOT, whereas others are dominated by automated count devices installed in a permanent counter network with short-term installations to fill in the spatial gaps, like Delaware Valley RPC.

Active transportation count data programs across North America are helping agencies to better understand the non-motorized transportation activity in their jurisdictions and assess general use trends and accommodations by designing and prescribing:

- data collection locations to count non-motorized transportation users;
- methods appropriate for counting at each location;
- data processing and management structures to assemble and quality assure data; and,
- web portals to disseminate the information to the public and other stakeholders.

Depending on the goals of the agency for the count program, these features are adjusted within the guidelines set forth by a number of national efforts to suit local agency needs.

In this section, a review of the leading national efforts to guide and standardize non-motorized count programs, as well as a number of established agency count programs, provided an overview of how other jurisdictions account for non-motorized transportation and how that information is shared with the public.

The focus of national efforts reviewed were:

- Guidebook on Pedestrian and Bicycle Volume Data NCHRP Report 797
- National Bicycle and Pedestrian Documentation Project
- Federal Highway Administration Traffic Monitoring Guide Chapter 4
- Coding Non-motorized Station Location Information in the 2016 Traffic Monitoring Guide Format
- Portland State University Bike-Ped Portal

Agencies included in the review were:

- Washington State Department of Transportation (WSDOT)
- Delaware Valley Regional Planning Commission (DVRPC)
- Bike Arlington
- Central Lane Metropolitan Planning Organization
- City of Ottawa
- Southern California Association of Governments
- Greater Portland Council of Governments
- Colorado Department of Transportation (CDOT)
- Ohio Department of Transportation (ODOT)

These lists were not intended to be exhaustive, but instead provide the most prevalent guidance and breadth of practice currently available.

2.2 Count Location Selection

Once a geographic boundary for the count program is in place, often set by the jurisdictional coverage of the administering agency, the locations at which non-motorized counts will be conducted are selected. As set out in the Guidebook on Pedestrian and Bicycle Volume Data Collection, selection of non-motorized data collection locations can be accomplished by four general approaches, including random, representative, targeted, and control location selection (Ryus et al., 2014). The goal of the counts dictates the type of location selection process that should be implemented. Each selection type was briefly summarized here; see Ryus et al. (2014) for full explanations.

Random sampling is one way in which locations may be identified. Simple random sampling selects sites without accounting for any other characteristics of the site locations. Indexing all of the possible facilities and generating numbers to select the site indices at random would provide a set of count sites, but would not necessarily be representative of the broader bicycle and pedestrian activity distributed across a community. Stratified random sampling, where random locations are selected from a strata or category of the available facilities, is one method used to select count locations where the goal is to have counts representative of each category. Typically, these are characteristics of the site that are expected to influence levels of bicyclist and pedestrian activity, including features like number of vehicle lanes, presence of bicycle or pedestrian dedicated infrastructure, road classification, surrounding land use, proximity to schools and parks, or other distinguishing features.

Representative locations are selected in a similar fashion, except that the process is guided by count program administrators or some advisory committee. Again, the goal of the counts is to be representative of all of the non-motorized activity across a community and gauge how the general use trends change. Care must be taken to choose sites in a way that does not place particular bias on high usage locations or locations of the greatest convenience. A representative sample will have site locations across all of the land uses, facility types, geographic areas, and community characteristics that exist in the jurisdiction.

If the goal is to capture before and after usage patterns for new infrastructure projects or assess particular safety concerns, targeted location selection is appropriate. For return on investment assessments, sites are selected based on their candidacy for non-motorized accommodation or infrastructure projects. Counts should be collected before and after the infrastructure improvements are installed. The targeted locations should be coupled with the selection of control locations that have similar characteristics, but are not affected by the project. Assessment of the ROI at the target site can then be corrected for general use trends according to counts from the control sites over the same temporal span. Targeted sites may also be used to assess safety concerns at particular sites, where crashes or other safety metrics need to be normalized by exposure (i.e. counts) to compare across locations.

2.3 Methods for Counting Bicyclists and Pedestrians

There are many considerations to weigh when selecting a method to count non-motorized activity at a particular site. In general, the goals of the count program and the counting limitations based on the site characteristics will help guide the decision-making on the following considerations:

- screenline versus intersection counts;
- manual versus automated counts; and,
- permanent versus short-term counts.

2.3.1 Screenline vs. Intersection

In traffic monitoring, there are typically two types of counts: screenline and intersection. Screenline counts are observations of traffic, in this case bicyclist and pedestrian traffic, that cross a single imaginary line tangential to the facility on which individuals are traveling. These are typically conducted away from intersections with other facilities, so as to capture just the activity on a particular corridor. Screenline counts inform the general use trends for the mode they are observing, in this case bicyclists and pedestrians.

Bicyclists and pedestrians are also often counted during routine vehicular intersection turning movement counts. Observations at intersections are critical for accommodating bicyclist and pedestrian activity at intersecting roadways, particularly when it comes to crosswalk geometries and signal timing, but the focus is on informing the safety and operational aspects of the intersection.

If the goal of the count program is to inform the traffic operations accommodation of non-motorized transport, then intersection data is valuable. However, if the primary goal of the count program is to better understand non-motorized activity patterns, then screenline counts are the priority.

2.3.2 Manual vs. Automated

Automated counting requires a counting device installation to make observations at a point location. In general, count technologies use a sensor to tally each individual passing a targeted area, whether it is pneumatic, piezoelectric, inductive, pressure, infrared signal, or other methods. There are a multitude of devices available to automate the counting process; however, there are limitations to the count technologies that are currently available, depending on what mode is being captured and what facility is being observed. The guidance for Los Angeles County jurisdictions enumerates the technology options and the appropriate applications in the decision flow chart below (Kittelson & Associates, Inc. et al. 2013).

As with any technology, there are limitations to the accuracy of each device and validation is necessary to ensure discrepancies are known and adjusted for in various contexts. The behavior of individuals walking and biking differs from vehicles passing a targeted count area. Vehicles are regulated and their operation governed by traffic laws, making their passage of a targeted count area very predictable. However, in walking and biking the likelihood of individuals passing a counter outside of the targeted count area boundaries or in pairs or groups is much greater. That makes placement of counters and occlusion particularly challenging for bicycle and pedestrian counts. With occlusion, count devices rely on a single person to pass the counter, triggering the device to tally the user. Depending on the technology, the device may or may not account for multiple, simultaneous users. Furthermore, depending on the particular location, the rates at which more than one user passes the count point at the same time may vary.

Thorough explanations of the different currently available non-motorized count technologies have been compiled elsewhere, like in O'Toole et al. (2016) and Kittelson and Associates et al. (2013). For the sake of brevity, only the technologies that have been used within the state to date are detailed here.

The passive infrared EcoCounter devices that have been used with frequency across the state of Vermont, according to the technology decision flow chart, are appropriate for counting pedestrian-only activity on sidewalks, pedestrians and bicyclists together on traffic-separated facilities, and bicyclist-only activity on bicyclist-only facilities. This of course assumes that no pedestrians will use bicyclist-only facilities and no bicyclists will use sidewalks. Essentially, the technology is effective at capturing both bicyclists and pedestrians in places where non-motorized traffic is physically separated from the vehicular traffic.

In order to capture mixed traffic streams, like what one would expect on the two-lane highways that criss-cross the state, some other solution is necessary. For non-motorized activity on or adjacent to the vehicular traffic, solutions like bicycle-specific tube counters may be effective for counting bicyclists only. The limitation here is that any pedestrian activity on these roadways would be missed. According to the flow chart, to capture bicyclists and pedestrians on or adjacent to the roadway, video is the chosen technology.

Although it provides a thorough overview of where the technology may be applied, it is important to note that one of the challenges for count technology in Vermont is the seasonal weather patterns. Winter weather limits the potential use of technologies like tube counters outside of the warmer weather months due to snow and ice control activities.

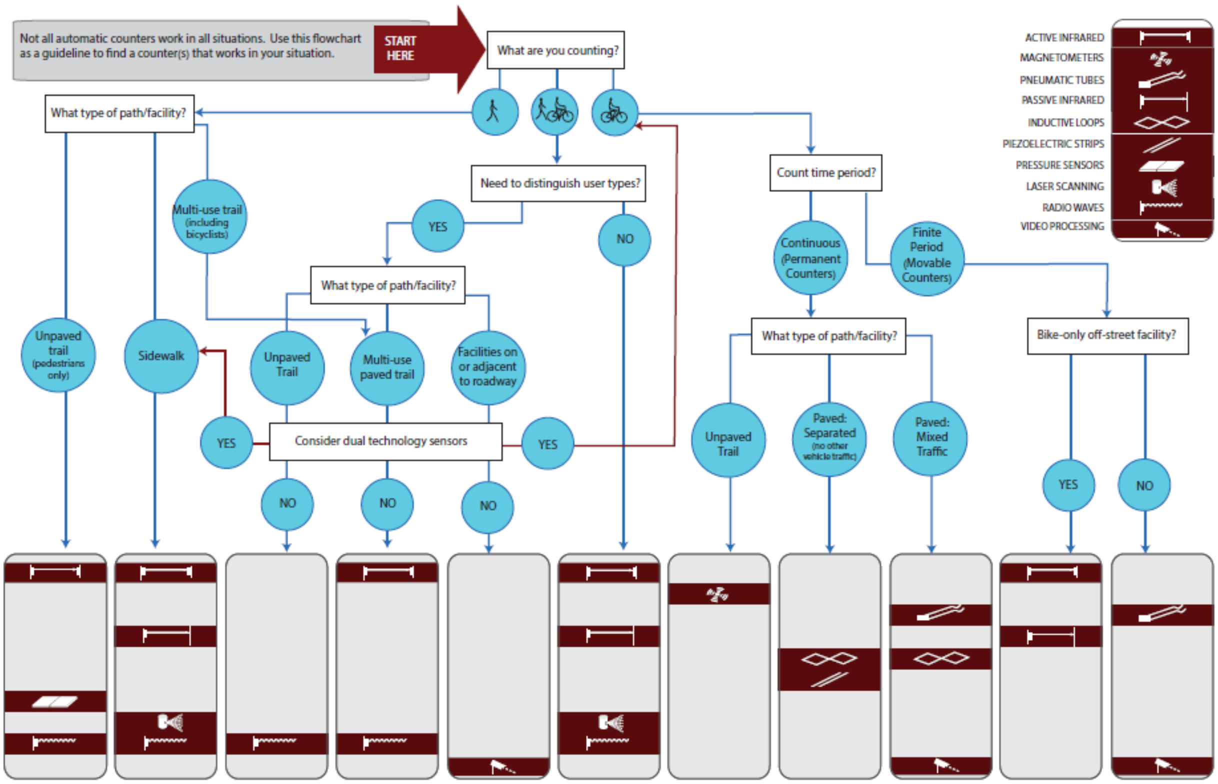


Figure 1. Data collection technology decision flowchart (Kittelson & Associates, Inc. et al., 2013).

Manual counting is one way in which the limitations of the automated technology can be overcome. A manual count is when an observer goes to the count site location and records a tally for each non-motorized user that passes on the corridor. Due to the necessity of putting a person in the field to record the counts, there is a temporal limitation with manual counting as compared to automated counting. Although the observer will capture all activity crossing the entire screenline, the person will likely only count for a few hours in a day.

Some count programs rely on manual observations to populate their non-motorized count data sets. For instance, WSDOT collaborates with a number of volunteer organizations to put observers in the field to collect their manual counts. The Cascade Bicycle Club, Feet First, Washington Bikes are just a few of the organizations the agency names as volunteer conduits for collecting the manual counts. Their manual counting campaign is prescribed by the agency with a broad set of spatial locations and supplements a number of automated counters that capture the temporal variability not observed by manual counts.

2.3.3 Permanent vs. Short-Term

For automated counts, the decision of whether an installation of a device is permanent or short-term should be based on the goals of the count program. Most count programs across the country have a small number of strategically placed permanent installations capturing the temporal variabilities of biking and walking activity year-round. Permanent sites provide insights on seasonal, time-of-day, and day-of-week variability based on the local non-motorized activity, social contexts, and culture. These sites can be supplemented by selecting additional locations to gain broader spatial coverage through a greater selection of facilities and contexts. Conducting either manual counts or installing automated counters for short-term counts (i.e. two-week installations) at these locations provide more detail across a broader region, while capturing data relative to the permanent sites that can be scaled or factored appropriately.

2.4 Data Protocols and Management

Although no mandate yet exists, efforts to assemble data from many of the existing data resources are underway. There are already established programs, like the National Bicycle and Pedestrian Documentation (NBPD) Project (NBPD, 2010), and programs in the process of being established, like the FHWA Non-Motorized Traffic Monitoring Analysis System (TMAS) or Portland State University's program (Laustsen et al., 2016; Nordback et al., 2017), that aim to gather non-motorized count data from many jurisdictions. These programs provide data protocols to guide potential contributors on appropriate data fields for including data in the program repository. Data protocols include the acceptable data attributes, definitions, formats, and response options.

FHWA, through the TMAS program, recently released a supplement to the Traffic Monitoring Guide (TMG) regarding non-motorized count protocols (FHWA, 2016; Laustesen et al., 2016). The TMAS program and affiliated TMG provides the roadmap for states to report motorized vehicle data to FHWA. The program will begin to accept non-motorized data from other resources in the near future, but is not yet fully operational. The NBPD provides many resources and a one-size-fits-all solution to counting non-motorized transportation activity. Their protocols are well-defined and available through their website (NBPD, 2010). In addition, Portland State

University has completed its first phase of a project to create a national bicycle and pedestrian count portal. As part of the data protocol decision-making process, PSU also conducted reviews of data protocols and portals available (Nordbeck et al., 2015). Direct contact with the project lead allowed for access to the guidance documents and the input portal for review. Each of these programs provides their own data protocol, a compilation of which is included in Table 1 indicating whether the fields are required (✓) or optional (o) for each program.

Table 1. Data Fields for Count Programs

Category	Field	TMG	NBPD	PSU
Affiliation	Agency/Organization		✓	
	Contact Information		✓	
Location	Station ID	✓	✓	
	State	✓		✓
	County	✓		✓
	Year Station Established/Discontinued	✓		
	Latitude/Longitude	✓		✓
	Station or Segment Location	o	✓	✓
Segment	Functional Classification of the Roadway	✓		✓
	Direction of Route	✓		
	Posted Speed Limit	o	✓	o
	National Highway System	o		
	Posted Route Signing	o		o
	Posted Signed Route Number	o		o
	Traffic Volumes (AADT)		✓	
Facility	Location of Count Relative to Roadway	✓		
	Direction of Movement	✓		o
	Facility Type	✓	✓	✓
	Paved			o
	Side			o
	Facility Width			o
	Buffer			o
	Overpass/Underpass			o
	Condition		✓	
	Intersection	o		
Count	Type of Count	✓		o
	Method of Counting	✓		
	Type of Sensor / Detector Details	o		✓
	Primary Count Purpose	o		

Category	Field	TMG	NBPD	PSU
	Date	✓	✓	✓
	Time	✓	✓	✓
	Weather	o	✓	
	Count Interval(s)	✓	✓	✓
	Total Count for Each Interval	✓		✓
	Count of Bicycles		✓	
	Count of Pedestrians		✓	
	Count of Others		✓	
	Count of Helmet Use	o		
	Count of Gender	o		
	Count of Age Categories	o		
	Factor Groups	o		
Surrounding Area	Land Use		✓	o
	Type of Setting (urban, rural, suburban)		✓	
	Scenic Quality		✓	
	Schools, parks, visitor destinations within 1 mi		✓	
	Quality of Connecting Facilities		✓	
	Length of Facility		✓	
	Access to Facility		✓	
	Quality of Overall Network		✓	
	Topography		✓	
Demographics	Source of demographic data		✓	
	Year of data		✓	
	Population		✓	
	Density (people per square mile)		✓	
	Bicycle Mode Share: US Journey to Work		✓	
	Pedestrian Mode Share: US Journey to Work		✓	
	Median Age		✓	
	Median Income		✓	
	Number of annual visitors to area		✓	

Lausten et al., 2016; NBPD, 2010; Nordback et al., 2017

The guidelines provided by the TMG, NBPD, and PSU programs were a starting off point for the Vermont Bicyclist and Pedestrian Count Program. The protocols for these programs were reviewed to understand the critical information needed if Vermont wanted to share some or all of their data with these national clearinghouses in the future. Key attributes that were essential to the reviewed count programs were considered for Vermont's non-motorized count program data collection guidance. Data that were easily obtained through other sources, like demographic data for the area or surrounding area characteristics were not considered for the preliminary data assembly, but should be revisited in the future.

The data protocols and management systems associated with commercial platforms, like MS2 and EcoVisio, as well as the national count programs above, were reviewed for feasibility as a data management solution for the Vermont count program.

MS2, the company that provides Vermont's traffic count data management software, has a non-motorized database system module. The system handles non-motorized count data in a very similar fashion to the motorized count data, where both screenline and intersection counts can be handled. The database management system is comprehensive, but for the current goals of the non-motorized count program, comes at a significant cost.

EcoVisio, the data management program available through EcoCounter, is one way in which data may be managed. The product was designed to handle data from any of the EcoCounter devices. However, the opportunity for mixed data streams, particularly inclusion of manually collected count data, is limited.

The first phase of the PSU bike-ped portal project aimed to implement a data uploading, formatted database, and data downloading interface. The portal allows users to log in, upload their site information and count data, download data from all users, and add the data to the larger, national database. The second phase of the project will make the information available through an interactive user portal. The stipulation of using the portal for data management was that all count data be automated, 15-minute interval data, which would limit the data that could be archived for Vermont.

2.5 Public Portals

Review of a number of count programs and their public facing portals provided an overview of what other jurisdictions were doing to account for bicyclists and pedestrians, and how that information is shared with the public. Features of each of the data portals were enumerated in Table 2. Key features that were identified on each portal included:

- Count modes (bike or pedestrian)
- Platform or software for website

- Count types (manual or automated)
- Interactive map
- Photo of count location
- Graphs summarizing count data
- Weather data
- Data download functionality

Table 2. Bicyclist and Pedestrian Count Program Review Agencies

Agency	Count Mode	Platform(s)	Count Type	Interactive Map	Photo of Location	Count Data Graphs	Weather	Data Download	Website
Washington State DOT	Bike/ Ped	OpenStreetMaps; ESRI	Manual	✓		✓		✓	http://wsdot.wa.gov/data/tools/bikepedcounts/
			Automated	✓				✓	
Delaware Valley RPC	Bike/ Ped	Leaflet; OpenStreetMaps; CartoDB; pdf Report	Automated	✓	✓	✓	✓	✓	http://www.dvrpc.org/webmaps/pedbikecounts/
Bike Arlington	Bike	Google Maps; highcharts.com	Automated	✓		✓	✓	✓	http://www.bikearlington.com/pages/biking-in-arlington/counting-bikes-to-plan-for-bikes/counter-dashboard/
Central Lane MPO	Bike/ Ped	tableau	Automated	✓		✓		✓	http://www.thempo.org/356/Bicycle-Counts
City of Ottawa	Bike	Data Download XLSX; API	Automated					✓	http://data.ottawa.ca/dataset/bicycle-trip-counters-automated
Southern California AOG	Bike	Google Maps; Data Download CSV	Manual/ Automated	✓	✓			✓	http://www.bikecounts.luskin.ucla.edu/Map.aspx
Greater Portland COG	Bike/ Ped	Google Maps; Data Download Dropbox	Manual	✓				✓	http://www.pactsplan.org/long-range-transportation-planning/mapping-data/bike-ped-counts/

Agency	Count Mode	Platform(s)	Count Type	Interactive Map	Photo of Location	Count Data Graphs	Weather	Data Download	Website
Colorado DOT	Bike/ Ped	Google Maps; Formatted pdf Report	Automated	✓		✓		✓	https://www.codot.gov/programs/bikeped/cdot-bicycle-pedestrian-counts/bike-pedestrian-counts
Ohio DOT	Bike/ Ped	MS2	Automated	✓		✓			http://odot.ms2soft.com/tdms.ui/nmds/dashboard/index?loc=odot

Some of the count data portals were as simple as a website with a data download, like Ottawa's portal. Others had all of the above features included in their portals, like Delaware Valley RPC (Figure 2). Most of the count programs had public facing portals that included some of the key features, catering to their particular needs for the program and their constituents.

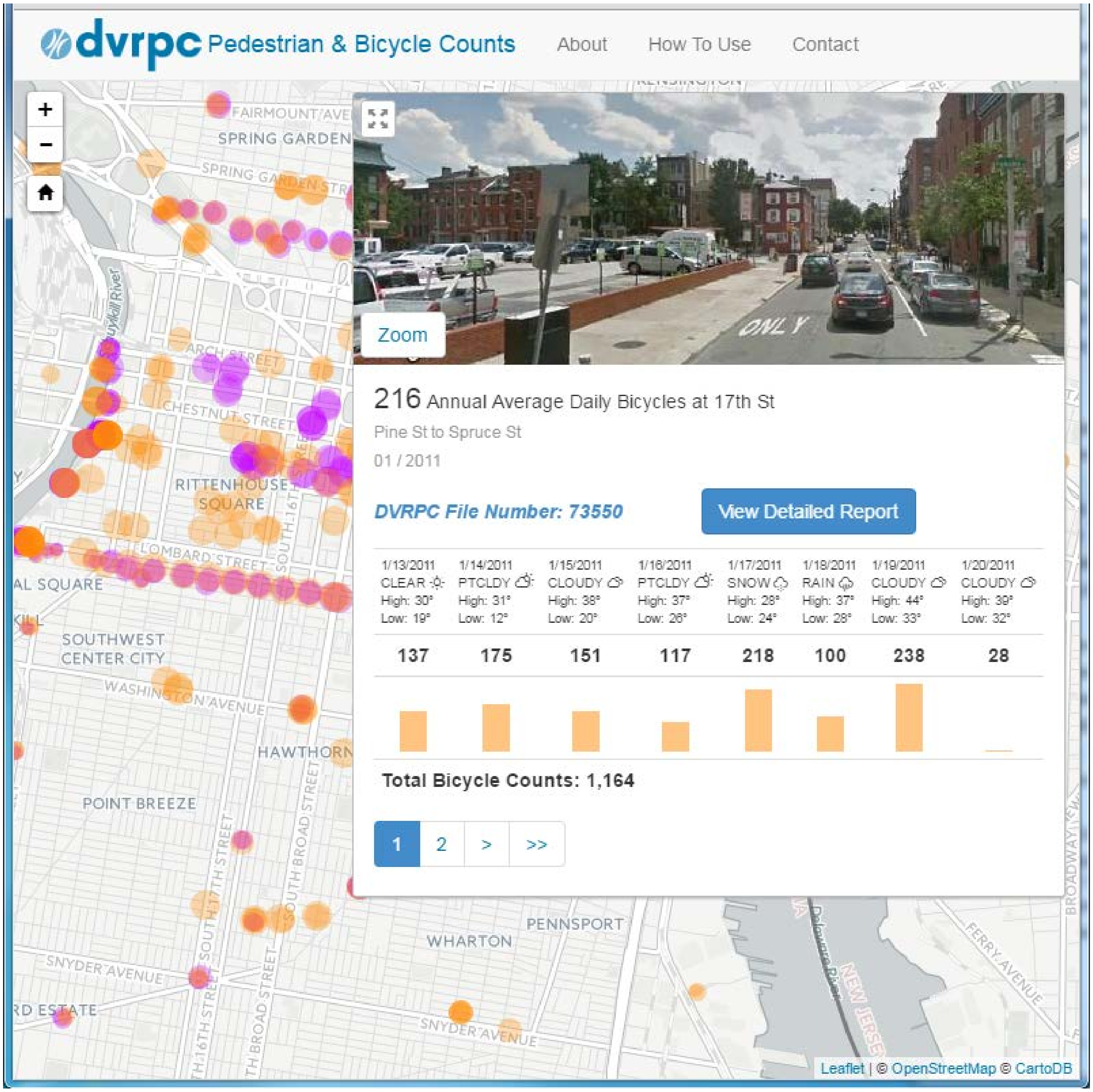


Figure 2. An example of a public data portal from the DVRPC with site details open displaying count data.

Popular platforms for viewing the data included interactive mapping of the count sites and data through tools available by Google Maps, Leaflet, OpenStreetMaps, CartoDB, and ESRI. Other platforms that included interactive mapping and additional graphics summarizing the data were software packages like tableau and MS2.

Data downloads from the various organizations included direct download of tabulated data in CSV or XLSX. Some agencies allowed for site data to be downloaded in a PDF report, like the document generated by the View Detailed Report button on the DVRPC in Figure 2.

Of the public portals reviewed, the majority included an interactive map of the count sites, summaries of counts either in graphs or reported metrics, and data downloading. To be consistent with the state of practice in other jurisdictions, these features will be essential to the Vermont count program portal.

3 Description of Data

3.1 Data Gathered from Other Sources

3.1.1 Manual Counts

Since 2011, VTrans' Traffic Research Unit and various RPCs have been manually collecting screenline counts of cyclists and pedestrians on sidewalks, shared-use paths, and roadways throughout the state. Through the summer of 2016, 149 unique locations have been counted, with durations ranging from 45 minutes to 17 hours. Since none of the manual counts spanned 24 continuous hours, average daily traffic (ADT) and peak daily traffic (PDT) totals for these sites are not available.

Manual counts are conducted during temperate summer months to facilitate on-site manual observation and recording of data. Many locations are counted repeatedly, so the total hours of observation for any one site are as high as 259 hours. The peak-hour traffic (PHT) at these sites ranged from 2 cyclists/pedestrians to 684, with an average of 71. The highest PHT in the state was recorded in St. Johnsbury on the morning of May 30, 2012 (a Wednesday) on the Main Street sidewalk outside of the St. Johnsbury Academy, whose enrollment is approximately 1,000 students (Figure 3).

Figure 3. Street view of the sidewalk outside of St. Johnsbury Academy.

3.1.2 Automated Infrared Count Data

Automated collection of cyclist/pedestrian counts is conducted in Vermont by VTrans, the RPCs, and the UVM TRC. These automated counts utilize pyroelectric sensors in the EcoCounter device to detect the infrared emitted by the human body allowing multiple people to be counted individually even if they are close together. The devices are capable of collecting bidirectional counts of bicycle and pedestrian traffic, recorded as total counts (bicycle + pedestrian volume). However, these devices need to be mounted to a fixed vertical object so that the infrared is aimed perpendicular to the traffic stream where the count is desired at about waist height, without interference from other objects and traffic. This requirement makes them perfect for counting traffic on sidewalks and shared-use paths (Figure 4), but not suitable for counting traffic on on-road cycling facilities, where the infrared would also pick up motorized vehicles, and not be able to distinguish non-motorized activity. In addition, when used for a sidewalk or a shared-use path that is aligned with a roadway, these counters are not capable of collecting a complete screenline, as only one side of the road can be counted at a time.

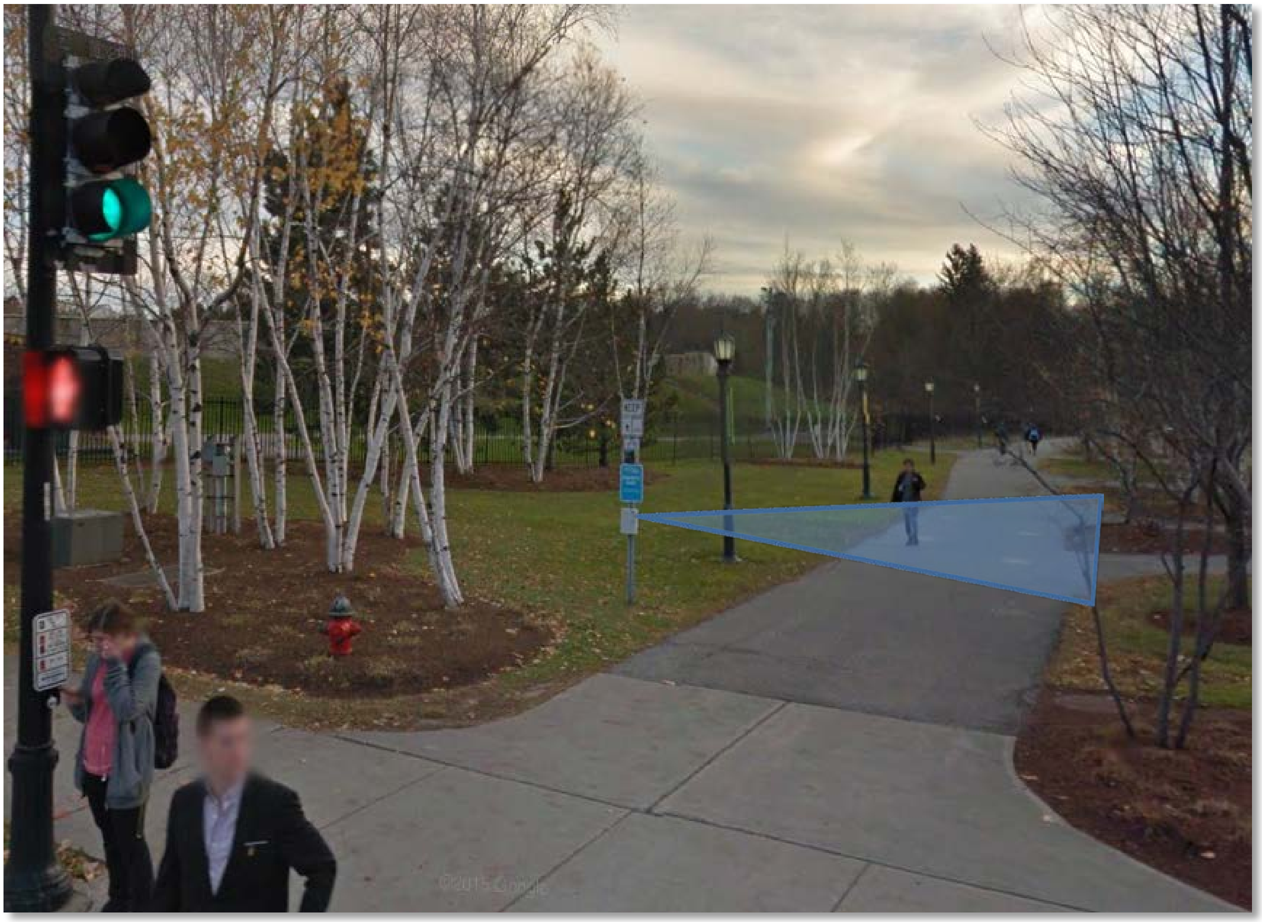


Figure 4. Application of an automated infrared counter on a shared-use path

Through the end of 2016, 48 unique locations have been counted, with durations ranging from 11 hours to 73,165 hours, including 26 of the sites where manual counts have also been collected. For 47 of these 48 sites, ADT, PDT and PHT aggregate totals are available. One of the sites was in place for only 11 continuous hours, so ADT and PDT are not available.

Automated counts are conducted continuously in a variety of seasons at shared-use paths, sidewalks, and trails. Table 3 summarizes the automated data at the 47 sites that were counted for at least 24 continuous hours.

Table 3. Automated count site summary of metrics.

	ADT	PDT	PHT	Duration (hrs)
Maximum	1,864	4,966	899	73,165
Minimum	4	68	15	120

	ADT	PDT	PHT	Duration (hrs)
Average	442	1,129	260	4,243

Both the highest PHT and PDT in the state were recorded in Rutland on July 2, 2010 (a Friday) on the Center Street sidewalk outside of the Paramount Theater, whose capacity is approximately 900 people (Figure 5).

Figure 5. Street view of Center Street in Rutland, outside of the Paramount Theater.

The peak of 899 occurred at 8:00pm that evening, so it likely comprised audience members for a show at the theater. However, this hour was an unusual one for the location – the average hourly count is only 43 (Figure 6).

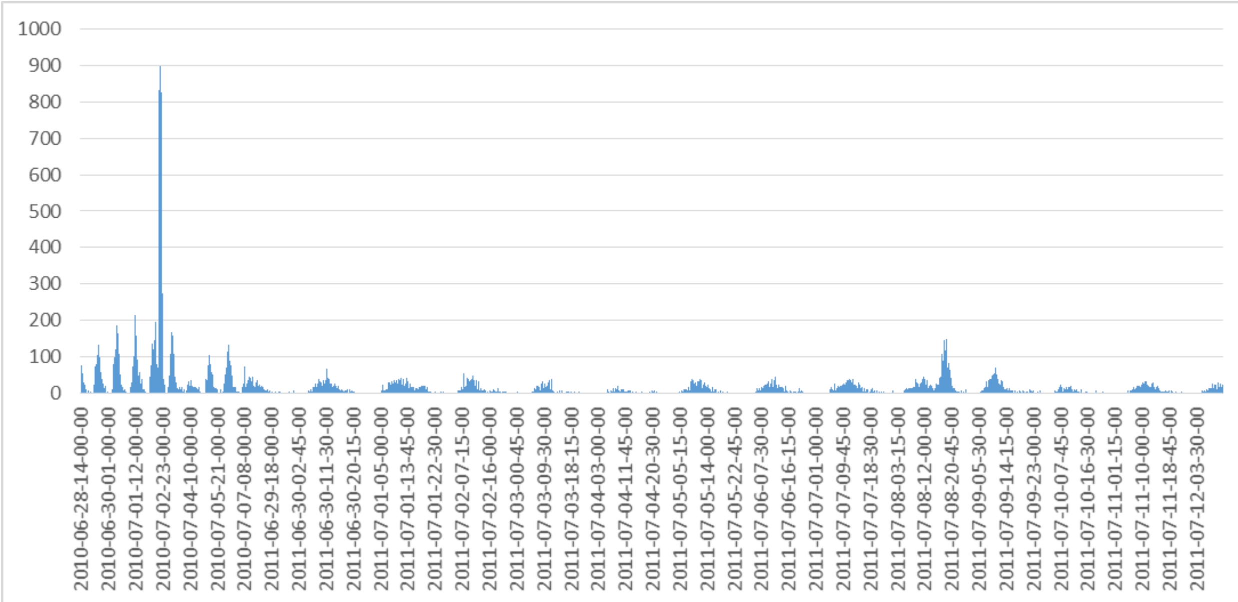


Figure 6. Hourly counts on Center Street in Rutland.

3.1.3 Video-Based Manual Counts

The need for screenline count data at locations without sidewalks or shared-use paths is challenging. As described previously, the use of the pyroelectric sensor is impossible without also picking up the motorized vehicles on the roadway, since a separated path for motorized and non-motorized travelers is required between the sensor and the edge of the non-motorized travel path for these sensors to work effectively. Methods considered for collection of counts at these locations included the pyroelectric sensor, a pavement-loop counter, a video camera in a parked vehicle, and a video camera mounted on a power pole. Given limited shoulder width, a video camera mounted on a power pole or tree is the most effective method. A closed-circuit digital video camera with motion-sensitive activation, color-infrared LEDs for night vision, a weatherproof metal housing, and a mounting bracket was used (Figure 7) to collect manual counts facilitated by video recording. These

Figure 7. Motion activated video camera.

screenline counts were collected at 23 rural locations over 1- to 3-day periods in 2011 and 2012 by the UVM TRC during a research project for the USDOT (Sullivan et al., 2015). These video recordings were manually reviewed at a desktop computer to count cyclists and pedestrians. The use of high-speed playback limits the amount of time needed to review the video and record counts.

The following guidelines are used to optimize the positioning of the camera relative to the roadway being counted:

- Orient the camera orthogonally to the roadway travel direction
- Limit obstructions in the foreground of the image
- Avoid intersections in the image
- Minimize or avoid locations where sunlight or reflective surfaces are directed toward the camera

Use of a video camera for data collection imposed a number of constraints on the data. In particular, due to the limited storage capacity and battery power of the camera system, full-week counts were not feasible. In lieu of full-week counts, 24- to 72-hour count periods were used, ensuring that a daily count could be computed at each site so ADT, PDT and PHT aggregate totals are available. All sites were on roadways with minimal or no shoulder, and both directions of travel on the roadway were counted. Table 4 summarizes the combined (cyclists + pedestrians) count data at the 23 sites.

Table 4. Video-based manual count summary of metrics.

	ADT	PDT	PHT	Duration (hrs)
Maximum	130	130	26	72
Minimum	0	0	0	24
Average	33	35	8	33

The maximum PDT and PHT were on Spear Street in Shelburne and Greenbush Road in Charlotte, both popular cycling facilities in spite of the fact that neither has a dedicated cycling lane.

3.1.4 Strava Metro Data

VTrans purchased data from Strava, Inc. in support of its On-Road Bicycle Plan (RSG, 2016), aimed at enhancing on-road bicycle improvements by categorizing state highways as high, moderate and low-use/priority corridors, based on current and potential future cycling activity on these roadways. Strava data is instrumental in this assessment because it is derived from the smartphone GPS of the users of its app, meaning that it can provide count data on highways where automated count methods are not feasible. Strava's mobile app and its desktop website interface allow athletes to track, analyze, plan, and share their training rides and runs.

The Strava Metro package of data consists of coverage for the entire state covering two periods of time:

- October 2014 to December 2015 (appears to include data through July 2016)
- January 2016 to December 2016

In each delivery, the Strava Metro product anonymizes and aggregates all of the cycling (and running) data recorded by Strava members for the given time frame aggregated onto a GIS of the street network. A variety of temporal resolutions are provided, with the hourly data aggregated to weekend, weekday, monthly and annual summaries. The summaries are linked to a road segment ID and to a node (intersection) ID so that they can be tagged to the Agency's road network in GIS. For convenience, the road network that the IDs come from is also provided with the delivery in a variety of GIS formats. Between the first delivery and the second delivery, the road network was improved through interactions with VTrans GIS section, and off-road facilities like shared-use paths were added. Therefore, only the 2016 delivery was used for the analysis in this project.

For this project, the road network shapefile provided with the data was used, along with the overall annual total for 2016, for both cyclists and runners, linked to VTrans' road segment ("Edges") IDs:

- vtrans_201601_201612_ride_rollup_total.csv
- vtrans_201601_201612_ped_rollup_total.csv

There are 85,780 links in the Vermont GIS provided with the Strava Metro delivery. In the 2016 data, annual cycling totals are provided for 53,892 of these links and annual running totals are provided for 44,589 of these links. The average annual total runners in the dataset is 11.3 athletes per year and the average totals cyclists is 65.8 athletes per year. The average daily sum of these datasets was 0.21 athletes per day.

3.1.5 GIS Data Resources and Multiuse Path Inventory

Spatial analyses to inform new count site selection required an assembly of GIS data resources. Although it was sought, there is no comprehensive non-motorized facility inventory for Vermont. Non-motorized activity occurs on Vermont's road network as well as established on- and off-network multiuse paths, sidewalks, crosswalks, bridges, tunnels, and trails. These dedicated non-motorized facilities range from sidewalks adjacent to Class 1 Town Highways in village centers to single-track mountain bike trails in rugged trail networks. CCRPC has developed a sidewalk and bikeway GIS inventory for Chittenden County, but the state as a whole is lacking a similar product. Because an inventory of all dedicated facility types was not available, the focus of this effort was to gather information regarding on- and off-network facility types that have already been targeted for counting. Essentially, the effort concentrated on a typology for the road network and inventory of multiuse paths. Future efforts should consider all on- and off-network non-motorized facility types.

The most recent road centerline data (TransRoad_RDS) from the Vermont Open Geodata Portal was used as the basis for a road network facility inventory (VCGI, 2017). This data layer is maintained and updated by VAOT to match the official highway mileage mapping, making it the recognized source for accurate VAOT road classification information. The VAOT road classification (AOTCLASS) was used to identify the different general classes of on-network facilities available for walking and biking, including US Highway, State Highway, Class 1, 2, 3, and 4 Town Highway, National or State Forest Highway, and Private. Note that Interstate highways were not considered based on their prohibitive access for non-vehicular modes. In addition, due to the lack of additional information at this time, locations with on-network, dedicated facilities like sidewalks were coupled with their adjacent road class (i.e. no distinction between State Highways with or without an adjacent sidewalk).

For off-network, dedicated bike and pedestrian facilities, predominantly multiuse or shared-use paths in this case, an inventory of multiuse paths was assembled. The inventory of multiuse paths in Vermont was developed based on data from TrailLink (Rails-to-Trails Conservancy, 2017), supplemented by the Chittenden County Bikeway Shapefile (provided by CCRPC) and locations with other known shared use paths (verified and measured with Google Maps). The facilities included in the current multiuse path inventory are listed in Table 5, totaling approximately 240 linear miles of dedicated bicyclist and pedestrian infrastructure.

Table 5. Multiuse path facility inventory with associated trail name, town jurisdiction, length in miles, data source, and whether a count has been conducted on a site along the facility to date.

Town	Trail Name	Length (mi)	Existing Counts?	Source
Colchester	Airport Park Trail	1.5		TrailLink
Alburg	Alburg Recreational Rail-Trail	3.5		TrailLink
North Hero	Allen Point Access Area Trail	1.25		TrailLink
Burlington	Arms Park Trail	1.4		TrailLink
Burlington	Bank Street Extension Path	0.3	✓	Chittenden Bikeway
Middlebury	Battell Woods Trail	5		TrailLink
Newport	Beebe Spur Rail Trail	4	✓	TrailLink
Bennington	Bennington College Back Path	0.5	✓	Google Maps
South Burlington	Butler Farms Path	1.7		Chittenden Bikeway
Cambridge	Cambridge Greenway	1.4		TrailLink
Colchester	Colchester Bayside to Village Path	3.8		TrailLink
St. Albans (Town)	Collins Perley Path	1.5	✓	Google Maps
Multiple	Cross Vermont Trail	0		TrailLink
Multiple	Delaware and Hudson Rail-Trail	23.5		TrailLink
South Burlington	Dorset Street Path	2.2	✓	Chittenden Bikeway
Searsburg	East Branch Trail (VT)	5.1		TrailLink
Bennington	East Road Path	0.9	✓	Google Maps

Town	Trail Name	Length (mi)	Existing Counts?	Source
Essex	Essex Bike Paths	4.7		TrailLink
Burlington	Ethan Allen Park Trails	4		TrailLink
South Burlington	Farrell Park Path	1		Chittenden Bikeway
Hartford	Hartford Avenue Recreation Path	1	✓	Google Maps
Wilmington	Hoot, Toot and Whistle Trail	0.5		TrailLink
Burlington	Intervale Trail	2		TrailLink
Multiple	Island Line Rail Trail	14	✓	TrailLink
Richmond	Johnnie Brook Road Trail	0.7		TrailLink
South Burlington	Kennedy Drive Path	1.8	✓	Chittenden Bikeway
Multiple	Lamoille Valley Rail Trail	35.5	✓	TrailLink
Manchester	Lye Brook Falls Trail	2.2		TrailLink
Williston	Marshall Avenue Bike Path	1.4		TrailLink
Middlebury	Means Woods Trail	0.5		TrailLink
Barre (Town)	Millstone Hill West Bike Path	2.4	✓	TrailLink
Multiple	Missisquoi Valley Rail-Trail	26.1	✓	TrailLink
Multiple	Montpelier & Wells River Trail	21.8		TrailLink
Montpelier	Montpelier Recreation Path	1.7	✓	TrailLink
Newport	Newport Bike Path	0.8	✓	Google Maps
Colchester	Niquette Bay - Allen Trail	0.6		TrailLink

Town	Trail Name	Length (mi)	Existing Counts?	Source
Morristown	Oxbow Trail	0.5	✓	Google Maps
South Burlington	Park Road Bike Path	1	✓	Chittenden Bikeway
Burlington	Riverside Avenue Bike Path	1.1	✓	TrailLink
Burlington	Route 127 Path	3.2	✓	TrailLink
Rutland	Rutland Amtrak Path	0.3	✓	Google Maps
Rutland	Rutland Creek Path	0.6	✓	Google Maps
Shelburne	Shelburne Bay Park Rec Path	3.5		TrailLink
Barre	South Barre Bike Path	1	✓	TrailLink
South Burlington	South Burlington Rec Paths	0		TrailLink
South Burlington	Spear Street Path	1.8	✓	Chittenden Bikeway
Stowe	Stowe Recreation Path	5.3	✓	TrailLink
Swanton	Swanton Recreation Path	1	✓	TrailLink
South Burlington	Szymanski Park Path	1.1	✓	Chittenden Bikeway
St. Johnsbury	Three Rivers Bike Path	1.5		TrailLink
Shelburne	Ti-Haul Trail	1		TrailLink
Springfield	Toonerville Rail-Trail	3.1	✓	TrailLink
Burlington	UVM Shared-Use Paths	3.8	✓	Chittenden Bikeway
Dover	Valley Trail	0.8		TrailLink
Essex Junction	VT 15 Bike Path	1	✓	Google Maps

Town	Trail Name	Length (mi)	Existing Counts?	Source
Bennington	Walloomsac Pathway	0.4	✓	Google Maps
Multiple	West River Trail	16		TrailLink
West Rutland	West Rutland Recreation Path	0.3	✓	Google Maps
South Burlington	Williston Road Path	1.3		Chittenden Bikeway
Williston	Williston Village Bike Paths	3.6		TrailLink
Middlebury	Wright Park Trail	3.8		TrailLink

Researchers explored the use of the Strava shapefile to inform the dedicated facility inventory. The Strava shapefile is a VAOT geographic file representing all facilities available to non-motorized activities and provided to Strava Metro to enable the application's user data to be snapped to a network link. In its current form, the geographic file has a large inventory of designated non-motorized travelways (AOTCLASS = 101), totaling 2,651 miles. This includes mountain bike trail systems and long distance hiking trails like the Long Trail, but lacks attributes differentiating between facility types, like paved multiuse paths versus rugged hiking trails. Therefore, the current use of the Strava data resource is limited, with noted opportunity for future improvement and use. Most notably, the Strava shapefile may be well-suited to get a reasonable estimate of the other non-motorized, off-network trails available in Vermont, mainly for the purposes of hiking, mountain biking, and cross-country skiing. Until more data for off-network walking and biking is incorporated into the bicyclist and pedestrian database, focus remains on multiuse paths that are either on-network (i.e. side paths) or off-network and resemble typical rail-trail or recreation path design (i.e. not single-track, rugged-terrain trails).

In addition to the road centerline GIS data, other general mapping data was gathered from the Vermont Geodata Portal, including town, county, and RPC boundary layers (VCGI, 2017). Additional map making layers, like waterways, were assembled from the Caliper Corporation base data, available through a Caliper TransCAD license.

3.2 Data Collected During this Project

3.2.1 Stakeholder Focus Group for Data Web Portal

To support the development of the data web portal, a focus group meeting was convened on November 30th, 2016. The purpose of the meeting was to provide a project summary, including an overview of best practices in data wbeb portals for non-motorized traffic counts, and to answer questions about the project, and to solicit input on the requirements of the portal. The following stakeholders were present:

- David Saladino, VHB
- Nicole Losch, City of Burlington
- Chris Dubin, CCRPC
- Katelin Brewer, Local Motion
- Corey Line, City of Montpelier
- Jon Kaplan, VTrans
- Nicholas Meltzer, VTrans
- Maureen Carr, VTrans
- Sommer Raefaro, VTrans

A variety of interactive, "dashboard"-like formats for viewing NMT counts were shown, and the pros and cons of each were discussed, including:

- Delaware Valley Regional Planning Commission: http://www.dvrpc.org/webmaps/pedbikecounts

- Washington State DOT: http://wsdot.wa.gov/data/tools/bikepedcounts/

- Southern California Association of Governments: http://www.bikecounts.luskin.ucla.edu/

- Central Lane MPO Area (Eugene, Oregon): http://www.thempo.org/356/Bicycle-Counts

- Bike Arlington http://www.bikearlington.com/pages/biking-in-arlington/counting-bikes-to-plan-for-bikes/counter-dashboard/

The following questions were presented to each of the attendees as a prompt for input, and each attendee was given the opportunity to respond:

- Do you use bike-ped count data in Vermont in your work?
    - How have you used it?

    - What features of an online web portal for statewide data would have been useful to you?

- Would you use bike-ped count data in new ways if it were more readily available?
    - What features of an online web portal would make a potential future use better for you?

Based on the input received during the meeting, it was determined that a map-based tool, with site info that comes up when a site is selected, is preferable to meet stakeholder needs. The portal should allow the viewer to easily display the count site location with a photograph and count summary data accessible when a site is selected. Stakeholders also wanted to be able to access the data through a download feature.

For interoperability, a subset of the stakeholders also expressed a need for a tool that would allow the user to identify nearby counts on similar infrastructure when an existing count site, or a random point where no count exists, is selected. From these counts, it would also be desirable for summary information, like the average count for all of the proximate sites, to be displayed. Other desired features of the tool included:

- Include VTrans projects as a layer to show (points and segments) and bike-ped crash data as a layer to show (points)
- "All data" download
- Symbology for site points based on ADT (bike/ped); three-tier color coding based on volume (use the tiers from the On-Road Bike Plan)
- When a random point is selected, records the coordinates of the point in a “count-request” table.
- Make intersection-based counts into segment-based
- Display estimated counts at a random location based on the average of nearby locations and/or the location characteristics relevant to bike/ped activity
- Forecast: growth in counts based on growth in relevant demographics and infrastructure at the site
- Before/After Analysis:
    - Past: Enter a date in the past for a site with counts and get Site Counts before and after that date

  - Future 1: Enter a date in the future for a site with counts and get the projected Site Counts after a project is built on that date
  - Future 2: Enter a date in the future for a site without counts and get the estimated & projected Site Counts before & after a project is built on that date
- Incorporate other spatial data layers from VTrans, including:
  - Crashes involving a cyclist or pedestrian
  - Roadway projects from VTransparency

It was also agreed during the meeting that approximately once a quarter, or once every six months, newly entered data should be incorporated into the master database, and the web portal should be updated with new sites and new count summary information. Every 6 months or once a year, the other spatial data layers included on the web portal display should also be updated.

3.2.2 Validation of Automated Infrared Count Data

In order to support the validation of the automated infrared count data collection devices, which are used frequently in Vermont to collection long-duration counts, simultaneous Eco Counter and manual video data was collected for comparison. On May 11 and 12, 2017, an Eco Counter and a closed-circuit video camera were co-installed to observe non-motorized traffic on a sidewalk on Colchester Avenue in Burlington. One frame of the video is provided in Figure 8, with the Eco Counter visible attached to a sign in the green strip between the sidewalk and the travelled way.

Figure 8. Video data validation of the EcoCounter attached to the sign post in the frame above.

The video files were reviewed at 4x their collection speed, and a tally of total cyclists and pedestrians passing the Eco Counter was logged, using a MS Excel form developed for this purpose. Total counts were recorded, along with the direction of travel, in 15-minute increments to align with the output produced by the Eco Counter. A total of 27 hours of video was reviewed.

4 Methodology

4.1 Database Development and Estimation of Site Summary Parameters

The manual counts, automated infrared counts, and video manual counts were synthesized into a common database. The database structure then sets the standard for future data collection statewide. To the extent possible, national standards for non-motorized count database structures were maintained. This standardization meant that new site IDs, based on the geographic location of the count site, were established to be consistent with national standards. The new IDs incorporate the state & county subdivision (town) portions of the official ANSI code. So each of the site IDs begins with a “50” to identify that it is in Vermont, then contains a five-digit ANSI code to identify the town, and then contains a 3-digit sequential number to indicate the order that it was considered or entered into the database for that town. This geographic identification system will allow Vermont’s sites to stand alongside those in other states without losing their state identification. In addition, the ANSI codes are easily available for any other state to download and map (US Census Bureau, 2010).

Following the establishment of the new site IDs, the standard data fields in the database were checked for completeness and consistency. Where problems were identified, data was manually added or edited to fit the standard. All of the edits increased the amount of information available about each site – no discernible descriptive or identifying information was removed. For example, obviously misspelled town names were edited to a common spelling, so that database filtering would work effectively.

New sites were also added from the historic manual count data where the precise location of the site could be ascertained from the available information. For some manual counts, the precise location could not be determined, so the data was left out. In this case, it is expected that the RPC responsible for the data collection will add it at a later date.

Finally, a spatial check was conducted to identify co-located or otherwise duplicate sites. Since the sites in this database are screenline counts, previously separated sites on either side of a roadway were merged into the same site ID, and their data was combined. In some cases, geographic identifying information like latitude and longitude were found to be inconsistent with the descriptive information about the site location, so the coordinates were edited to match the descriptive information. Table 6 provides the precise number of records and the attributes in each data table in the database.

Table 6. Vermont Bicycling and Pedestrian Count Database Structure

Site Data (194)		
SITE_ID	FACILITY_NAME	DESCRIPTION
COUNT_TYPE	LOCATION	ADT
TOWN	SEGMENT_TYPE	PHT
RPC	PRIMARY_FACILITY_TYPE	PDT
LATITUDE	PRIMARY_PAVED	Duration
LONGITUDE	SECONDARY_FACILITYTYPE	SITEVIEW
	SECONDARY_PAVED	

Auto Infrared Data (519,907)	Manual Data (1,236)	Video Manual Data (32)
SITE_ID	SITE_ID	SITE_ID
Name	COUNT_ID	Town
Interval	DATE	Road
Date/Time	COUNT_START	Date
Total	COUNT_END	Duration
IN	DURATION	EB/NBBikes
OUT	DURATION_UNIT	EB/NBPeds
	TOT_PED_DIRA	WB/SBBikes
	TOT_BIKE_DIRA	WB/SBPeds
	TOT_PED_DIRB	TotalBikes
	TOT_BIKE_DIRB	TotalPeds
	PK_HR_START	Total Bike/Ped
	PK_HR_PED_DIRA	MaxDaily
	PK_HR_BIKE_DIRA	PHT
	PK_HR_PED_DIRB	
	PK_HR_BIKE_DIRB	
	FLAG	
	EntireCount	
	PeakHourCount	

Once all of the synthesizing and checking was completed, four site summary parameters were calculated for display on the data web portal – the ADT (average daily traffic, or the average of any full calendar days of counts), the PHT (peak hour traffic, or the highest count in a single 60-minute period, or 4 consecutive 15-minute periods, at this location), the PDT (peak daily traffic, or the highest count in 24 consecutive 60-minute periods at this location), and the Duration (total hours of counting conducted at this location). The specific formulae for the calculation of these parameters are provided in Appendix A. The results of the database development and the site summary parameters are in Section 5.1.

4.2 Development of Data Web Portal

A web portal was developed with an html index script that enlists map tiles from OpenStreetMap and CartoDB (now CARTO), and aerial imagery from USGS to view and interact with the Site Data in a GIS web environment. The data mapper also uses Bootleaf, an application template for building web mapping applications with Bootstrap and Leaflet, coded by Bryan McBride, and code snippets developed by Ricardo Oliveira using Turf, a modular geospatial engine written in JavaScript. Individual site views are provided with a live link to Google Streetview. The PHT Averager Tool is an open-source Javascript tool found on Leaflet, an open-source JavaScript library for mobile-friendly interactive maps.

The tool includes a number of useful features for viewing and accessing data. Count locations are indicated by colored circles on the map, showing their approximate locations in yellow for areas with more than 10 sites, and green for areas with less than 10 sites (Figure 9).

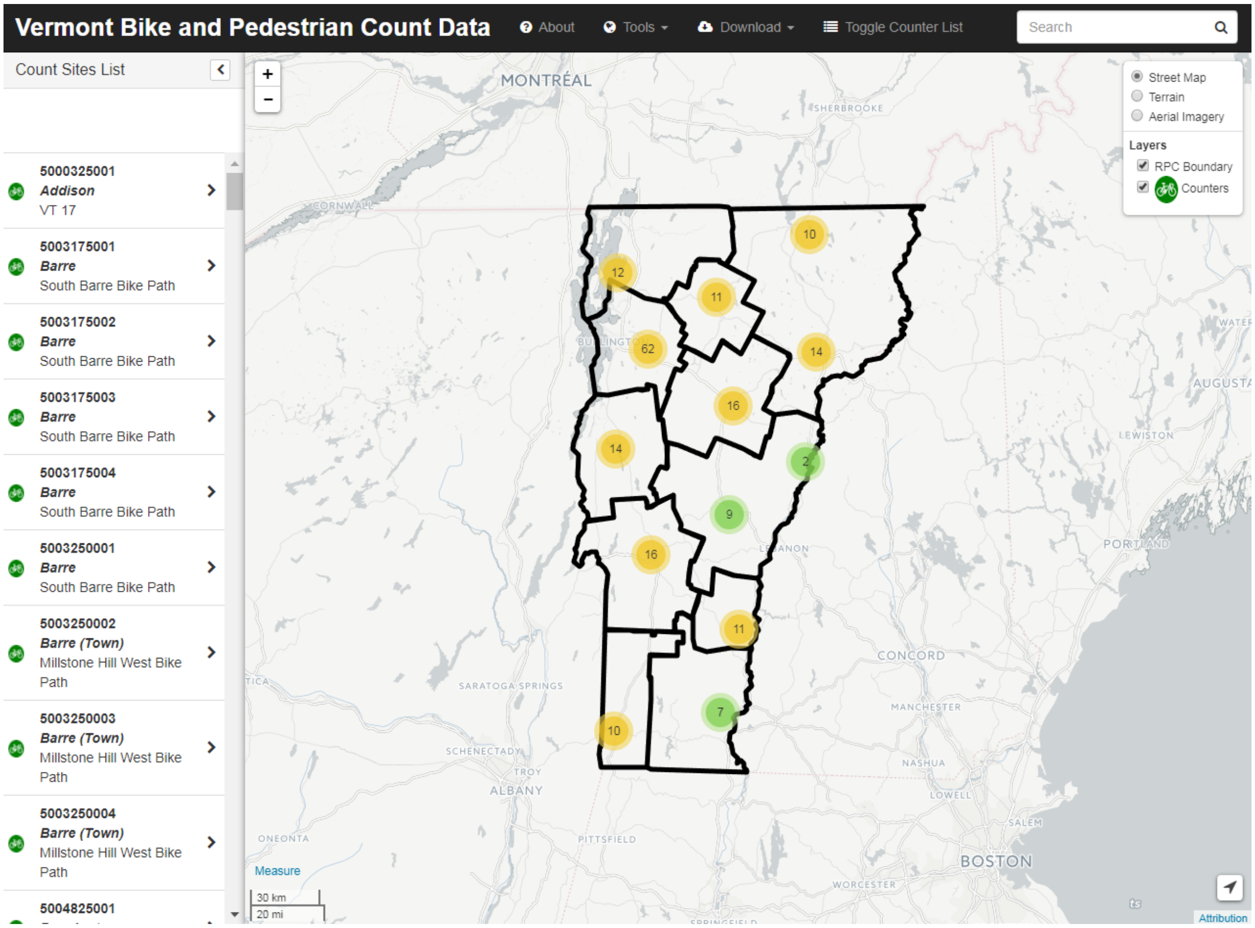


Figure 9. Vermont Bike and Pedestrian Count Data web portal map view of count locations.

The map can be re-scaled using the +/- buttons in the upper left, or zoomed with a double-click. Upon zooming in on a set of locations, individual sites become more distinct. The background imagery can be toggled between a street map, a terrain map, or aerial imagery with the radio buttons at the upper right. Also on the upper right, the user can choose to hide or display the RPC boundaries, and the count locations themselves.

Once zoomed in, a green bicycle symbol will indicate the location of a specific site. As shown in Figure 10, clicking on the symbol brings up the details of the site, including the Site ID, the RPC and Town where the site is located, the Location and Counter Types, and the ADT (average daily traffic, or the average of any full calendar days of counts), PHT (peak-hour traffic, or the highest count in a single 60-minute period, or 4 consecutive 15-minute periods, at this location), PDT (peak daily traffic, or the highest count in 24 consecutive 60-minute periods at this location), and Duration (total hours of counts at this location).

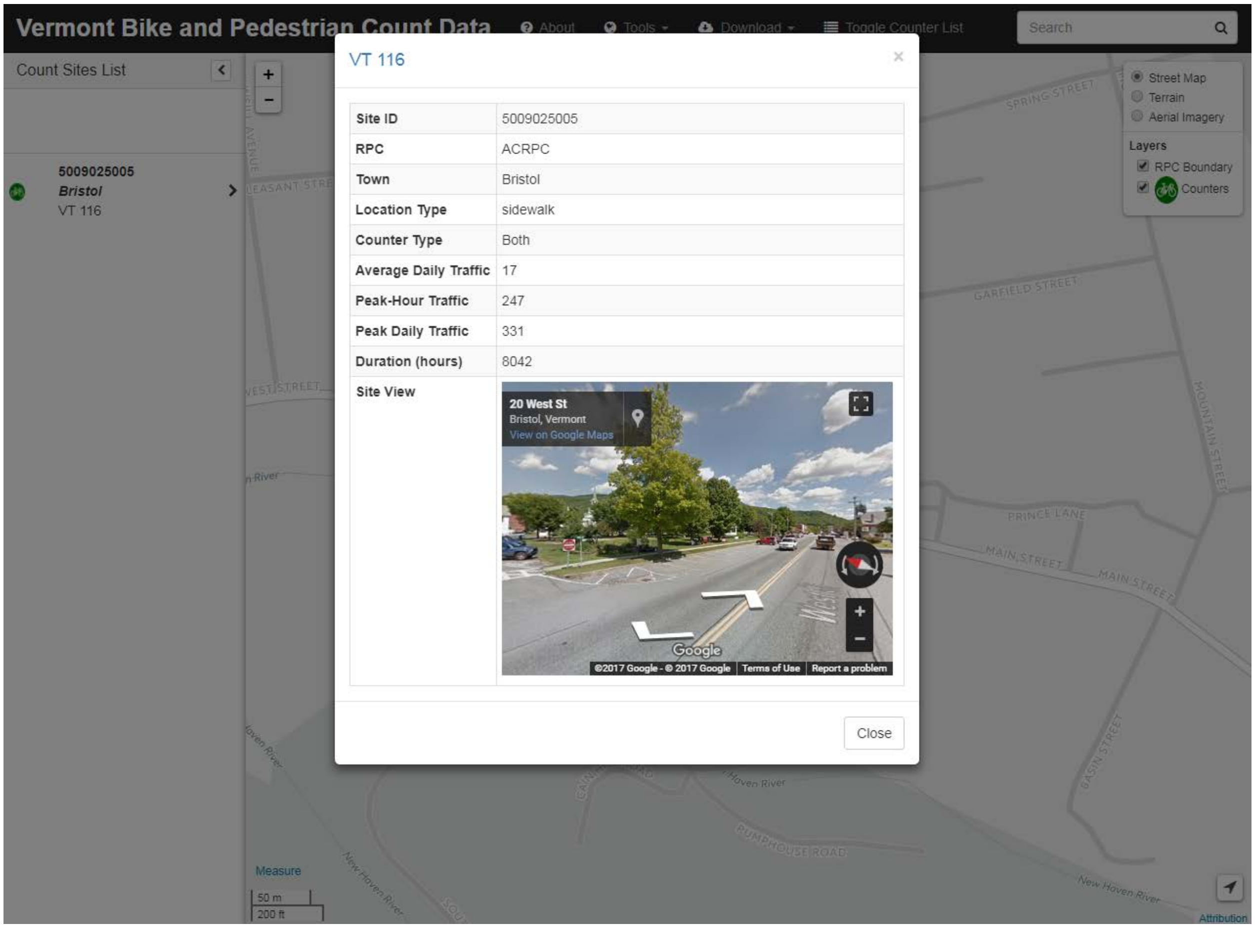


Figure 10. Vermont Bike and Pedestrian Count Data site detail.

The Site View is an image of the site from Google StreetView (if available), or from Google Maps. This image is an actual link to the Google view, so it will update automatically as Google's imagery is updated.

Three additional tools are available to supplement count analyses. First, the "Measure" tool at the bottom left calls up a link to "Create new measurement" when it is hovered over. Clicking on the link allows the user to set points on the map. As the points are set, information on the coordinates of the points, and the distances and/or areas between the points is provided. Second, a "PHT Averager" can be selected in the "Tools" dropdown in the top menu. Making this selection translates the view to a tool which displays the average PHT at a set of proximate sites by dragging the bicycle symbol and its buffer over the set of sites (Figure 11).

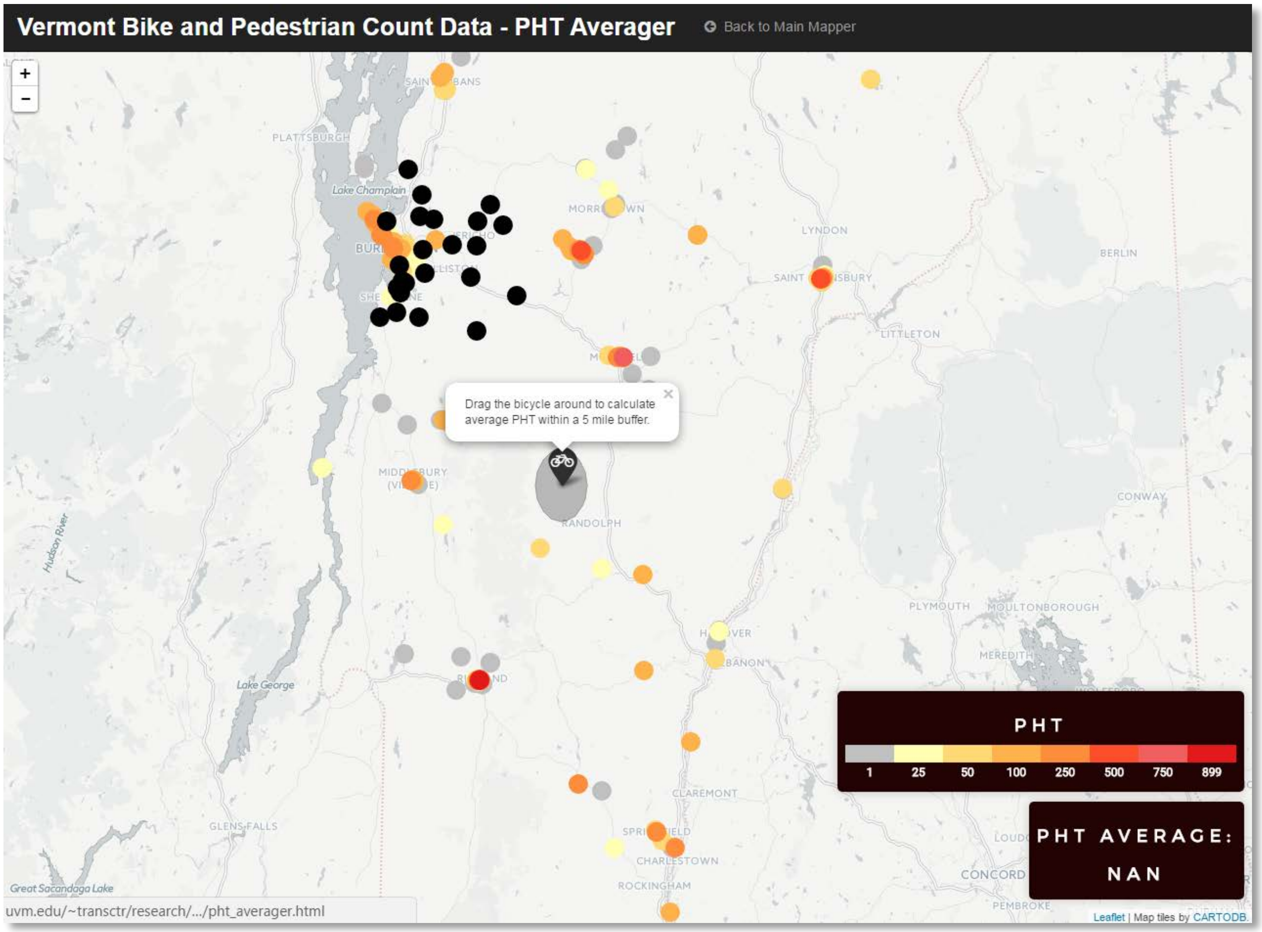


Figure 11. Peak-hour travel averager, which takes the average PHT for all of the sites that fall within the gray shadow area, representing a 5-mile radius.

Return to the standard view by selecting "Back to Main Mapper" at the top. Finally, for additional analyses, the data itself can be downloaded to an Excel file by clicking on the "Download" dropdown on the top menu, then selecting the desired data.

4.3 Development of Data Input Tool

It is anticipated that many individuals affiliated with multiple organizations will be in the field, collecting the non-motorized data across the state. In order to achieve organized and uniformly-formatted data input from many different resources, controlling the input data accepted by the Agency was critical. The team investigated options for controlling data input. The primary criteria for selecting a suitable platform included:

- End user ease of use;

- Fixed response to control input format;
- Mandatory response options;
- Control logic to limit burden; and,
- Method for pinpointing map location.

There are many platforms that are able to achieve some or all of the above criteria. Google Forms is a free and ubiquitous option; however, the platform lacks control logic to either eliminate or enable questions based on previous answers. There are hundreds of options for survey tools and software that have control logic available on the market. Survey administrators at UVM have selected LimeSurvey as the open source tool for administering surveys for research purposes. LimeSurvey met all of the criteria and, with our UVM affiliation, was able to be designed and administered from UVM's secure and redundant servers. Prior to downloading the survey responses (input data from end users) directly by a survey administrator, the data will be stored in an SQL database on the UVM server. From the administrator's portal on LimeSurvey, the data will then be directly downloaded for use, with the original copy of the data remaining on the UVM system. The same system can be set up for use by VAOT on VAOT servers, as the LimeSurvey survey design is open source and exportable, meaning it can be imported to direct VAOT administration at any time.

The design of the data input tool was done in conjunction with the design of the database and its attributes. Information critical to the site and count descriptions were well defined and properly formatted through the input tool. This included controlling response options where possible to limit the potential for erroneous data. Quality data inputs ensure quality assurance procedures and transfer of data to the database are simple and straightforward in the future.

For the historical data gathered for this effort, the most prevalent issue was the connection of data, particularly from automated counting devices, to a physical location. Much of the EcoVisio data that was gathered did not have any location data affiliated with the counts. In addition, automated counters are often set up in a temporary data collection scenario where setup and take down procedures or previous installation data may be included in the raw count data. If additional information about the active count period are not reported, these data are impossible to validate. Thoughtful design on data inputs will help to alleviate these data attribution issues in future data gathering efforts.

This section guides users through the input portal step-by-step and makes clarifications on the data inputs that users will expect to see in the portal. In addition, Appendix B contains a complementary field data sheet designed to be printed and filled out in the field. The information on the field data sheet is consistent with the data input tool to ease the burden of digital data entry. Also, an exhaustive list of the data input tool questions, data attributes and possible response options was included in Appendix E.

4.3.1 Data Input Information

The first page of the data input tool, Figure 12, will prompt the user to identify their affiliation and provide contact information. This information will be securely stored along with the count data in the data upload, but will not be pushed to the database or shared through the data portal. The reason for this request is simply to have access to contact information in case follow up is necessary to ensure quality data is transferred to the database.

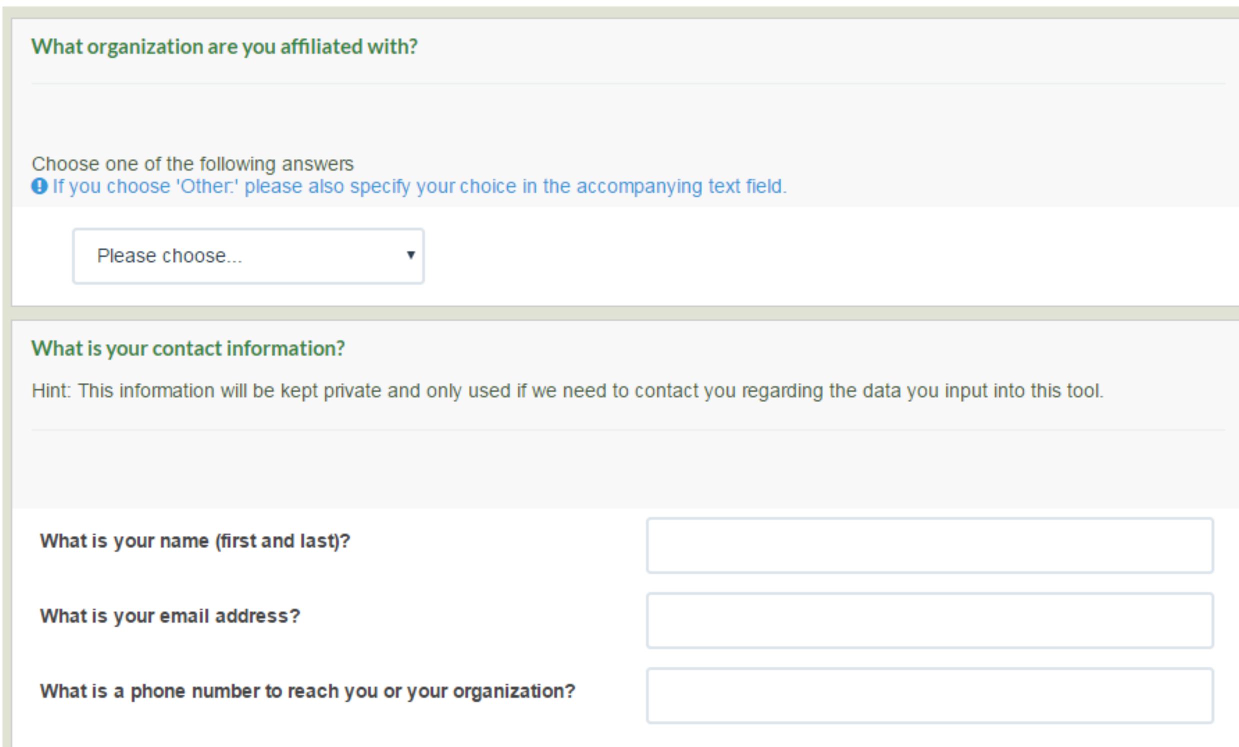


Figure 12. The Data Input Information section of the data input tool prompts the user for their affiliation and contact information.

4.3.2 New or Repeat Site Location

There are already nearly 200 site descriptions populated in the database. In many cases, these sites are visited annually to conduct counts, creating a unique, longitudinal data set. To save time, particularly for counts at sites revisited regularly, users will be able to either define a new site location or select an old site location. The selection of a *New Site Location,* as in Figure 13, will guide the user to the Site Location Data section of the input portal.

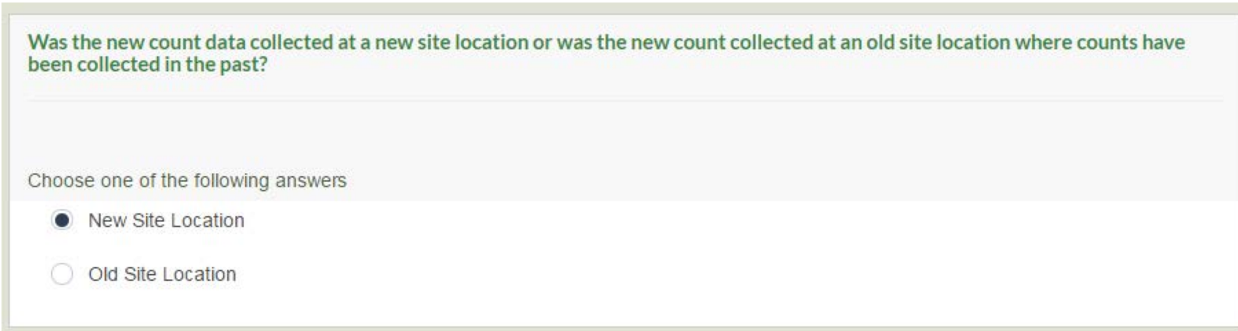
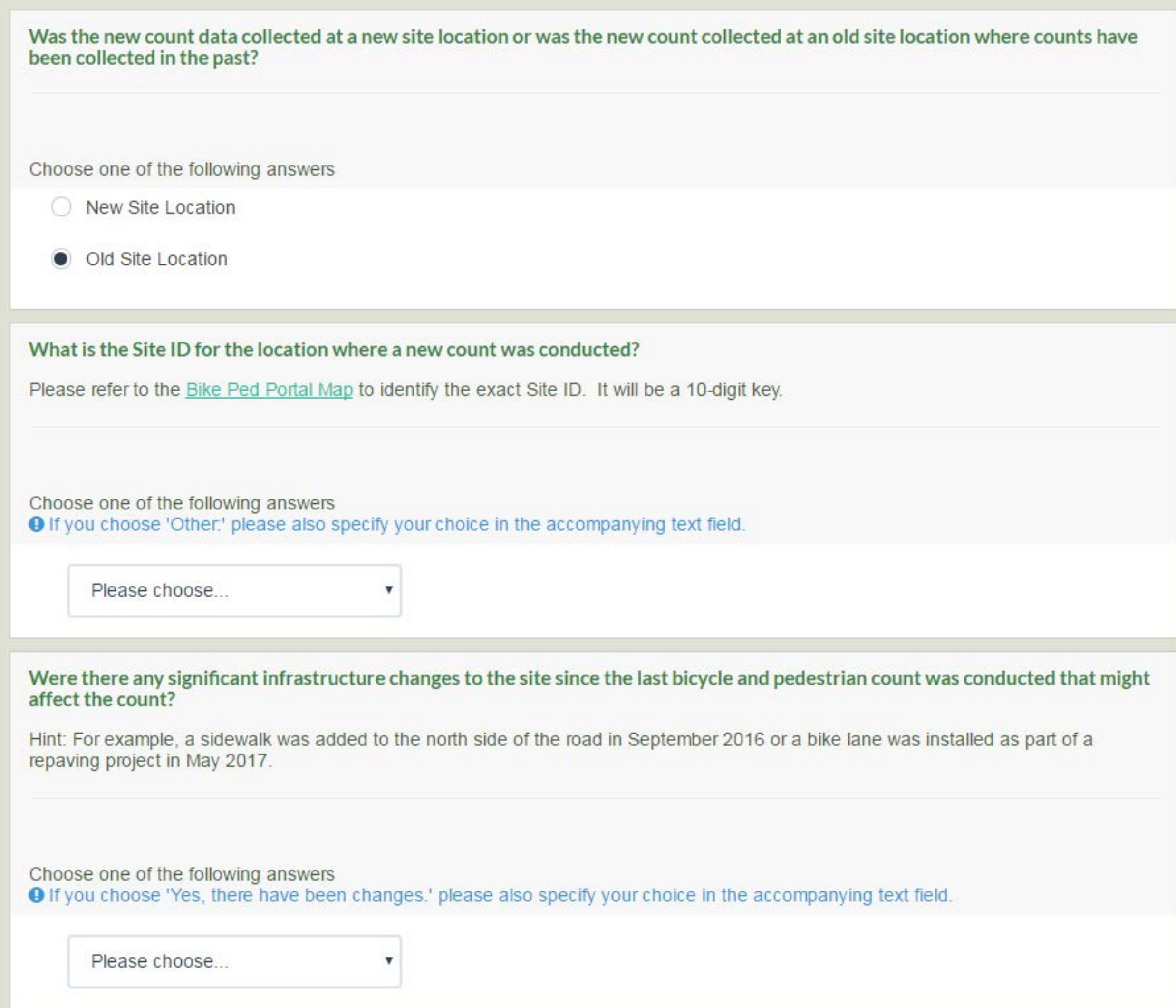


Figure 13. New Site Location selection will lead user to define the new site for the database.

If an *Old Site Location* is selected, as in Figure 14, a pull down menu is pre-populated with the 10-digit identification number of sites already in the database. A hyperlink to the data portal allows users to locate the site on the portal map and identify the site via the Site ID. Given that there are new projects every year implemented in the effort to better accommodate bicyclists and pedestrians, users are also prompted to provide any information about new infrastructure or changes to the bicycling and walking facilities available at the old site. With the selection of *Yes, there have been changes*, an open ended entry allows for a brief description of the change. The aim is to eventually flag these changes temporally; providing non-motorized usage rates before and after infrastructure improvements. These data will support the desire to understand return on investments for non-motorized facility improvements.



Was the new count data collected at a new site location or was the new count collected at an old site location where counts have been collected in the past?

Choose one of the following answers

- New Site Location
- Old Site Location

What is the Site ID for the location where a new count was conducted?

Please refer to the Bike Ped Portal Map to identify the exact Site ID. It will be a 10-digit key.

Choose one of the following answers

If you choose 'Other:' please also specify your choice in the accompanying text field.

Please choose...

Were there any significant infrastructure changes to the site since the last bicycle and pedestrian count was conducted that might affect the count?

Hint: For example, a sidewalk was added to the north side of the road in September 2016 or a bike lane was installed as part of a repaving project in May 2017.

Choose one of the following answers

If you choose 'Yes, there have been changes.' please also specify your choice in the accompanying text field.

Please choose...

Figure 14. Old Site Location selection will prompt the user for the Site ID from the Vermont Bike and Pedestrian Data Portal and ask if any changes in infrastructure have been introduced since the site was last counted.

4.3.3 Site Location Data

If the user selected *New Site Location* in Figure 13, they will go through a series of questions to define the new count location. If the user entered a Site ID from an exisiting location in the database, they will be able to skip ahead to the next section.

Definition of a new site location includes identification of the Town (Figure 15) and the RPC (Figure 16), which are pre-populated pull down menus to ensure proper format.

Figure 15. In defining a new site location, user is prompted to select one of the 255 towns in Vermont.

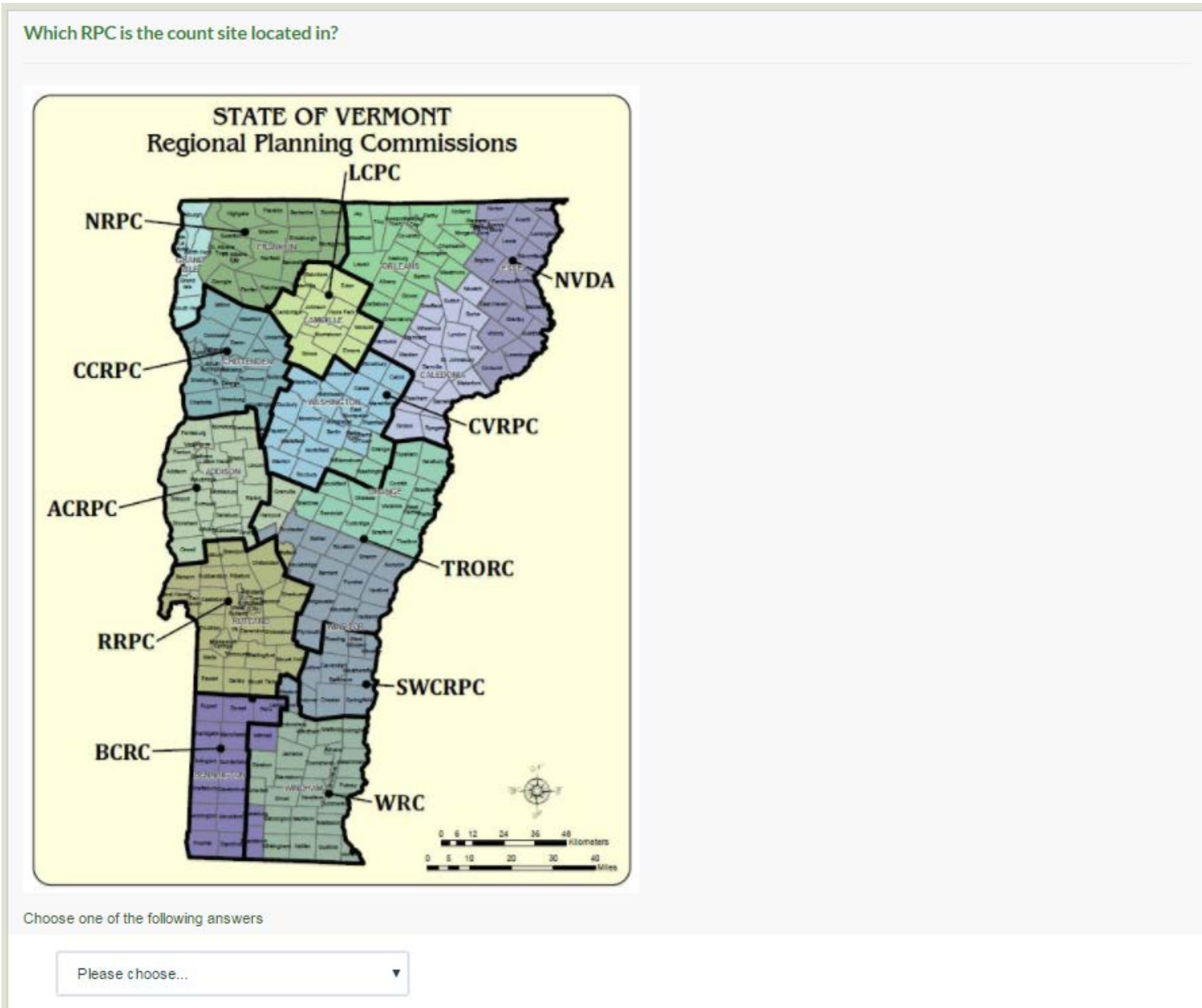
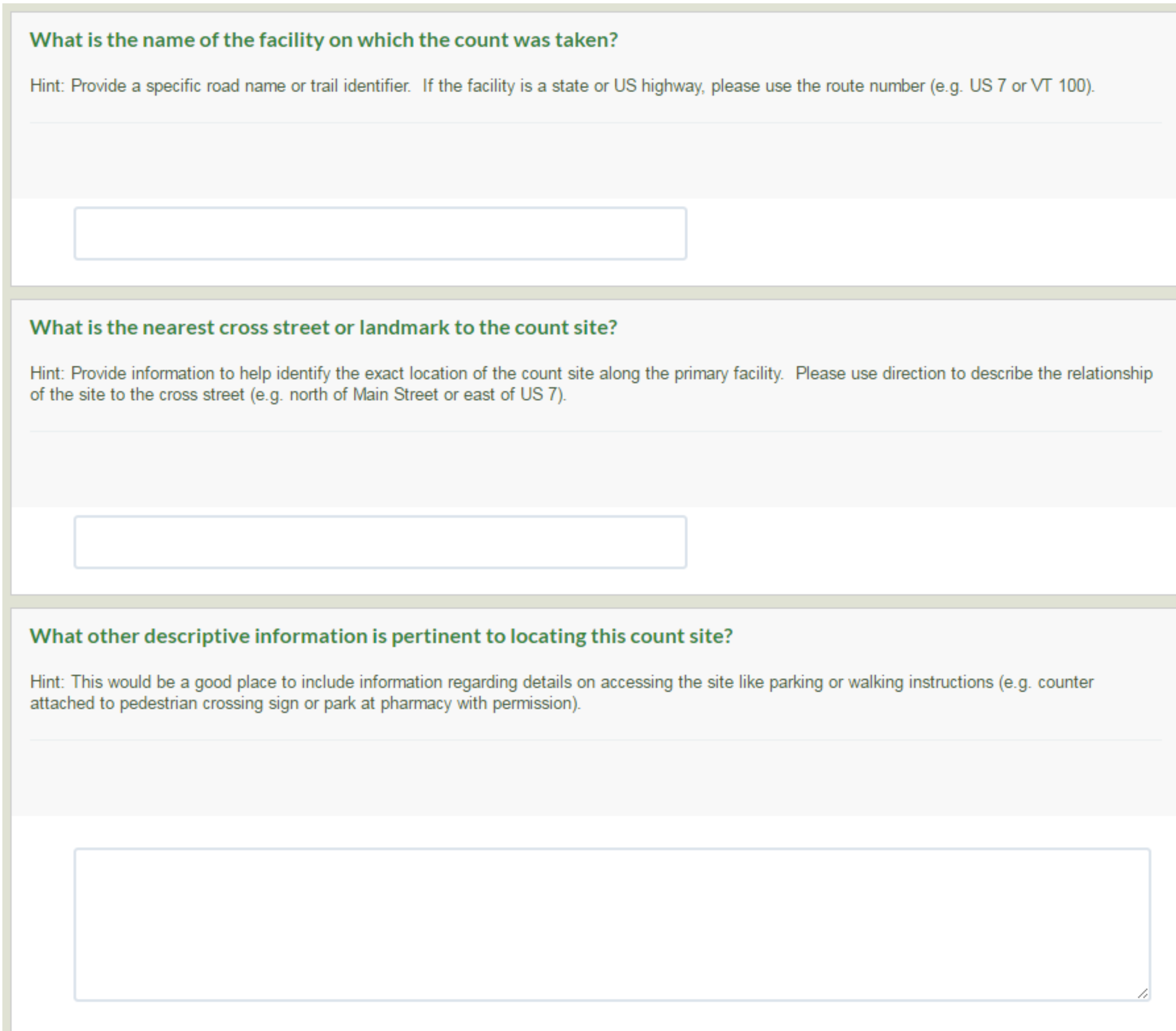


Figure 16. The map of the Regional Planning Commissions in Vermont accompanies the pre-populated pull down menu to select which RPC jurisdiction the new count site is located.

The facility name, nearest cross street or landmark, and site description are open ended entries, as shown in Figure 17. For the facility name and cross street, if applicable, use the route designation and number to identify the facility as opposed to the local name. For instance, use US 7 instead of Main Street.


What is the name of the facility on which the count was taken?

Hint: Provide a specific road name or trail identifier. If the facility is a state or US highway, please use the route number (e.g. US 7 or VT 100).

What is the nearest cross street or landmark to the count site?

Hint: Provide information to help identify the exact location of the count site along the primary facility. Please use direction to describe the relationship of the site to the cross street (e.g. north of Main Street or east of US 7).

What other descriptive information is pertinent to locating this count site?

Hint: This would be a good place to include information regarding details on accessing the site like parking or walking instructions (e.g. counter attached to pedestrian crossing sign or park at pharmacy with permission).

Figure 17. Open ended entries to define the facility name, nearest cross street or landmark, and additional description of the count site.

An interactive map then enables the user to pinpoint the exact location of the count, Figure 18.

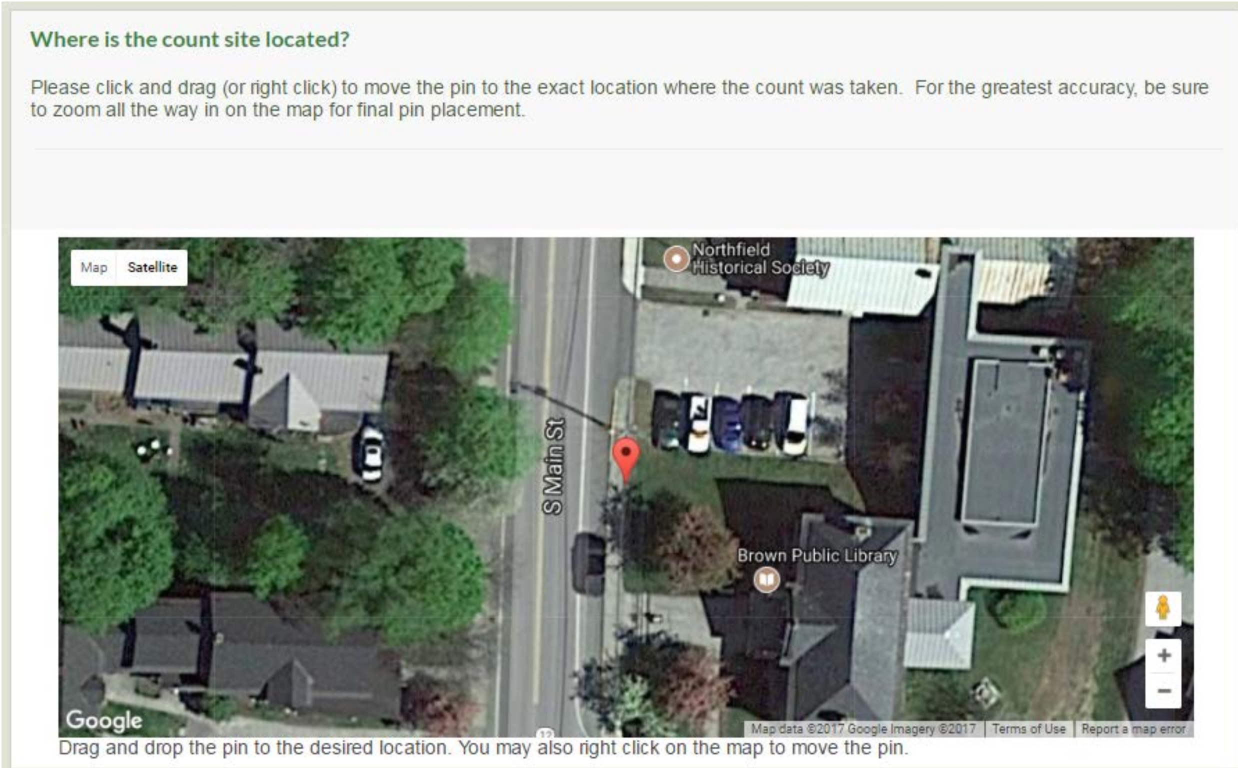


Figure 18. Interactive map to pinpoint the exact count location. In this example, the map is zoomed in all of the way with satellite view toggled on.

The pin can be moved by either right-clicking on the map or by click and dragging the pin. The pin should be placed at the exact location of the counter, whether automated or manual. The final placement should be adjusted with the map zoomed in all of the way. It is important to note that the user can toggle between map and satellite view to help pinpoint the location of the counter by identifying the surrounding landmarks. Having this feature allows the user to skip collecting latitude and longitude in the field if the description of the site is well-defined. The data field that is produce from this pin location includes latitude, longitude, town, and county.

If the count site facility shares the right-of-way with a vehicular corridor (e.g. the count facility is a sidewalk adjacent to a Class 1 Town Highway), the count site is considered *on* the road network. If a count facility does not share right-of-way with vehicle traffic, it is considered *off* of the network. Some facilities, particularly multiuse paths and sidewalks, change from on-network to off-network along the length of the facility. It is important that the user indicate whether the facility is *on* or *off* of the network at the exact location of the count. If on-network is selected, the user will be asked what the road classification and speed limit are at the count site, see Figure 19. The road classification question has a link to the town highway maps, in case the classification is not known users can look up the facility on the appropriate town highway map.

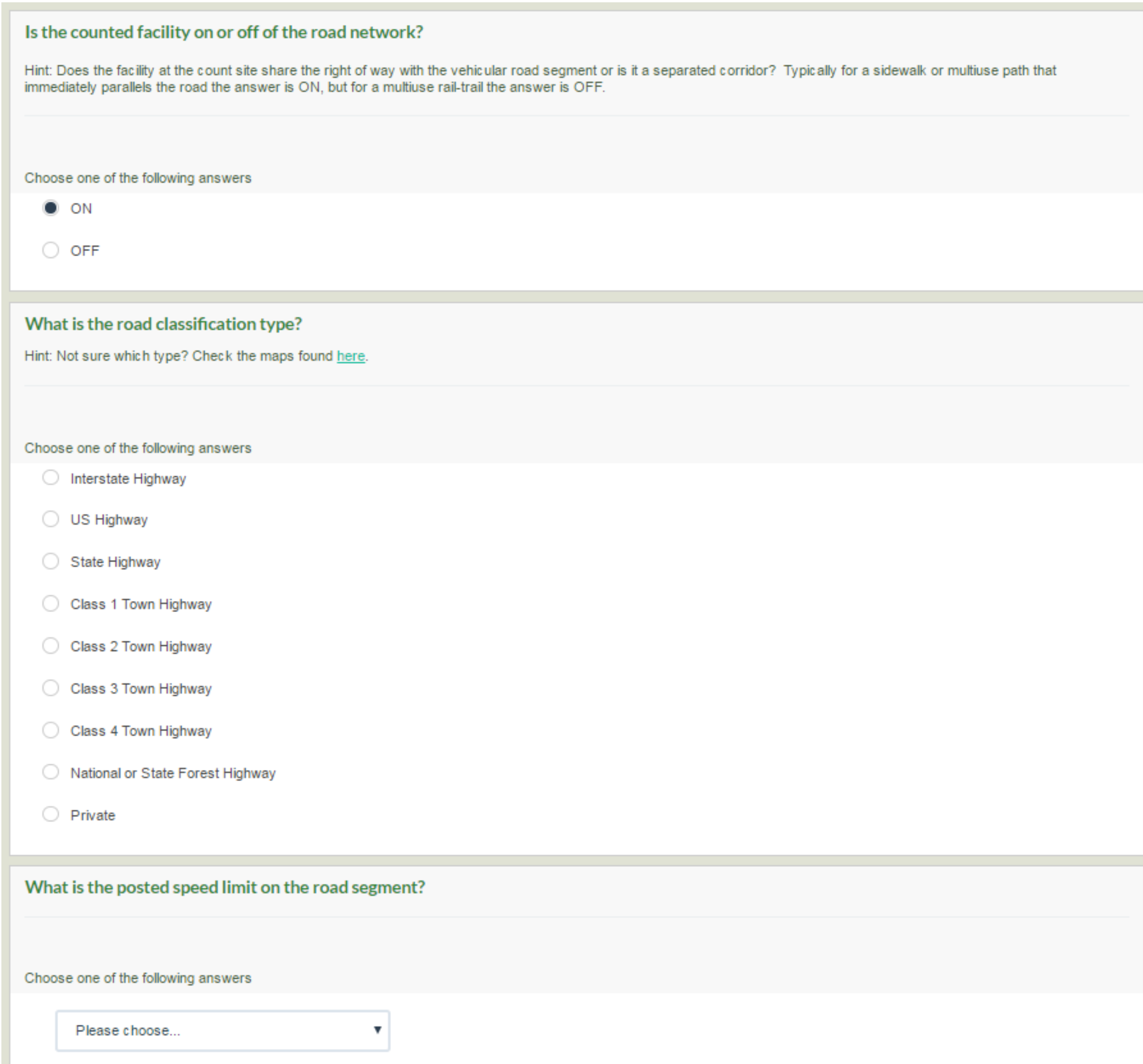
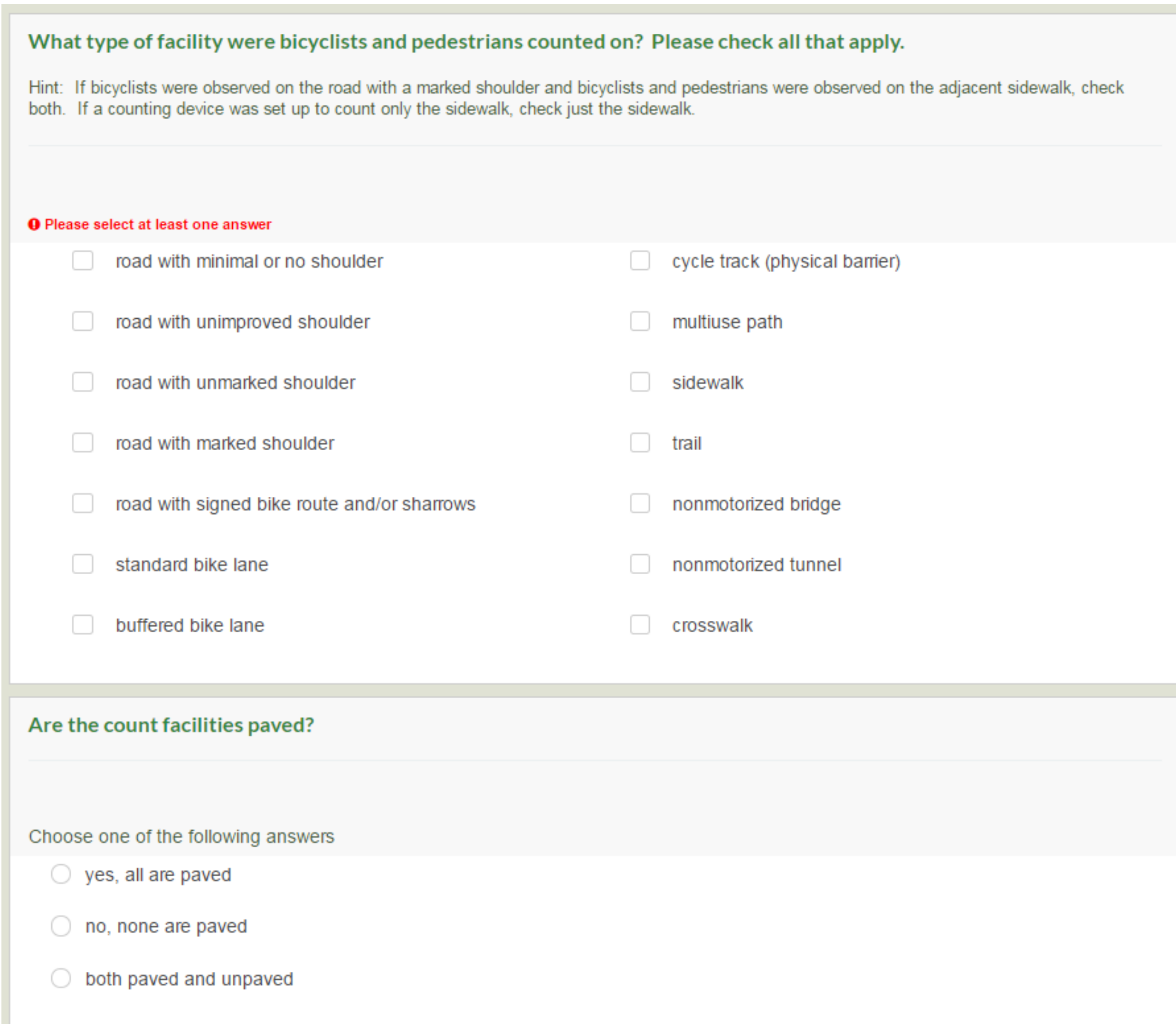


Figure 19. Defining the count facility as on-network will prompt the user to identify the road classification type and the posted speed limit.

4.3.4 Count Site Detail

The purpose of this section of the data input tool was to define information about the count location, specifically about the facilities at the site, that could potentially change count-to-count. The first set of questions help the user define all of the available facilities at a count site and distinguish between facilities that were included and not included in the count in this particular instance. The second set of questions defines the directions of travel for this particular count.

For the first question, Figure 20, the user selects all of the facility types available across the count screenline that were *included* in this specific count. The check all that apply feature allows users to select multiple facility types for cases where several facilities are available for and used by bicyclists and pedestrians.


What type of facility were bicyclists and pedestrians counted on? Please check all that apply.

Hint: If bicyclists were observed on the road with a marked shoulder and bicyclists and pedestrians were observed on the adjacent sidewalk, check both. If a counting device was set up to count only the sidewalk, check just the sidewalk.

Please select at least one answer

- road with minimal or no shoulder
- road with unimproved shoulder
- road with unmarked shoulder
- road with marked shoulder
- road with signed bike route and/or sharrows
- standard bike lane
- buffered bike lane
- cycle track (physical barrier)
- multiuse path
- sidewalk
- trail
- nonmotorized bridge
- nonmotorized tunnel
- crosswalk

Are the count facilities paved?

Choose one of the following answers

- yes, all are paved
- no, none are paved
- both paved and unpaved

Figure 20. Count site details Questions 1 and 2 define the facilities counted and if they are paved or not.

Given that there are more miles of unpaved facilities available for travel in Vermont than there are paved, the surface material on which non-motorized activity is occurring throughout the state is of interest. Therefore, users will select whether *yes, all were paved*, *no, none were paved*, or *both paved and unpaved* facilities were counted at the site.

In addition, users will be prompted to provide information regarding whether there were facilities available across the screenline at the count site that were *not included* in the count, Figure 21. Question 3 will ask if there were facilities that were available at the site, but not counted – *yes* or *no*. A *yes* will prompt Question 4 to appear, which will spell out which types of facilities were not counted at the site. The most common occurrence of this is a location where a sidewalk or multiuse path is adjacent to a road and an automated counter is set up to count the dedicated facility as opposed to all of those available in the full right-of-way cross section.

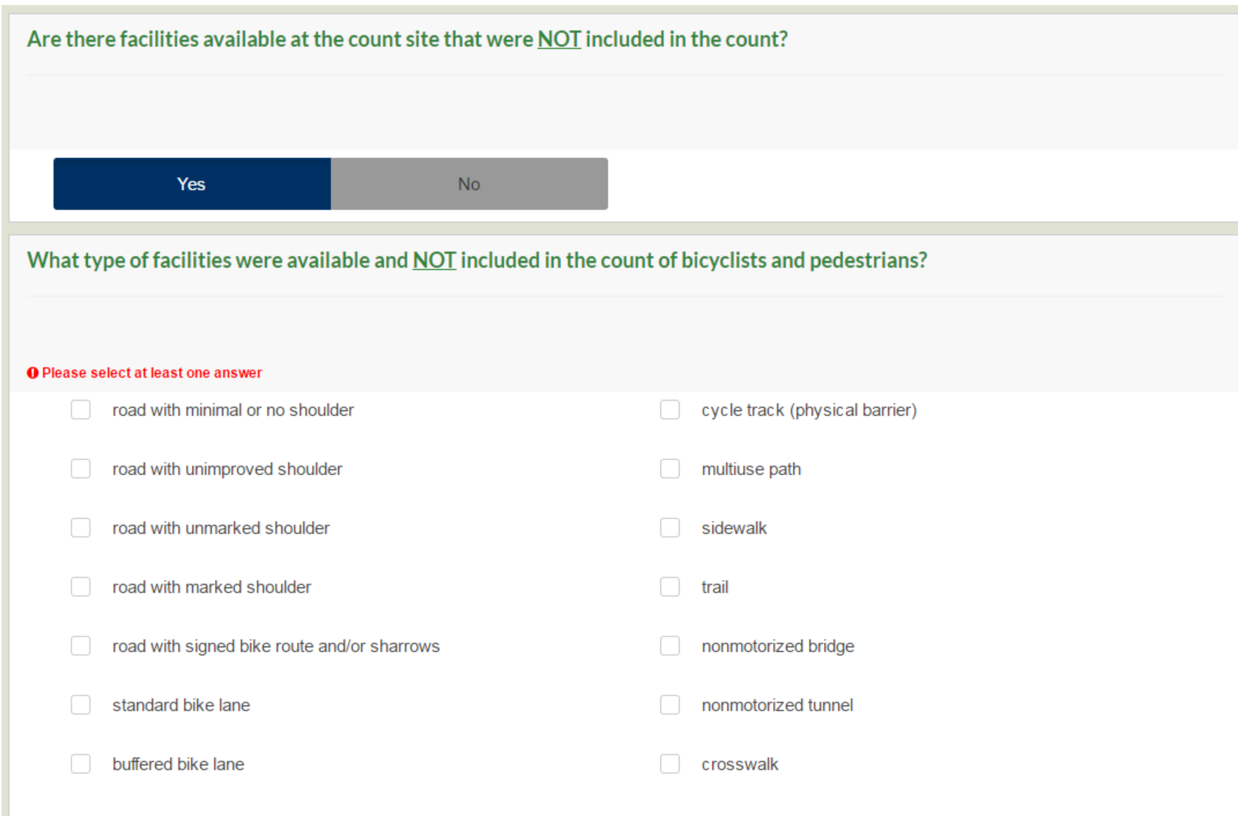


Figure 21. If facilities were not included in the count, but exist at the count site, the user will be prompted to identify which facility types were NOT counted.

For the sake of clarification, detailed definitions of each facility type option for Questions 2 and 4 are included below and an example count site detail is defined for two different count types at a hypothetical count site.

Road with minimal or no shoulder should be selected where either there is no shoulder available (marked or unmarked) to accommodate bicyclists or pedestrians without interfering with the vehicular travel lane or where there is a shoulder available (marked) but the width is narrower than 2 feet.

Road with unimproved shoulder should be selected in the cases where there is a sufficient width of shoulder beyond the vehicular travel lane but the additional width consist of a different material than the travel way and of lesser quality. In many places in Vermont, for example, additional shoulder width in the right-of-way is gravel, whereas the vehicle lanes are paved.

Road with unmarked shoulder should be selected in the cases where there is sufficient pavement width for vehicular travel and additional width to accommodate pedestrians or bicyclists, but the edge of the vehicular travel lane is not marked with a white line. This choice should only be selected in cases where the travel way is paved and the travel lane width is at least 12 feet from centerline with at least 4 feet of additional paved unmarked shoulder. Locations that meet this description may be candidates for striping of shoulders or addition of bike lanes without additional roadway improvement beyond painting.

Road with marked shoulder should be selected in the cases where distinction between the vehicular travel lane and shoulder are defined by a painted white line and the shoulder is greater than 2 feet wide.

Road with signed bike route and/or sharrows should be selected in cases where there are painted sharrows along the corridor in close proximity to the count location and/or there is signage along the corridor designating the route as a bicycle route. If there are sharrows in one travel direction and bike lanes in the other travel direction, please select both *road with signed bike route and/ or sharrows* and *standard bike lane*.

Roads with *standard bike lanes*, *buffered bike lanes*, and *cycle tracks* are all selections that relate to bicycle specific design features in the traveled right-of-way. The distinction between the three is the level of separation between vehicular traffic and the bicycle facility. Standard bike lanes are designated with a painted line and bicycle symbols. Buffered bike lanes are similar to standard bike lanes, but have additional striping that provides a horizontal buffer of separation between vehicles and bicycles. A cycle track is a bicycle facility that is physically separated from the vehicle travel lane by bollards, curbs, or some other vertical separator. These can be one-way or two-way facilities.

Multiuse paths, *sidewalks*, and *trails* are distinguished primarily by design geometry. Multiuse paths are wider than sidewalks, usually 10’ or wider, typically accommodating bicyclists and pedestrians in both directions of travel simultaneously. They may exist off-network on their own dedicated corridor or on-network as a side path to the vehicular right-of-way. Multiuse paths may be gravel or crushed stone, but in many places are paved asphalt. Sidewalks also accommodate both directions of travel, but are narrower in geometry, usually at least 4’ width, and either limited to pedestrian use only or allow for slower moving bicyclists. These typically exist as side paths to the vehicular right-of-way, but at times provide pedestrian access off-network. Most often, sidewalks are concrete, but can be constructed with different materials. Trails, on the other hand, typically accommodate a single bicyclist or pedestrian in one direction at a time. A footpath, rugged hiking trail, or mountain bike trail may all qualify as a trail. Trails are most often dirt and may be over rugged terrain. Each of these non-motorized, dedicated facilities should be selected as appropriate.

Often *non-motorized bridges* and *tunnels* are pinch points for pedestrian and/or bicyclist activity. The funneling of non-motorized activity at these facility types make them prime candidates for targeted count locations. They are also typically well-suited to automated count technologies, as the path that individuals can take through the tunnel or across the bridge is limited.

Although most often occurring at intersections, where an intersection count may be appropriate, at times *crosswalks* are treated as a screenline site when counted. In these cases, an imaginary screenline would be drawn perpendicular to the direction of travel in the crosswalk, or parallel to the facility that is being crossed. Each person utilizing the crosswalk, not the facility it crosses, would be tallied. These may prove to be most useful in cases where there are midblock crossings or intersections where particular focus on a single pedestrian or cyclist approach or movement is necessary (e.g. count on a crosswalk for a multiuse path that crosses a highway corridor where a Rectangular Rapid Flash Beacon installation is being considered).

The hypothetical count site, depicted in Figure 22, provides two example count types, A and B, with two different answer sets for the count site detail section of the data input tool. In the instance that a manual count was conducted on the corridor (Count A) and included travel in both directions on all of the available facilities across the screenline, the users selections for this series of questions would be:

Question 1: *sidewalk*, *standard bike lane*, and *road with bike route and/or sharrows*

Question 2: *yes, all are paved*

Question 3: *No*

However, in the case where an automated counter, like an infrared EcoCounter, was installed to count just the sidewalk on the east side of the corridor (Count B), then it would be important to distinguish that just the sidewalk was counted, but that the count is potentially missing the bike lane activity in one direction, a road with sharrows in the other direction, and another sidewalk on the other side of the road.

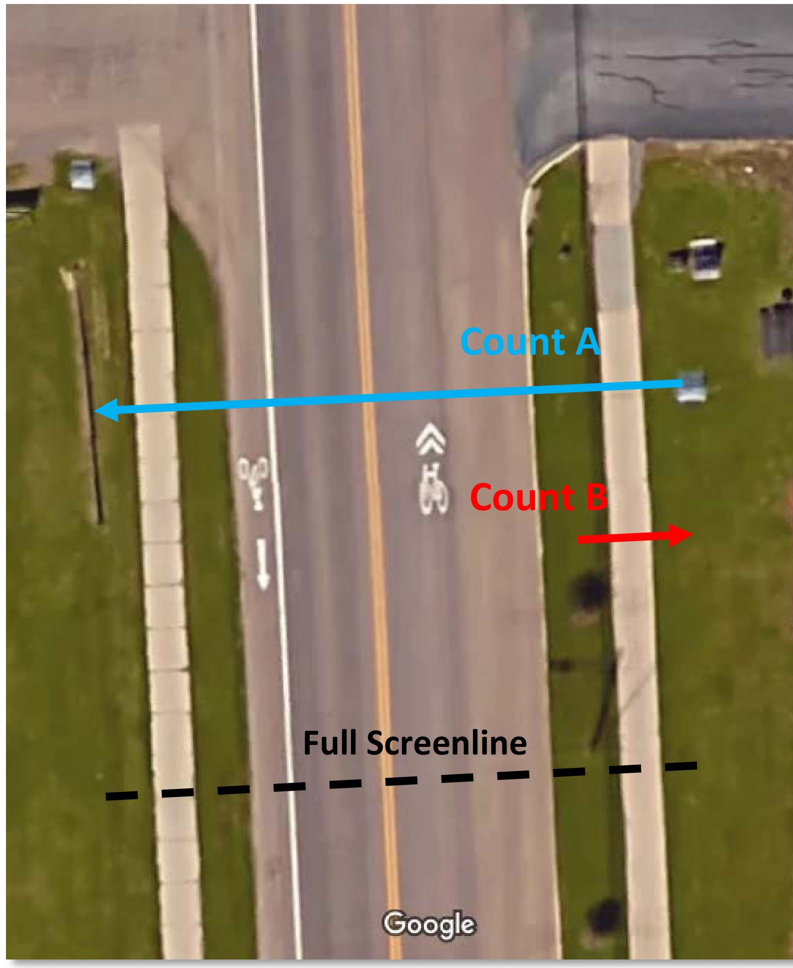


Figure 22. Aerial view of example count site location where multiple facility types would be selected depending on the count type.

Question 1: *sidewalk*

Question 2: *yes, all are paved*

Question 3: *Yes* (which would prompt Question 4 to appear)

Question 4: *sidewalk, standard bike lane,* and *road with bike route and/or sharrows*

The counts that are conducted and included in the database are directional screenline counts. This means that counters, whether automated or manual, will tally activity operating in both directions and distinguish between the two directions of travel in the data upload. Therefore, the direction of travel associated with each count will have to be specified. This is especially pertinent as someone could return to the same site location of a previous count and count directional activity in the opposing directions.

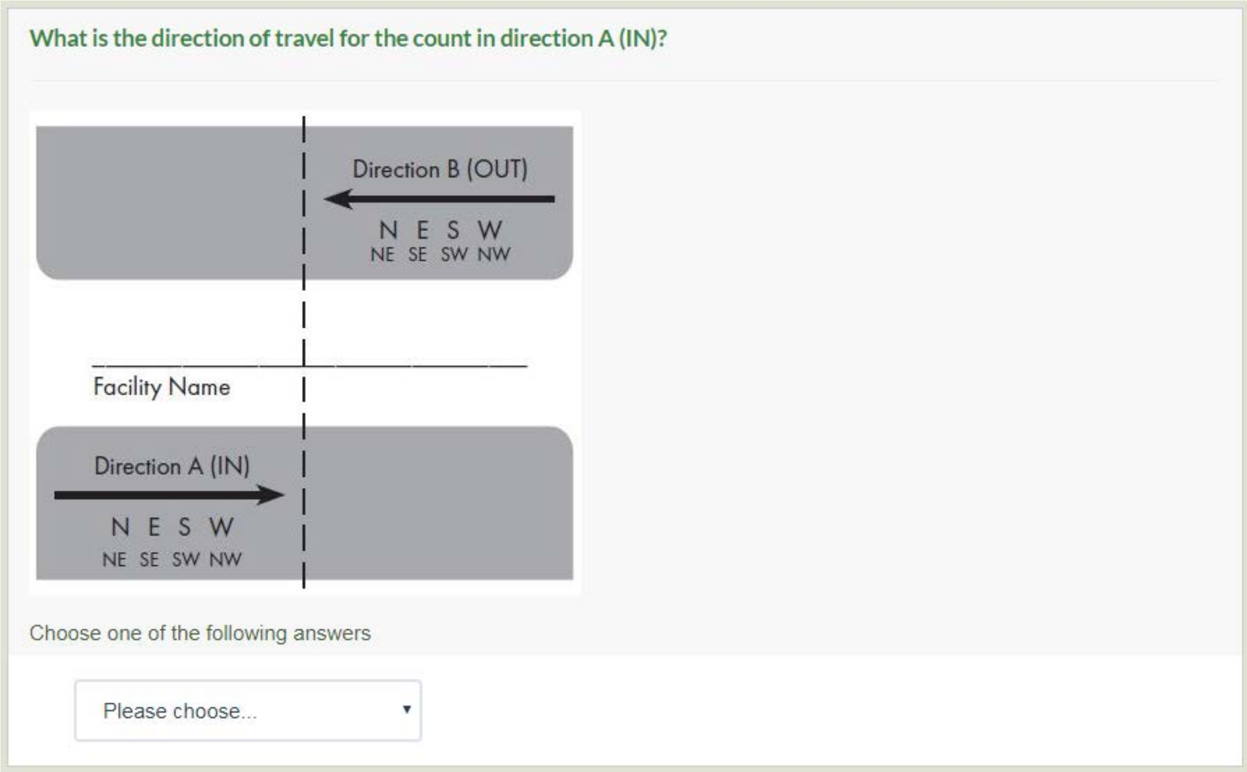


Figure 23. Count directional indication for Direction A with site diagram.

4.3.5 Count Data

First and foremost, the count data collection information was dictated by the type of count. If a manual count was conducted, or a video-count with manual review, the data upload will be in the manual count template (see Appendix C). If the data was collected through an automated process, either with a counting device or an automated video-based count, the automated data upload will be in the format provided by the device manufacturer. The answer to the question will later guide the user to the appropriate data upload page, manual or automated.

In the case of a manual count, the user will be asked to specify information about the person making observations. This information will be kept private and, like the information about the individual uploading the data, will be kept on file only as a contact if there are any data anomalies that need to be validated. In the case of a video-based count with manual review, contact information for the person responsible for the review will be requested as well as information about the video device.

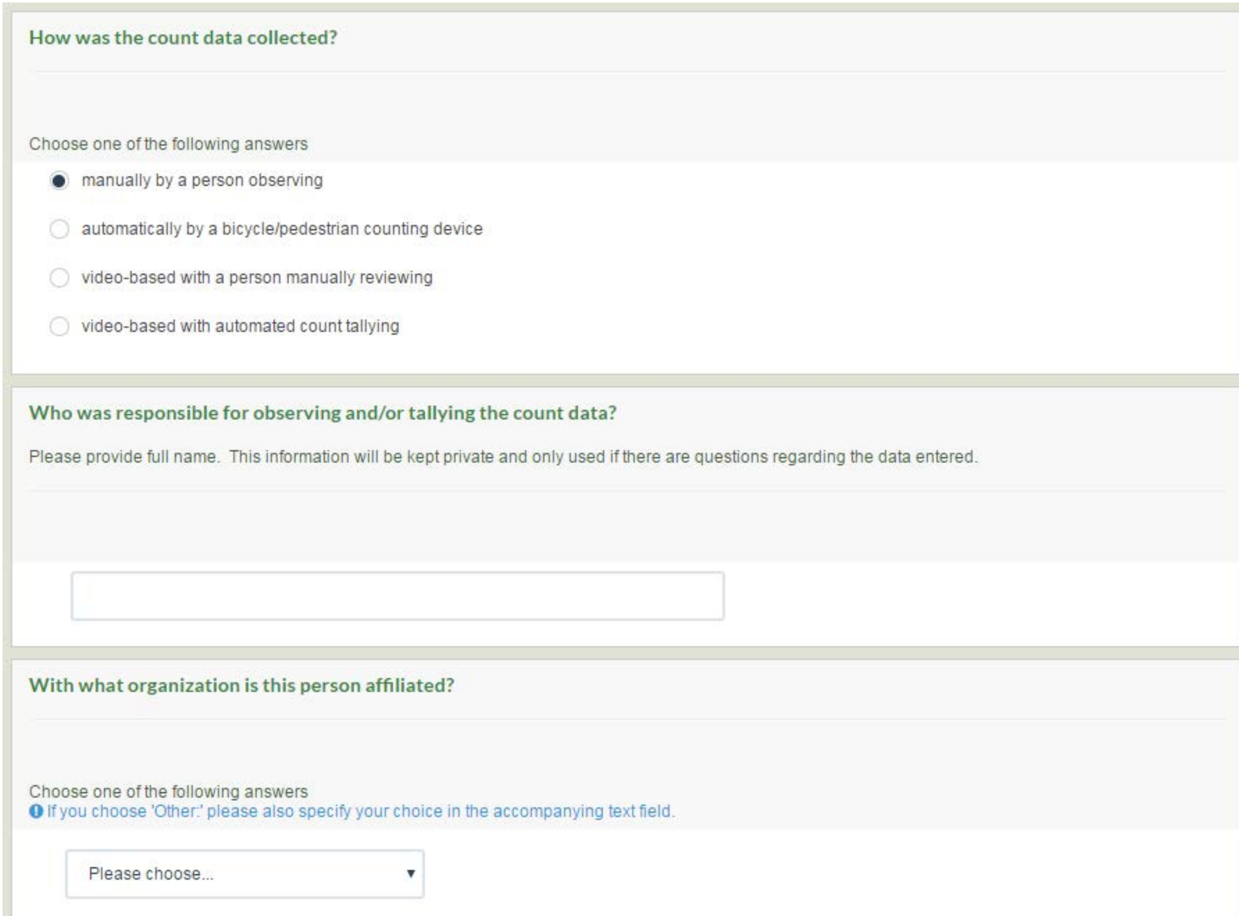


Figure 24. Count data collection specifics if the observation was manually conducted.

In the case of an automated count, or a video-based count with automatic or manual review, information about the device will be requested, including the make, model, serial number, and a nickname for the device. This will allow for data administrators to verify counts from different counters are validated, adjusted if necessary, and flagged if there are particular count devices that are problematic or erroneous. This is particularly important in a place where count devices are often shared across organizations and installed at various locations on a short-term basis.

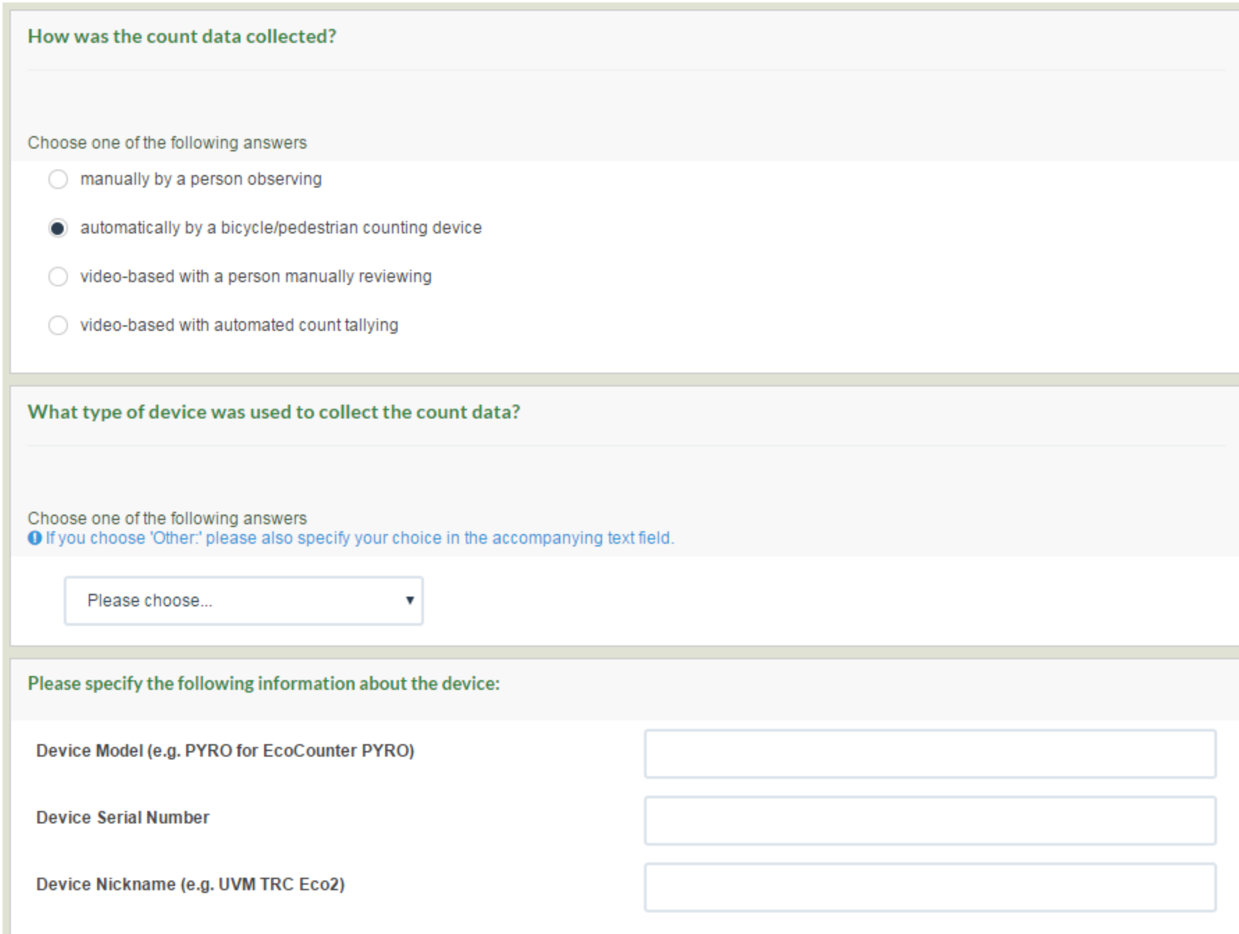


Figure 25. Count data collection specifics if the count was automatically collected.

The count start date and time will be used as a method for validating the count data uploaded to the portal. Often device memory is not wiped clean between counts at various locations. Having the start date and time reported for a particular count will allow for quality control between the data upload and the inclusion in the database. Any data in the data file from before the start date and time will be considered invalid and omitted from the database. This is also important as often there are erroneous counts included in data files that are a reflection of set up procedures.

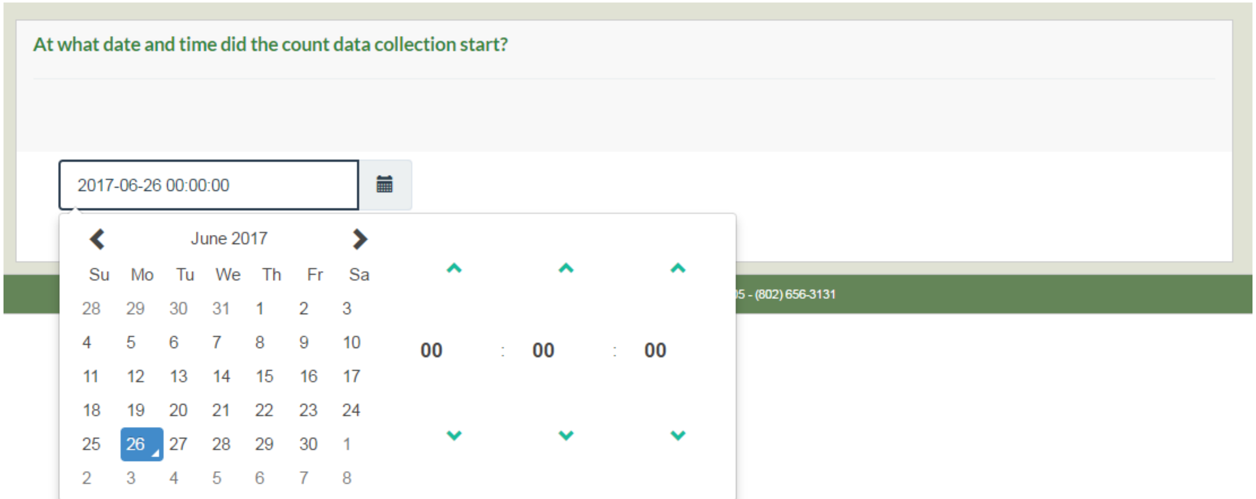


Figure 26. Question to specify the start date and time of data collection.

The other pertinent temporal data collection questions include the total duration of the count and the frequency at which the count was tallied or recorded. The duration of the count will be defined by a numerical input and selection of the appropriate units (i.e. hours, days, weeks, etc.). Efforts should be made to make this as accurate as possible (i.e. report in hours or fractions of hours if possible). Much like with the count start date and time, the duration figure will be used in quality control procedures to eliminate any data beyond the specified duration of the count as well as inform our total duration metric for the count site location. The frequency of the count will also be specified by the user. Most count technologies are capable of recording counts at 15-minute or hourly intervals, which will be the ideal standard for the count program. Daily and total counts will still be accepted, but will likely be phased out as the count program progresses.

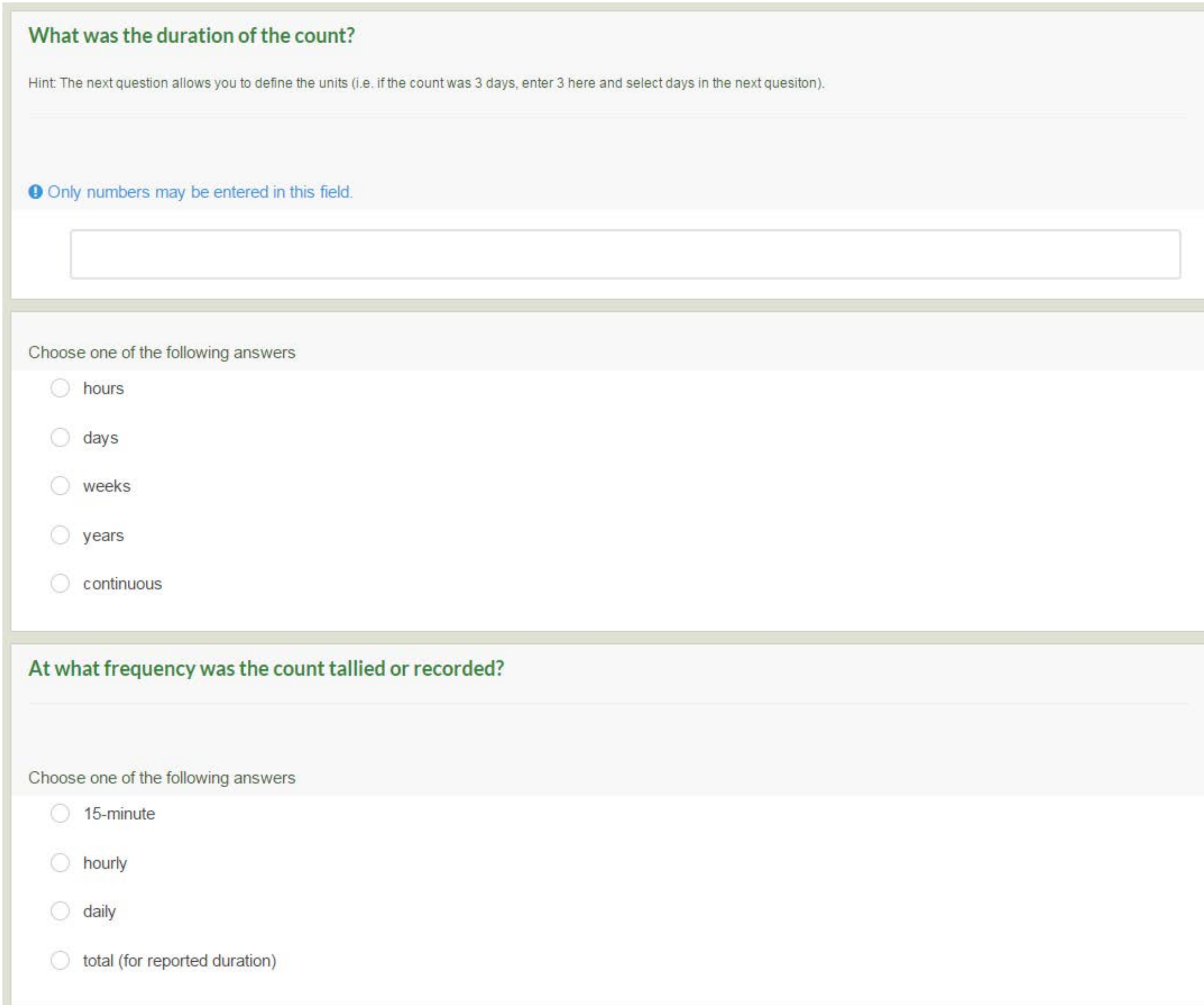


Figure 27. The duration and frequency of the count data collection.

The manual and automated data file upload pages will prompt users to upload data files directly from their computer. The data files should be in *.xlsx, *.xls, *.txt, or *.csv format. For the manual data upload, users should enter the data into the manual count template in Microsoft Excel. This will ensure formatting of the data is accurate for ease of transfer to the database. Further explanation of the manual count template and an example of a data count tally are included in Appendix C. Automated data should be uploaded in one of the acceptable file formats directly from the device or device's software. For instance, EcoCounter data should be downloaded directly from the device and retrieved in the *.txt file. This unformatted *.txt file should be assigned a file name and uploaded to the input portal.

Figure 28. Manual data file upload prompt.

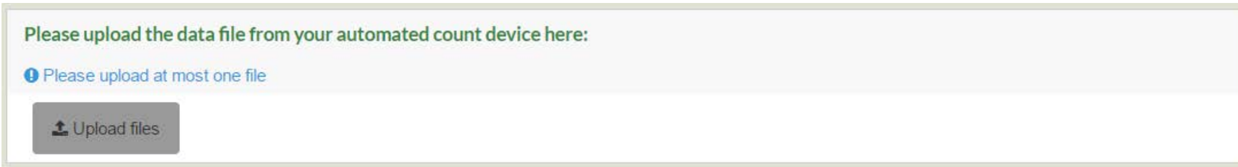


Figure 29. Automated data file upload prompt.

4.4 Gap Analysis and Selection of New Count Sites

The goals of gathering new screenline counts of non-motorized travel in Vermont are twofold. One is to justify the addition of new bicycling and pedestrian infrastructure or other investments in cycling and walking, and the other is to assess the level of non-motorized travel statewide to measure the effects of policies aimed at increasing miles of travel by these modes. The first step in achieving both of these goals is to create and maintain a database that is representative of the current state of bicycling and walking across the state.

Toward this end, it will be important to add new count locations in the coming years across the state on *all* facility types where non-motorized activity is possible, no matter the volumes anticipated, in proportion to their representative fraction on the statewide system. This concept is particularly important given the assumption that walking and biking is most prevalent in locations with dedicated infrastructure and higher density populations (i.e. downtowns or village centers), and is lower in places with less population density and more rural landscapes. However, rural landscapes in Vermont are still popular places to walk and bike recreationally, as some rural routes in Chittenden County have been shown to have significant non-motorized activity (Sullivan et al., 2015).

In order to gain this improved understanding of non-motorized travel activity, then, a robust set of count locations is needed. A spatiotemporal / categorical gap analysis and semi-random site selection process were employed in order to improve the robustness of the set of count locations in Vermont. First, a gap analysis was conducted to identify all of the roadway and path segments available for walking and biking in Vermont that were not yet represented by the existing 194 count locations. Facility classes for on-network facilities were generated from the Vermont road centerline AOTCLASS attribute and classes for off-network sites were assumed to be represented by a single category – multiuse path. Therefore, nine classes of non-motorized facilities were established for Vermont:

- US Highway
- State Highway
- Class 1 Town Highway
- Class 2 Town Highway
- Class 3 Town Highway
- Class 4 Town Highway
- Private
- National or State Forest Highway
- Multiuse Paths

A tabulation of the total mileage of each class was assumed to inform the ideal, representative temporal and spatial distribution of counts by class. For example, if Class 1 Town Highways are 10% of the total miles of all 9 classes, then the goal would be for 10% of the count locations to be located on Class 1 Highways. Tabulation of the number of count sites and the duration of total counts by class revealed what the current set of count locations represents. This cross-tabulation of available mileage with the duration of existing counts by class guided the new site selection process, as shown in Table 7.

Table 7. Tabulation Existing Count Sites and Statewide Mileage by Class

	Existing Count Sites		Statewide	
Class	**Percent of Total Sites**	**Percent of Total Duration**	**Total Length (mi.)**	**Percent of Total**
US Highway	6%	1%	619	3%
State Highway	9%	<1%	1771	9%
Class 1 Town Highway	22%	66%	141	1%

Class	Existing Count Sites		Statewide	
	Percent of Total Sites	Percent of Total Duration	Total Length (mi.)	Percent of Total
Class 2 Town Highway	12%	1%	2750	15%
Class 3 Town Highway	11%	2%	8427	45%
Class 4 Town Highway	0%	0%	1606	9%
Private	2%	<1%	2795	15%
National/State Forest Highway	0%	0%	316	2%
Multiuse Paths	37%	29%	237	1%

Long-term counting at a few of these site types provides information regarding temporal patterns of non-motorized activity, such as seasonality, time-of-day, day-of-week, and yearly trends. However, two classes of facilities are overrepresented in the existing count sites (Class 1 Town Highway and Multiuse Paths) whereas Class 2 and 3 Town Highways are underrepresented. The selection of new count sites will move toward improving this representation imbalance. A target of 20 new count sites was selected to “reduce the gap” between the current spatiotemporal distributions of count sites, and the desired distribution.

Since it is not feasible to add 20 new count sites for automated infrared counting, another assumption was made that a subset of the new sites would be intended for automated counting where feasible, while the rest would be targeted for counting methods that could provide at least 72 hours of continuous counting, meaning that the video-manual method would be the most feasible for the remaining new sites. Achieving this target would add at least another 1,440 hours of data to the database at a wide variety of new locations.

To remove bias from the process of selecting new sites in each class, a stratified random sampling technique was used. Each segment in the road network was assigned an identifier and a class. A random number generator was used to select the desired number of segments for each class. The process was done iteratively to ensure that new sites were distributed throughout all of the Vermont RPCs and did not fall within 1 mile from any current site. A total of 20 new sites were selected in this way, and 1 of them was identified for automated infrared counting as it was the only site where the infrastructure would allow the method to be used. The new sites are described in further detail in Section 5.4.

4.5 Comparison of Data Collection Methods

4.5.1 Comparison of Automated Infrared Counts and Video Manual Counts

There are challenges to counting bicyclists and pedestrians accurately with an automated infrared counter. The primary challenge is occlusion, which affects any device that counts users who cross an invisible screenline. When two or more people cross the line simultaneously, an undercount occurs because the device only registers the presence of one person (Figure 30).

Figure 30. Occlusion at an automated infrared counter.

In previous research, this effect has been found to become more pronounced with higher volumes and it was observed for the automated infrared counters at levels that would require correction factors (additions) of between 4% and 40% (Ryus et al., 2014).

Video-based manual counts are presumed to be the most accurate way of collecting count data, given the ability to re-watch video as needed. This method was used to develop the ground truth validation counts for NCHRP Project 07-19 (Ryus et al., 2014). Therefore, it was used to ground-truth the automated infrared counter in this project. Data downloaded from the Eco Counter was aligned by 15-minute segment with the data collected from the simultaneous video manual count. In order to minimize the effects of clock misalignment between the two devices, the 15-minute segments were aggregated up to 27 hourly totals for the comparison. Since the issue being explored was undercounting by the automated infrared device, correction factors were calculated for each hour of observation as:

- hourly total from video manual count / hourly total from EcoCounter

In addition, the effect of hourly count volume was explored by calculating the root-mean-square-percent-error (RMSPE) and comparing it to the average of the correction factors.

4.5.2 Comparison of Strava Metro Data and Count Summary Data

The purpose of this effort was to compare the Strava Metro data to counts collected statewide by a variety of methods. First, the Strava Metro cycling and running data was summed to get a number that could be compared to a typical non-motorized, screenline traffic count. These sums were then mapped in the GIS and "tagged" to one of the non-motorized count locations. The tagging process involves spatially matching points to line segments using a one-to-one proximity measurement, with a set tolerance of 0.01 miles (about 50 feet). 192 of the 194 count sites was successfully tagged with a line segment from the Strava Metro data.

Once the tagging was complete, the Site Data table from the screenline count database was filled with the average daily sum of cyclists and runners from the Strava Metro data, so a direct comparison could be made between this value and the ADT from the Site Data. Since most of the count sites do not have an ADT value, 66 of the 192 count sites are available for comparison. Five of these sites do not contain any Strava Metro data, so the final comparison is for 61 locations, where both Strava Metro average daily runners and cyclists and count data ADT are available.

The comparison ratio itself consisted of simply finding the ratio of Strava Metro average daily runners and cyclists to the ADT of the count data, to indicate what fraction of the total non-motorized traffic stream might be represented by the Strava Metro estimate.

5 Results

5.1 Database Development and Estimation of Site Summary Parameters

The vast majority of the available infrastructure mileage for walking and biking across the state is two-lane roadways, many of which do not have dedicated infrastructure and some of which are unpaved. Table 8 provides a complete list of classes by percent of total mileage available statewide, with the corresponding number of count sites and total durations within each class.

Table 8. Existing count sites by class

	Existing Count Sites			
Class	Number of Sites	Percent of Total Sites	Duration (hours)	Percent of Total Duration
US Highway	11	6%	2,084	1%
State Highway	18	9%	638	<1%
Class 1 Town Highway	43	22%	138,815	66%
Class 2 Town Highway	24	12%	1,759	1%
Class 3 Town Highway	22	11%	4,796	2%
Class 4 Town Highway	0	0%	0	0%
Private	4	2%	454	<1%
National/State Forest Highway	0	0%	0	0%
Multiuse Paths	72	37%	60,914	29%

The database contains over 200,000 hours of observation at 194 locations. The majority of count sites and durations were either on multiuse paths (72 sites with over 60,000 hours) or on-network sidewalks along Class 1 Town Highways (43 sites with nearly 140,000 hours). Class 1 Town Highways in

Vermont are predominantly located in the core of downtown districts or village centers.

All 194 locations have a PHT, since even the manual count sites covered at least one hour. The PHT represents the largest recorded count of cyclists and pedestrian over 4 consecutive 15-minute periods. The highest PHT in the state (899) was recorded in Rutland on July 2, 2010 (a Friday) on the Center Street sidewalk outside of the Paramount Theater. The average PHT across all 194 sites was 110, indicating that the focus of all counts to date has generally been locations high levels of walking and cycling are expected.

69 of the 194 sites also have an ADT, which is the average of any full calendar days of counts. This number excludes the manual counts, none of which spanned at least a full calendar day. Table 9 contains a summary of the ADT, PHT, and PDT at these 69 sites.

Table 9. Summary of ADT, PHT, and PDT at Sites with an ADT

	Minimum	Maximum	Mean
ADT	4	1,864	312
PHT	0	899	182
PDT	4	4,966	781
Duration (hours)	24	73,165	2,962

5.2 Spatial Distribution of Sites

Figure 31 shows the locations of the 194 count locations in Vermont, including the locations of the 69 counts with ADTs. The map also shows the normalized county ADT (average ADT ÷ population) for those counties that contained at least one location with an ADT.

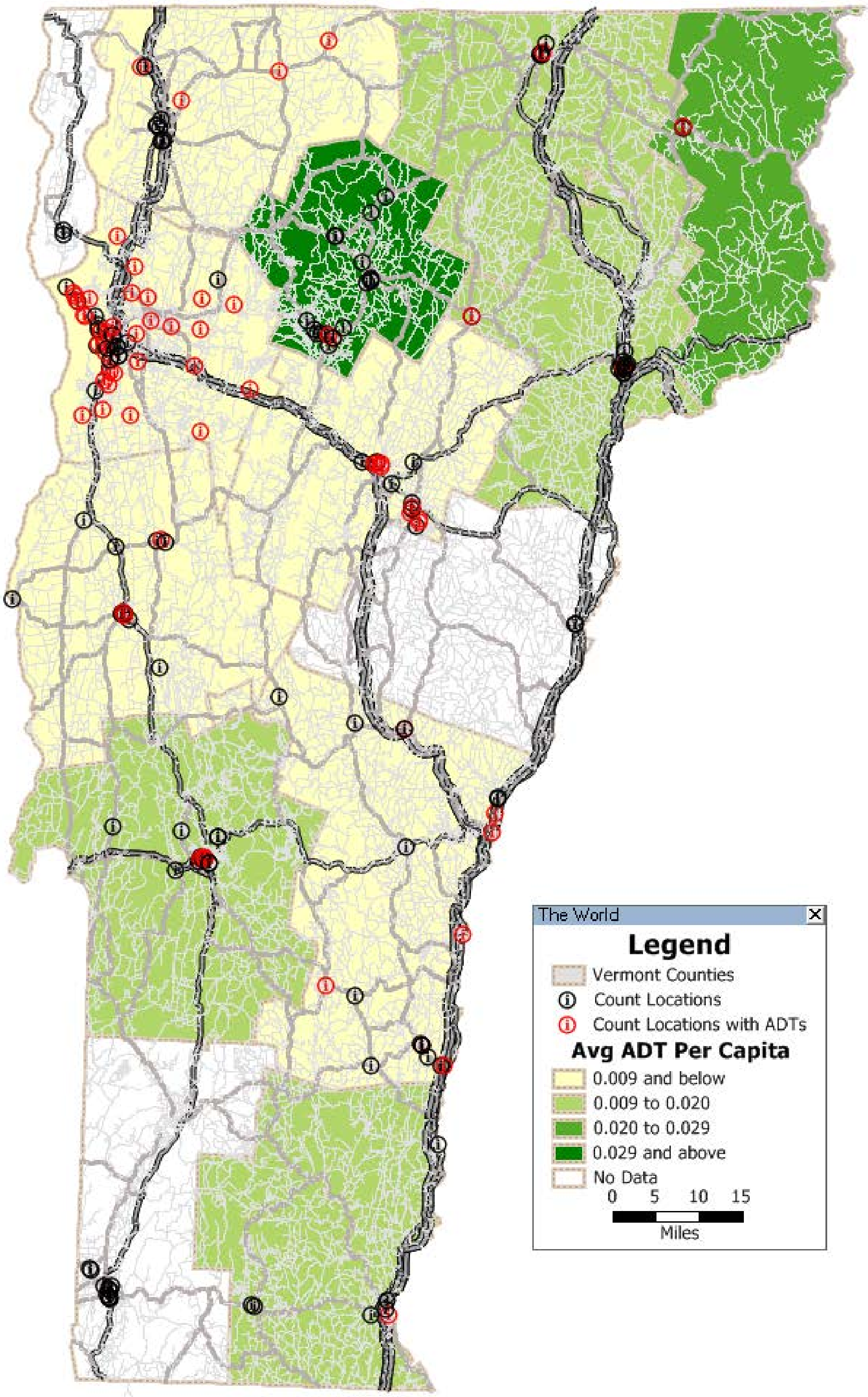


Figure 31. Count Locations in Vermont, with Normalized County ADTs

The normalized ADTs are a somewhat misleading indicator of biking and walking activity in each county, due to the continued sparseness of the data set in many counties. The counties with the highest per capita ADTs (Lamoille and Essex) right now are also those that have the smallest number of sites with a full day of observation (2 and 1, respectively). New sites are often introduced where non-motorized travel activity is expected to be highest, like on a recreational path, where infrastructure improvements are sought. However, this finding is evidence of the need for a more balanced distribution of sites when regional policy decisions are being made. It is not likely that non-motorized travel activity in Chittenden County is amongst the lowest in the state. More likely is the fact that the count locations in Chittenden are more established, and have been targeted randomly throughout the county, through the use of video manual methods. This improved distribution means that some sites are intentionally situated in locations where biking and walking are expected to be low, giving a more accurate estimation of the total level of activity county-wide.

5.3 Temporal Distribution of Counts

Count locations where an automated infrared counter or a video manual count was conducted can provide an indication of the distribution of non-motorized travel throughout the average day. Figure 32 provides the average hourly volume of cyclists and pedestrians observed at all sites where automated infrared counts were conducted in Vermont.

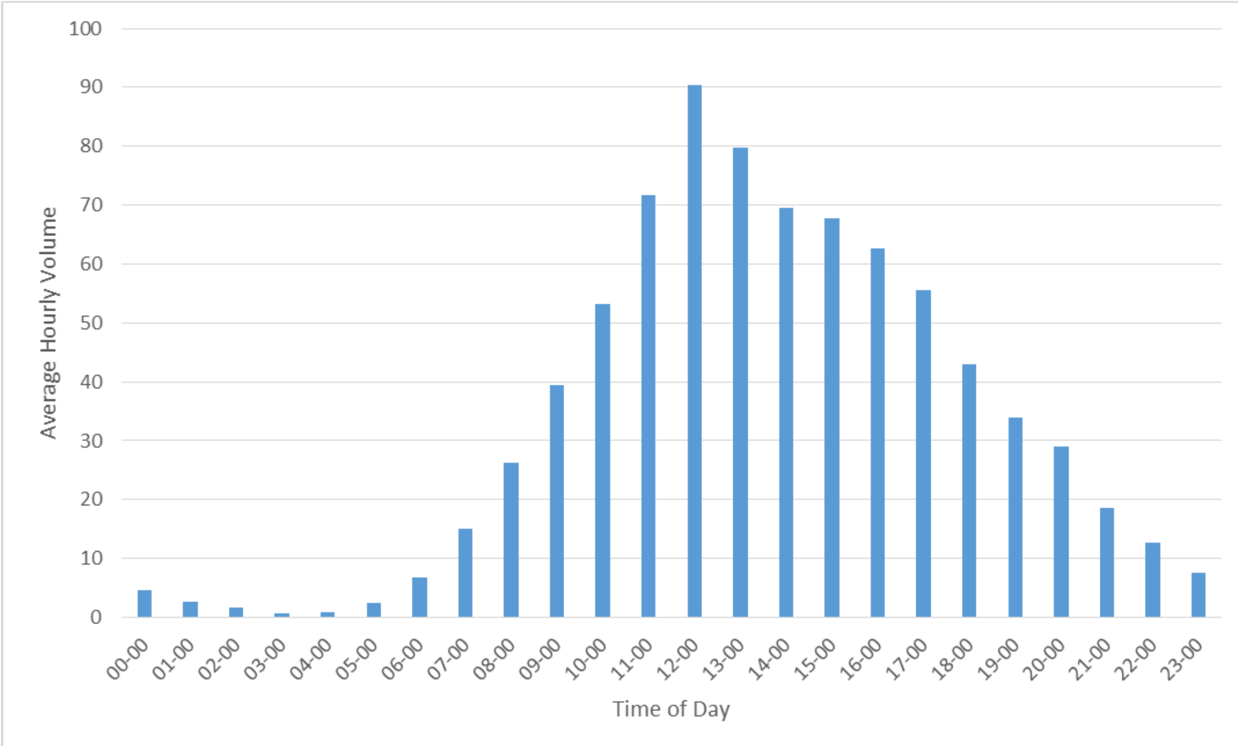


Figure 32. Average hourly volumes from all automated infrared count sites in Vermont

These hourly volumes also exhibit the effect of the focus on heavily traveled corridors with the existing count sites. In particular, the lunchtime peak is likely strongly affected by the ongoing multi-year count locations on busy urban sidewalks in Montpelier and Rutland. The continued high hourly volumes that persist later in the day are likely affected by the focus on recreational multiuse paths, where activity is more likely to peak in the evening. Both of these types of infrastructure are well suited to the use of an automated infrared counter. What seems to be lacking from this data is evidence of peak-hour commuter activity, which is less likely to show up on sidewalks and multiuse paths, and more likely to be represented by on-road infrastructure. On-road locations are not well suited to the use of the automated infrared counter, but would be better suited to the use of video manual methods.

Figure 33 provides the average daily volumes of cyclists and pedestrians at the automated infrared sites in Vermont by month of the year.

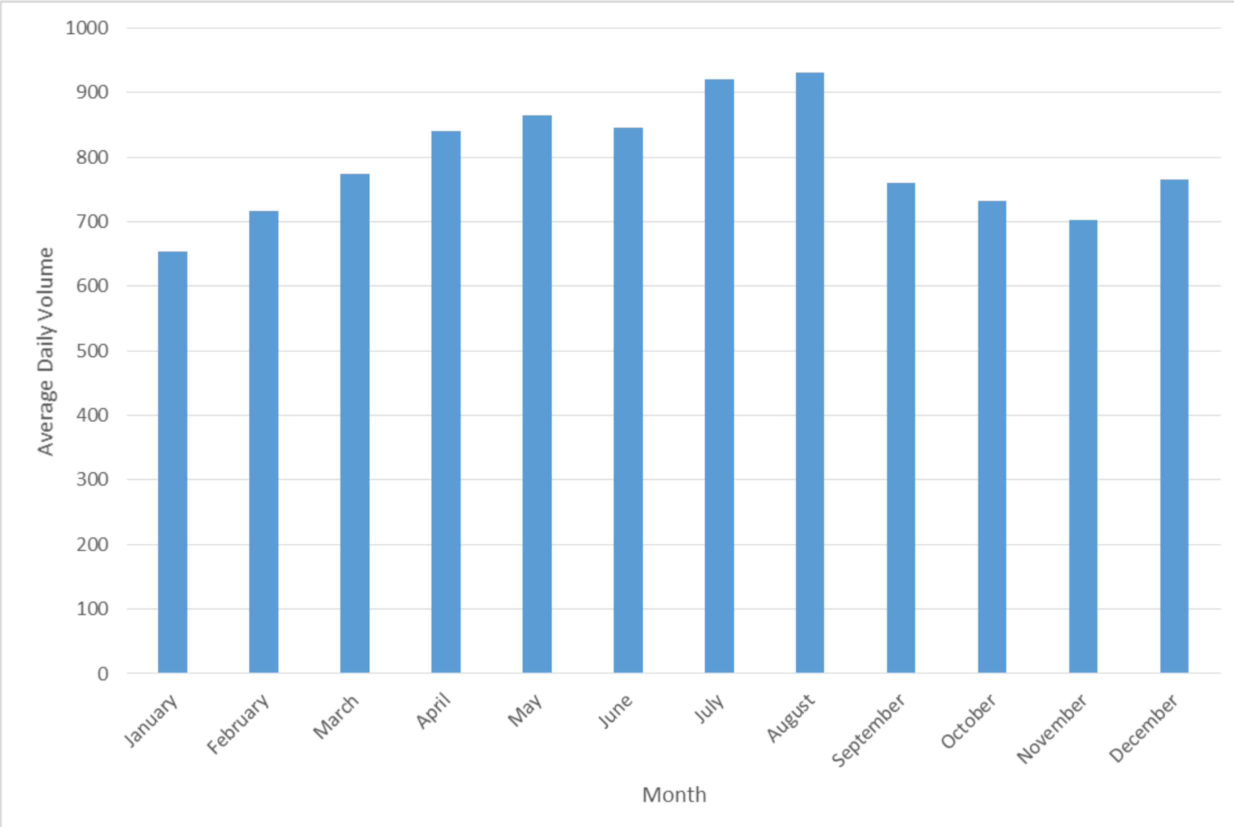


Figure 33. Average daily volumes by month from all automated infrared count sites in Vermont

The persistently high average daily volumes throughout the seasons are additional evidence of the placement of these sites on sidewalks in busy downtown areas, where seasonal fluctuation would be minimized. Nonetheless, evidence of the seasonal effects on cycling and walking activity are present. The lowest daily volumes occur in January, when the weather is cold and economic activity following the holiday season has diminished to its annual low point. From that time, the average daily volumes increase steadily throughout the spring and summer to a peak in August, interrupted only by the drop in volumes from May to June that is likely influenced by the departure of college students after the spring semester, particularly in the Burlington area.

Interestingly, these volumes do not rebound to their springtime levels when school resumes in September. Instead, they decline from the August peak of over 900 per day to about 700 per day in November, briefly rebounding for holiday shopping in December.

5.4 Gap Analysis and Selection of New Count Sites

The distribution of observed hours across facility classes is skewed towards locations where significant walking or bicycling activity was anticipated and where the facilities were well-suited for counting via automated infrared technology, generally where dedicated non-motorized infrastructure exists. Generating a more representative sampling procedure for the statewide count program required identifying new count sites through a gap analysis and semi-random site selection process. The results of this process identified 20 new count site locations (Table 10). Additional counting at these new site locations will begin to reduce the gap between existing and desired spatiotemporal representativeness.

Table 10. New Count Site Locations

Town	Facility Name	Facility Class
Lyndon	US-5	US Highway
Randolph	VT-14	State Highway
Sunderland	VT-7A	State Highway
Halifax	Green River Road	Class 2 Town Highway
Dorset	Mad Tom Road	Class 2 Town Highway
Rockingham	Saxtons River Road	Class 2 Town Highway
Pownal	Niles School Road	Class 3 Town Highway
Brattleboro	Fairground Road	Class 3 Town Highway
Manchester	Mt Aeolus Drive	Class 3 Town Highway
Rutland	North Street Extension	Class 3 Town Highway
Hancock	Texas Falls Road	Class 3 Town Highway
Grafton	Putnam Forest Road	Class 3 Town Highway
Randolph	Mountain Avenue	Class 3 Town Highway
Hartland	Shute Road	Class 3 Town Highway
Troy	River Road	Class 3 Town Highway

Town	Facility Name	Facility Class
Danville	North Shore Road	Class 4 Town Highway
Guilford	Town Highway-55	Class 4 Town Highway
Northfield	Falls Mobile Home	Private
Hartford	Catamount Road	Private
Warren	Stony Hill Road	Private

See Appendix D for more detailed information on the proposed count sites, including pinpointed locations conducive to full screenline counting and a map of the sites. Appendix D also contains an additional set of proposed sites selected using the same gap analysis and semi-random selection process to target 3000 total hours of additional count duration to include in the database at representative sites.

For all of the new count sites identified in Table 10, the full screenline count was recommended for a total of 72 hours at each site, requiring manual or video-based counting. However, there was one site that had sidewalks available, Fairground Road in Brattleboro, and therefore would be suitable for automated counting of the sidewalk facility with the currently available technology. It was suggested that this site have automated counting for a period of 2 weeks or a full screenline for a period of 72 hours. Because there is such a large data collection of longitudinal counts at these locations, it would take significant resources to add enough duration at the other facility types to make up the difference. Instead, we recommend continuing to count longitudinally in places well-suited to the count technologies available, while setting up new count locations to fill in the spatial gaps. These count locations were designated based on count duration proportional to mileage of facilities available. For the counts recommended on private roads, permission from the owner of the road or development will be required.

Not only are spatial considerations critical for creating a representative bicycle and pedestrian count database, but timing of the counts should also be addressed. In order to capture the temporal variability of non-motorized activity, seasonality, day-of-week, time-of-day, and consecutive duration should all be considered. The suggestion of at least 72-hours of counting at the candidate sites for multiple consecutive days not only provides the targeted additional count duration, but will inform if there are temporal trends or anomalies to account for at these locations. In addition, a selection of the sites from each class should be considered for counts across multiple seasons, including winter, to inform development of seasonal factors for site types.

Along with the gap analysis to identify new count sites for the state, continuing to target sites is recommended. Candidates for targeted counts would include:

- Locations for potential infrastructure changes, particularly accommodations for non-motorized activity;
- Locations anticipated to have different types cyclists and pedestrians, like recreational athletes or commuters
- Locations that bottleneck all travel activities, such as river crossings, where accommodations for non-motorized travel may be overlooked.

Targeting locations across the full spectrum of non-motorized activity and associated behavior in the state is vital to understanding the return on infrastructure investments, general non-motorized use trends, and estimating metrics like overall BMT or PMT.

Locations that are being considered for infrastructure improvements, particularly those focused on improving safety and accommodations for non-motorized activity, should be identified as potential sites for non-motorized counts. If selected, the sites should be counted both before any changes or construction staging is in place and after the changes have been implemented.

Observations at targeted locations that are anticipated to have different non-motorized activity subcultures or social contexts may also be candidates for targeted count sites. For instance, selecting a targeted location in the Village of East Burke on VT 114, with proximity to the outdoor recreation opportunities of the Kingdom Trails and Burke Mountain, would likely produce significant activity from bicyclists, particularly those accessing mountain bike trails via the on-road network. Although this site may have characteristics quite similar to a village like Pawlet, where VT 30 travels through the village center, the geographic surroundings, recreational opportunities, and subculture of non-motorized travel would produce different bicyclist and pedestrian counts. Having a multitude of these targeted and control sites in the database will make analyses of these subcultures possible and help in the development of adjustment factors.

5.5 Comparison of Data Collection Methods

5.5.1 Comparison of Automated Infrared Counts and Video Manual Counts

While conducting the video manual review count at the Colchester Avenue test site, obvious discrepancies began to emerge immediately due to the presence of clustered groups of pedestrians, which often result in undercounting by automated infrared counters. Figure 34 provides the hourly total non-motorized traffic on the sidewalk test site for comparison of the Eco Counter counts with a video manual review.

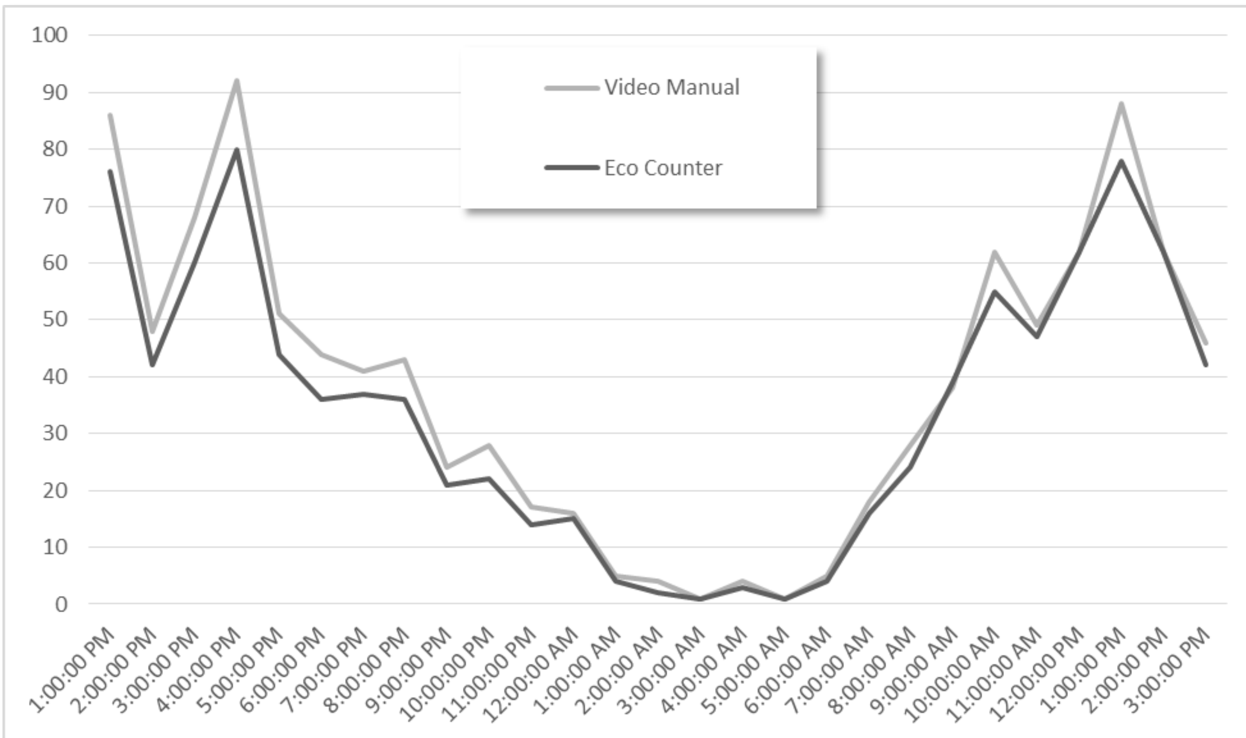


Figure 34. Video-based manual and EcoCounter count comparison.

The hourly counts from each method are also provided in Table 11, along with the calculated correction factors.

Table 11. Hourly Count Comparison

Day	Hour	Auto Infrared	Video Manual	Correction Factor
Thursday, May 11, 2017	1:00:00 PM	76	86	1.13
Thursday, May 11, 2017	2:00:00 PM	42	48	1.14

Day	Hour	Auto Infrared	Video Manual	Correction Factor
Thursday, May 11, 2017	3:00:00 PM	60	68	1.13
Thursday, May 11, 2017	4:00:00 PM	80	92	1.15
Thursday, May 11, 2017	5:00:00 PM	44	51	1.16
Thursday, May 11, 2017	6:00:00 PM	36	44	1.22
Thursday, May 11, 2017	7:00:00 PM	37	41	1.11
Thursday, May 11, 2017	8:00:00 PM	36	43	1.19
Thursday, May 11, 2017	9:00:00 PM	21	24	1.14
Thursday, May 11, 2017	10:00:00 PM	22	28	1.27
Thursday, May 11, 2017	11:00:00 PM	14	17	1.21
Friday, May 12, 2017	12:00:00 AM	15	16	1.07
Friday, May 12, 2017	1:00:00 AM	4	5	1.25
Friday, May 12, 2017	2:00:00 AM	2	4	2.00
Friday, May 12, 2017	3:00:00 AM	1	1	1.00
Friday, May 12, 2017	4:00:00 AM	3	4	1.33
Friday, May 12, 2017	5:00:00 AM	1	1	1.00
Friday, May 12, 2017	6:00:00 AM	4	5	1.25
Friday, May 12, 2017	7:00:00 AM	16	18	1.13
Friday, May 12, 2017	8:00:00 AM	24	28	1.17
Friday, May 12, 2017	9:00:00 AM	39	39	1.00
Friday, May 12, 2017	10:00:00 AM	55	62	1.13
Friday, May 12, 2017	11:00:00 AM	47	49	1.04
Friday, May 12, 2017	12:00:00 PM	62	62	1.00

Day	Hour	Auto Infrared	Video Manual	Correction Factor
Friday, May 12, 2017	1:00:00 PM	78	88	1.13
Friday, May 12, 2017	2:00:00 PM	62	62	1.00
Friday, May 12, 2017	3:00:00 PM	42	46	1.10

Correction factors varied between 1.00 and 2.00, with an average across all 27 hours of **1.17**. The RMSPE was calculated as 16% (correction factor of 1.16), indicating that the correction factors tended to diminish as the hourly count grew, so the raw average was a bit skewed by the abnormally high correction factors calculated for the relatively low counts at 10:00PM, 4:00AM, and 6:00AM. However, all of these calculated values are consistent with the findings of the NCHRP investigation (Ryus et al., 2014).

Two or more pedestrians walking side-by-side caused the automated infrared counter to register only one count when there was no discernible gap between the two individuals as they passed the counter. The counted subjects at our test site consisted mostly of pedestrians, and at certain times of day those pedestrians were traveling in social clusters, many of which did not permit the Eco Counter to identify each individual. This social clustering and the occlusion effects that it creates are also a challenge for automated identification of individual persons from video footage (An et al., 2016).

Therefore, the correction factors varied with the level of social clustering. This social clustering changed throughout the day, being minimized in the early and late hours when pedestrians are moving more determinedly to their work/class destination. In the middle of the day, possible when time constraints are more relaxed, social clusters prevailed and occlusion was common. The social clustering dynamics are also expected to vary significantly with location. This particular location is adjacent to a college campus, so social clusters are fairly common and can be quite large, which helps explain some of the higher values calculated during the 27 hours of observation conducted for this project (Figure 35).

Figure 35. Example of social cluster passing EcoCounter.

During the video manual review, a further issue with the use of the automated infrared counter was clarified. Due to the need for mounting on a vertical signpost, power pole, tree, or ground stake, the automated infrared counter is unable to count cyclists within the travelled way, or pedestrians on the other side of the street (Figure 36a and Figure 36b).

Figure 36. a) Bicyclist passes the infrared counter on a bike lane in the traveled way. b) Pedestrians on the opposing sidewalk are missed by the placement of the EcoCounter

Therefore, the automated infrared counts are further undercounting as a portion of the total screenline count, which is what can be obtained from a manual count or a video manual count. This finding attests to the need for *expansion* factors in addition to *correction* factors when automated infrared counters are used to estimate total screenline counts. Whereas our correction factors for this location were found to require increasing the automated infrared count by 12% (multiplying by 1.12), expansion of the sidewalk count to a full screenline count would likely require increasing the corrected count by a factor of over 100% (multiplying by 2).

This type of expansion may also be necessary when automated infrared counts from a shared-use path adjacent to a roadway are used to represent screenline counts for the roadway. The image in Figure 37 illustrates this challenge.

Figure 37. Google Streetview image of a cyclist along the travel way adjacent to a multiuse path (side path).

Although for some cyclists, the shared-use path would be the preferred facility on which to ride a bicycle, the case below illustrates the wide shoulder and low speed limit are attractive enough for many cyclists to use the roadway itself. In situations like this one, Strava Metro data on cycling activity at the location may represent a suitable supplement to an automated infrared count of the shared-use path.

Another interesting finding of the video observation are the apparent differences between cyclists who use separated and/or dedicated cycling infrastructure, and those who use the roadway. Cyclists on sidewalks and multiuse paths tend to travel at a much lower speed than those who ride in the roadway, and are often helmetless (Figure 38).

Figure 38. Example of a cyclist on the sidewalk being tallied by an infrared EcoCounter, instead of the adjacent on-road bike lane.

This tendency to travel more slowly and not wear a helmet may stem from the increased presence of pedestrians in the traffic stream on the dedicated infrastructure, which can prevent the faster, more focused trajectory typical of an on-road cyclist.

5.5.2 Comparison of Strava Metro Data and Count Summary Data

Table 12 contains a summary of the results of the comparison of Strava Metro Data and the count data ADTs.

Table 12. Comparison of Strava Metro data and count data ADTs

VTrans Count Database				2016 Strava Metro		
SITE_ID (50…)	**COUNT _TYPE***	**SEGMENT_TYPE; PRIMARY_FACILITY_TYPE**	**ADT**	**ID**	**Daily Total**	**Comparison Ratio**
03175001	AI	Off; multiuse path	231	43671	na	--
03250001	AI	Off; multiuse path	4	43355	0.07	1.62%
03250002	AI	Off; multiuse path	11	42654	0.04	0.33%

VTrans Count Database				2016 Strava Metro		
SITE_ID (50...)	COUNT _TYPE*	SEGMENT_TYPE; PRIMARY_FACILITY_TYPE	ADT	ID	Daily Total	Comparison Ratio
05425001	AI	Off; multiuse path	42	83442	0.08	0.19%
06550001	VM	On; road with minimal or no shoulder	12	53952	0.26	2.17%
07900008	Both	Off; foot bridge	516	2525	0.08	0.02%
08725002	Both	Off; foot bridge	137	78313	0.14	0.10%
09025005	Both	On; sidewalk	17	41009	0.71	4.12%
10675001	AI	Off; multiuse path	157	60223	0.01	0.01%
10675002	Both	Off; multiuse path	1,320	60381	4.08	0.31%
10675003	Both	Off; multiuse path	1,178	63282	5.01	0.43%
10675004	Both	Off; multiuse path	1,648	63321	0.29	0.02%
10675005	AI	Off; multiuse path	804	65977	4.11	0.51%
10675007	Both	Off; multiuse path	1,105	58492	1.72	0.16%
10675012	Both	On; multiuse path	451	85439	1.32	0.29%
10675016	AI	Off; multiuse path	579	60024	1.16	0.20%
10675017	AI	On; sidewalk	117	59004	0.13	0.11%
13300001	VM	On; road with minimal or no shoulder	107	50885	1.56	1.46%
13300002	VM	On; road with minimal or no shoulder	17	51206	0.14	0.84%
14875002	Both	Off; multiuse path	473	66448	2.36	0.50%
14875006	VM	On; road with minimal or no shoulder	13	55042	0.60	4.62%
14875007	VM	On; road with minimal or no shoulder	15	68727	0.08	0.51%
14875008	VM	On; road with minimal or no shoulder	35	66324	0.25	0.70%

VTrans Count Database				2016 Strava Metro		
SITE_ID (50…)	**COUNT _TYPE***	**SEGMENT_TYPE; PRIMARY_FACILITY_TYPE**	**ADT**	**ID**	**Daily Total**	**Comparison Ratio**
23875001	AI	On; multiuse path	33	81044	na	
24175001	VM	On; road with minimal or no shoulder	8	66270	0.01	0.17%
24175002	VM	On; sidewalk	120	60800	0.04	0.03%
24175003	VM	On; road with minimal or no shoulder	4	65925	0.04	0.96%
24175004	AI	On; multiuse path	89	61912	0.41	0.46%
31825001	Both	Off; foot bridge	249	62744	0.21	0.08%
32275001	Both	On; sidewalk	1,261	25996	0.18	0.01%
32275002	Both	Off; multiuse path	176	27517	na	
33475001	VM	On; road with minimal or no shoulder	25	50706	0.16	0.62%
34600001	VM	On; road with minimal or no shoulder	69	49345	1.05	1.51%
36700001	VM	On; road with minimal or no shoulder	14	60623	0.07	0.53%
41275001	Both	On; sidewalk	34	16942	1.67	4.90%
44350007	AI	On; sidewalk	125	37455	0.27	0.22%
44350008	AI	On; sidewalk	107	37393	0.01	0.01%
45250001	VM	On; road with minimal or no shoulder	10	71659	na	--
46000001	Both	Off; multiuse path	310	47229	0.42	0.14%
46000002	Both	Off; multiuse path	336	47188	0.46	0.14%
46000004	Both	On; multiuse path	31	46840	0.06	0.21%
46000006	Both	On; sidewalk	1,864	47093	0.53	0.03%
48850003	Both	Off; sidewalk	356	82449	0.01	0.00%

VTrans Count Database				2016 Strava Metro		
SITE_ID (50...)	COUNT _TYPE*	SEGMENT_TYPE; PRIMARY_FACILITY_TYPE	ADT	ID	Daily Total	Comparis on Ratio
59275001	VM	On; road with minimal or no shoulder	13	65754	0.04	0.32%
60850001	Both	On; sidewalk	297	31643	0.21	0.07%
61225002	AI	On; sidewalk	1,311	23044	0.03	0.00%
61225006	AI	Off; multiuse path	450	22992	0.01	0.00%
61225007	Both	Off; multiuse path	19	23059	0.07	0.38%
61225011	AI	On; sidewalk	200	23313	0.03	0.02%
62200008	Both	On; sidewalk	561	54672	0.12	0.02%
64300002	VM	On; road with minimal or no shoulder	30	53357	0.03	0.09%
64300003	VM	On; road with marked shoulder	130	54567	1.97	1.51%
64300004	VM	On; road with marked shoulder	49	53027	1.90	3.89%
66175007	AI	Off; multiuse path	61	56275	0.91	1.49%
66175014	VM	On; road with minimal or no shoulder	36	59977	na	--
66175015	VM	On; road with minimal or no shoulder	11	53991	0.71	6.48%
66175016	VM	On; road with minimal or no shoulder	20	56807	0.01	0.07%
69550003	AI	Off; multiuse path	112	14147	0.06	0.05%
69550007	AI	On; sidewalk	182	15075	0.19	0.11%
70525001	AI	Off; trail	623	59598	3.12	0.50%
70525009	AI	Off; multiuse path	758	59333	0.67	0.09%
71725003	Both	Off; multiuse path	52	79551	0.14	0.27%
71725004	Both	Off; multiuse path	94	81385	0.03	0.03%

VTrans Count Database				2016 Strava Metro		
SITE_ID (50…)	**COUNT _TYPE***	**SEGMENT_TYPE; PRIMARY_FACILITY_TYPE**	**ADT**	**ID**	**Daily Total**	**Comparison Ratio**
73975002	VM	On; road with minimal or no shoulder	12	65188	0.05	0.43%
84475001	VM	On; road with minimal or no shoulder	13	55846	0.18	1.41%
84925002	AI	On; sidewalk	110	19476	0.43	0.39%

***COUNT_TYPE Codes:** AI – automated infrared, VM – video manual, Both – automated infrared and manual

The average comparison ratio is 0.8%, indicating that only approximately 0.8% of the non-motorized traffic stream is represented by users of the Strava app. This ratio is significantly lower than comparable values reported by Strava for other regions in the U.S., but is not surprising because most of the average daily counts from the Strava Metro data were lower than 1.0. The average comparison ratios for sites by facility type are:

- Sidewalks or foot bridges – 0.6%,
- Multiuse paths and trails – 0.4%
- Roadways with no dedicated walking or cycling infrastructure – 1.5%.

These results confirm what was revealed by the comparison of automated infrared counts and video manual counts. Counts that were focused on dedicated walking and biking infrastructure, like multiuse paths and sidewalks, seem especially mismatched with the Strava Metro data. In the observations of the video used for the automated infrared validation, it became clear that more “serious” cyclists, and even some runners, chose not to use the dedicated infrastructure, and instead used the roadway. This tendency would make the two datasets (count and Strava Metro) disparate and the comparison ratio inappropriate.

Instead, in these situations, it will often be more suitable to consider the Strava Metro data supplementary to the data collected on the dedicated infrastructure. At locations where no dedicated infrastructure exists, the two non-motorized streams (Strava users and non-Strava users) are confined to the same infrastructure (the roadway), so we can be sure that the comparison ratio is appropriate. In fact, the comparison ratio for the roadway-based counts (typically video manual counts) was much closer to the ratios reported by Strava (2 to 5%), lending further support to the assertion that Strava Metro data should be considered supplemental on screenlines with non-motorized infrastructure, since the Strava users are not as likely to be using it.

6 Conclusions and Recommendations

The overarching goal of this effort was to lay the foundation for a comprehensive non-motorized count program for the state of Vermont.The key outcomes of this work included:

- Creation of a new data input tool that standardized the data formats and response options based on national protocols and adjusted them to suit the needs of the statewide count program.
- Creation of a new database with a linked Site ID that will prevent data duplication and loss, especially if the new data input tool is used to control how new count data is introduced into the database.
- Creation of a new web portal to view the existing count data in site summary form or to download raw data. The new web portal also contains a fixed link to the new data input tool allowing for easy navigation to data input and output by all other entities statewide.
- Recommendations on new count sites as sites to date have been too focused on sidewalks and multiuse paths where high non-motorized volumes are expected. Collecting data at new count sites will begin to rectify this situation and move toward a more representative sampling approach.
- Exploration of correction factors for existing counts collected with automated counters throughout the state. Automated infrared counts can be multiplied by a correction factor of 1.16 to account for occlusion, but this factor is affected by the social context of the pedestrian activity at the site.
- Exploration of Strava data resources as a complement to the non-motorized count data program. Strava Metro Data only accounts for about 0.8% of Vermont's daily non-motorized travel, but can be a useful source of complete-screenline data when sidewalk or on-network multiuse path counts need to be supplemented with roadway volumes.

We recommend the use of this guidance and the associated Data Input Tool and Data Web Portal as the primary methodology to collect and report data on non-motorized transportation across the state. This will ensure uniformly formatted count data for integration into a singular data repository.

The count data resources that are integral to this program require the continued efforts of various entities across the state to collect the non-motorized count data. Therefore, we strongly encourage continued support of the regional planning commissions to count non-motorized users as part of the Transportation Planning Initiative. We also encourage other individuals, including other representatives from municipalities, agencies, and advocacy groups, to report any non-motorized data they collect to the portal.

The count program tools and portal were designed with the presumption that regular maintenance tasks would be conducted. We are recommending that these maintenance tasks be initiated either biannually or quarterly. These tasks include the following:

- Retrieve data on a regular schedule from the input tool;
- Conduct quality assurance and quality control checks on the data following data retrievals from the input tool;
- Upload quality checked data to the database; and,
- Update data portal with newly acquired data metrics from the database.

It will be crucial to continue to transfer data from the input tool to the database, and from the database to the web portal, especially given the necessary quality assurance procedures. The manual check of the data required by this transfer is consistent with similar national efforts, including the efforts by FHWA to create a national repository of bicyclist and pedestrian data as an extension to the vehicular traffic counting program. In addition, the opportunity to review all input data and determine if it meets the standard for inclusion in the database and data portal will allow the inclusion of data outside the typical sources, like volunteer-collected data or crowd-sourced data.

Beyond the recommendations for continued data collection efforts and maintenance of the database and web portal, we recommend the following:

- Incorporate non-motorized counts at intersections from the Traffic Research section into the database
- Develop a GIS inventory of non-motorized infrastructure to facilitate analyses that require facility mileage. Unlike documentation of the on-road network through town highway maps and associated GIS products, a single repository for non-motorized facilities does not yet exist. Geographic information and relevant facility attributes should be gathered for on- and off-network non-motorized facilities throughout the state, including sidewalks, multiuse paths, and trails.
- Gather data from other non-motorized count resources and incorporate into the count database. Although data was gathered from many existing resources for this effort, at least one other data resource was

identified through the course of the project and there are likely others. Of interest may be data from the Agency of Natural Resources, which maintains a network of about 15 infrared counters that are rotated to trailside sites in each of their management districts.

- Include other factors in the database and data web portal that may be useful in future analyses. The national data protocols and other data portals reviewed as part of this effort included factors that may affect spatial patterns of non-motorized activity (e.g. proximity to schools, parks, retail opportunities, etc.) or temporal patterns of non-motorized activity (e.g. season, weather, precipitation, special events, etc.). Exploring the utility of these factors in explaining the spatiotemporal patterns of non-motorized activity in the state should be one of the next priorities for this work.

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Appendix A: Site Summary Parameters Calculation Formulae

Four site summary parameters were calculated for display on the data web portal. The parameters were calculated using the following MS Excel formulae:

- ADT: IF(Site Data:COUNT_TYPE="Manual", "-", IF(OR(Site Data:COUNT_TYPE="EcoCounter", Site Data:COUNT_TYPE="Both"), AVERAGEIF(Auto Infrared Data:SITE_ID, Site Data:SITE_ID, Auto Infrared Data:Daily), IF(Site Data:COUNT_TYPE="Video Manual", AVERAGEIF(Video Manual Data:SITE_ID, Site Data:SITE_ID, Video Manual Data:Total Bike/Ped), "-")))
- PHT: {IF(Site Data:COUNT_TYPE="Manual", MAX(IF(Manual Data:SITE_ID=Site Data:SITE_ID, Manual Data:PeakHourCount)), IF(Site Data:COUNT_TYPE="EcoCounter", MAX(IF(Auto Infrared Data:SITE_ID=Site Data:SITE_ID, Auto Infrared Data:Hourly)), IF(Site Data:COUNT_TYPE="Both", MAX(MAX(IF(Manual Data:SITE_ID=Site Data:SITE_ID, Manual Data:PeakHourCount)), MAX(IF(Auto Infrared Data:SITE_ID=Site Data:SITE_ID, Auto Infrared Data:Hourly))), IF(Site Data:COUNT_TYPE="Video Manual", MAX(IF(Video Manual Data:SITE_ID=Site Data:SITE_ID, Video Manual Data:PHT)), "-")))))}
- PDT: {IF(Site Data:COUNT_TYPE="Video Manual", MAX(IF(Video Manual Data:SITE_ID=Site Data:SITE_ID, Video Manual Data:Total Bike/Ped)), IF(OR(Site Data:COUNT_TYPE="EcoCounter",Site Data:COUNT_TYPE="Both"), MAX(IF(Auto Infrared Data:SITE_ID =Site Data:SITE_ID, Auto Infrared Data:Daily)), "-"))}
- Duration: SUMIF(Manual Data:SITE_ID, Site Data:SITE_ID, Manual Data:Duration) + (COUNTIFS(Auto Infrared Data:SITE_ID, Site Data:SITE_ID,Auto Infrared Data:Interval, "15-minute")/4) + (COUNTIFS(Auto Infrared Data:SITE_ID, Site Data:SITE_ID, Auto Infrared Data:Interval, "hour")) + (24*COUNTIF(Video Manual Data:SITE_ID, Site Data:SITE_ID))

Note that the formulae for PHT and PDT are array-type, and that ADTs and PDTs are not calculated for any of the sites where only manual counts have been conducted.

Appendix B: Bicycle and Pedestrian Count Program Field Data Sheet

The field data sheet is a printable document designed to help users record the information needed to fully populate a site location and new count in the data input tool. The expectation is that a hardcopy of the field data sheet be filled out by field technicians as they set up a site location with an automated count device, video-based count device, or conduct a manual count. The front of the field data sheet (Figure A1) defines the attributes regarding the site location and count data. The back of the field data sheet (Figure A2) provides a template for tallying manual counts or manual tallies of video-based counts. Multiple copies of the second page of the field data sheet can be reproduced if longer counts are expected to be tallied at the same site. These handwritten attributes and tallies can be transcribed directly into the data input tool and manual count data template for upload.

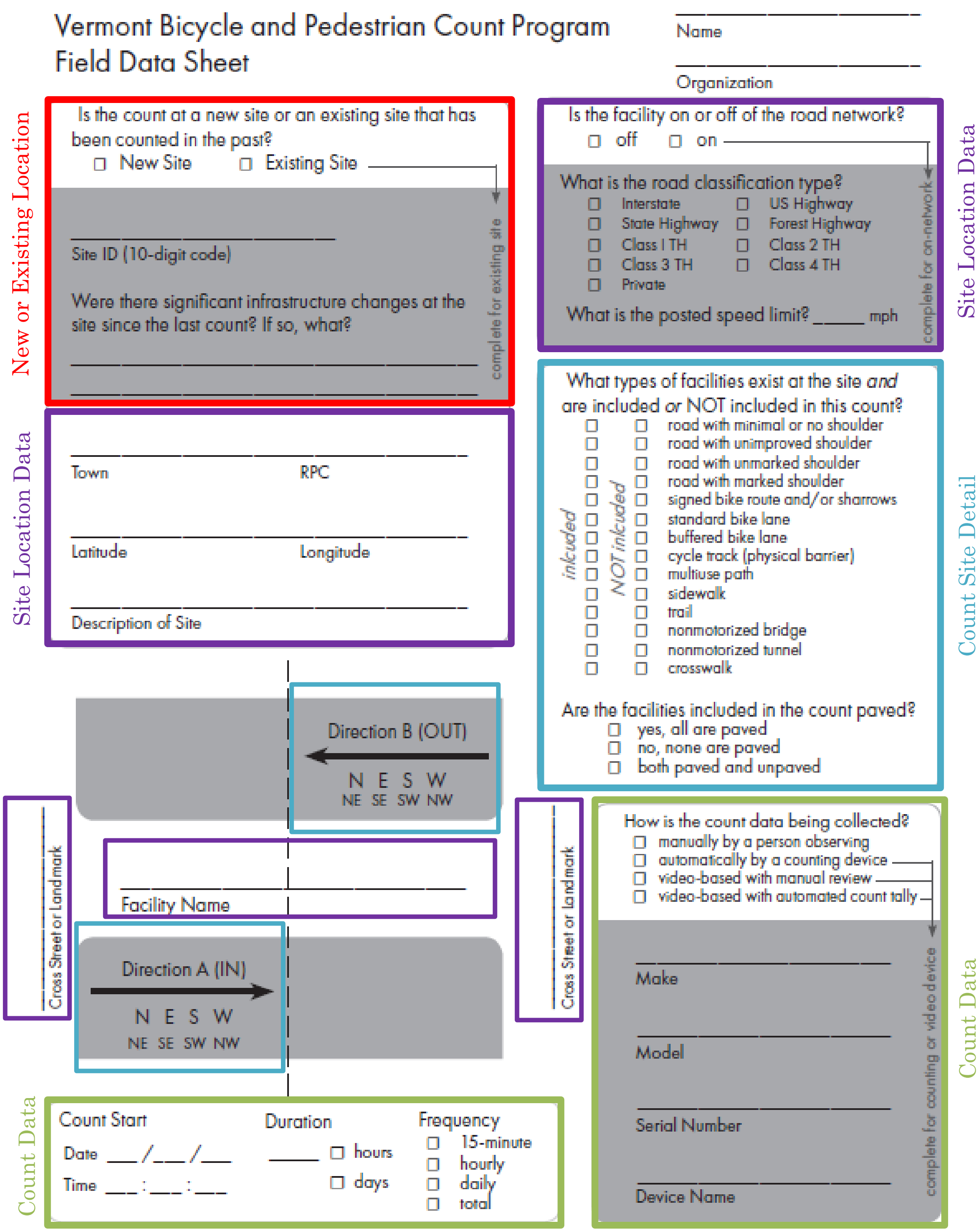
The sections of the field data sheet match with those in the data input tool. Field users will be prompted whether the site is a new or existing count location (highlighted in red, Figure A1). If existing site is selected, users should provide the 10-digit code identifying the existing site from the bike and pedestrian portal and record if there are changes to the infrastructure since the last count.

Many of the site location information fields (highlighted in purple, Figure A1) have space for text responses, including town, RPC, latitude, longitude, description of site, facility name, and nearby cross streets or landmarks. The individuals uploading count data to the input portal will be able to identify latitude and longitude on the interactive map; therefore, latitude and longitude on the field data sheet are optional. It is, however, highly recommended these fields be populated if the field technician recording the data is not going to do the data input step. This will ensure that the exact location of the counter is properly identified. Additional site location data regarding the segment type will prompt users to identify the road classification type and posted speed limit if the facility is on the road network (i.e. shares the right of way with vehicular corridor).

Count site details (highlighted in turquoise, Figure A1) outline all of the options for selection of facility types available at the current site that were both included and not included in the screenline count. Note that all of the facilities *available* and *included* in the count should be checked on the left and all those *available* and *not included* should be checked on the right. The paved status of the facilities should be indicated. In addition, on the screenline site diagram, the direction of the facility and the bicyclist and pedestrian movements should be identified by circling one of the directional choices: North (N), East (E), South (S), West (W), Northeast (NE), Southeast (SE), Southwest (SW), or Northwest (NW).

Count data (highlighted in green, Figure A1) regarding the count type, count start date/time, duration, and frequency should be recorded. If an automated counting device or video-based system was installed, the information regarding that system should be recorded, including make, model, serial number, and nickname or shorthand name for the device.

The back of the field data sheet (Figure A2) is a template for the manual count or manual tally of the video-based count. An example is included in the first record, which shows the proper time format and a count tally example. Bicyclists and pedestrians should be counted in each direction separately, in accordance with the directions identified in the diagram on the front of the field data sheet.



Vermont Bicycle and Pedestrian Count Program
Field Data Sheet

Name ____________
Organization ____________

New or Existing Location

Is the count at a new site or an existing site that has been counted in the past?
- ☐ New Site
- ☐ Existing Site

complete for existing site

Site ID (10-digit code) ____________

Were there significant infrastructure changes at the site since the last count? If so, what?
____

Site Location Data

Is the facility on or off of the road network?
- ☐ off
- ☐ on

complete for on-network

What is the road classification type?
- ☐ Interstate
- ☐ US Highway
- ☐ State Highway
- ☐ Forest Highway
- ☐ Class I TH
- ☐ Class 2 TH
- ☐ Class 3 TH
- ☐ Class 4 TH
- ☐ Private

What is the posted speed limit? _____ mph

Site Location Data

Town ____________ RPC ____________
Latitude ____________ Longitude ____________
Description of Site ____________

Count Site Detail

What types of facilities exist at the site *and* are included *or* NOT included in this count?

(*included* / *NOT included*)
- ☐ ☐ road with minimal or no shoulder
- ☐ ☐ road with unimproved shoulder
- ☐ ☐ road with unmarked shoulder
- ☐ ☐ road with marked shoulder
- ☐ ☐ signed bike route and/or sharrows
- ☐ ☐ standard bike lane
- ☐ ☐ buffered bike lane
- ☐ ☐ cycle track (physical barrier)
- ☐ ☐ multiuse path
- ☐ ☐ sidewalk
- ☐ ☐ trail
- ☐ ☐ nonmotorized bridge
- ☐ ☐ nonmotorized tunnel
- ☐ ☐ crosswalk

Are the facilities included in the count paved?
- ☐ yes, all are paved
- ☐ no, none are paved
- ☐ both paved and unpaved

Direction B (OUT)
N E S W
NE SE SW NW

Cross Street or Landmark ____________

Facility Name ____________

Direction A (IN)
N E S W
NE SE SW NW

Cross Street or Landmark ____________

Count Data

How is the count data being collected?
- ☐ manually by a person observing
- ☐ automatically by a counting device
- ☐ video-based with manual review
- ☐ video-based with automated count tally

complete for counting or video device

Make ____________
Model ____________
Serial Number ____________
Device Name ____________

Count Data

Count Start
Date ___/___/___
Time ___:___:___

Duration
_____ ☐ hours
☐ days

Frequency
- ☐ 15-minute
- ☐ hourly
- ☐ daily
- ☐ total

Figure B1. Front page of field data sheet.

Date ___/___/___	Direction A		Direction B	
Time	Pedestrians	Bicyclists	Pedestrians	Bicyclists
14:45:00	𝍸			

Figure B2. Back page of field data sheet.

Appendix C: Manual Count Template

The manual count data tallied on the back of the field data sheet should be entered into the manual count template in Microsoft Excel (Table B1), in order to get the data into the appropriate format for uploading into the database. This will ensure that the appropriate data fields are populated by the counter or count agency, as well as minimize the data processing steps for the database administrators.

Users will be expected to take tallies at regular time intervals, 15-minute or hourly are recommended. The manual data template has been programed to format the date and time appropriately. This date and time entered should be the leading timestamp of the interval (i.e. 2017-01-31 14:45:00 timestamp represents all counts between 2:45 PM and 3:00 PM). Counts are expected to be directional and discriminate between bicyclists and pedestrians. Therefore, four columns are available for tallies, including Pedestrians in Direction A, Bicyclists in Direction A, Pedestrians in Direction B, and Bicyclists in Direction B.

The additional populated fields on the right in the example in Table B1, including Total for Count Duration, Duration of Count, and Interval of Count, are fields that are locked and will be automatically populated when the user fills in the count date/time and tallies.

Table C1. Manual Count Data Entry Template with Example Count

Date Time	Direction A		Direction B	
yyyy-mm-dd HH:MM:SS	Pedestrians	Bicyclists	Pedestrians	Bicyclists
2017-01-31 14:45:00	18	9	11	5
2017-01-31 15:00:00	24	13	7	10
2017-01-31 15:15:00	30	17	10	13
2017-01-31 15:30:00	36	21	16	15
2017-01-31 15:45:00	42	25	17	16
2017-01-31 16:00:00	48	29	15	13
2017-01-31 16:15:00	51	30	18	20
2017-01-31 16:30:00	38	41	10	12
2017-01-31 16:45:00	45	35	8	13
2017-01-31 17:00:00	37	40	4	11
2017-01-31 17:15:00	29	32	18	13
2017-01-31 17:30:00	20	35	9	4
2017-01-31 17:45:00	12	28	13	9
2017-01-31 18:00:00	21	25	5	10
2017-01-31 18:15:00	18	15	8	5
2017-01-31 18:30:00	10	13	1	3
2017-01-31 18:45:00	8	18	4	2

Total for Count Duration	
Pedestrians	Bicyclists
661	600

Duration of Count
4.00 hours

Interval of Count
15-minute

Appendix D: Site Selection Additional Information

The recommended sites that were identified through a gap analysis and representative, random site selection process are enumerated in Table D1 below. The additional attributes included are the segment type, facility types available, surface material, latitude, and longitude.

Table D1. Details for New Count Sites – Target 20 Representative Sites

Town	Facility Name	Facility Class	Segment Type	Facility Types Available	Paved	Latitude	Longitude
Lyndon	US-5	US Highway	ON	road with marked shoulder	yes	44.57896	-71.9857
Randolph	VT-14	State Highway	ON	road with minimal or no shoulder	yes	43.93132	-72.5527
Sunderland	VT-7A	State Highway	ON	road with marked shoulder	yes	43.11673	-73.1128
Halifax	Green River Road	Class 2 TH	ON	road with minimal or no shoulder	yes	42.79993	-72.6847
Dorset	Mad Tom Road	Class 2 TH	ON	road with minimal or no shoulder	no	43.26343	-72.9911
Rockingham	Saxtons River Road	Class 2 TH	ON	road with minimal or no shoulder	yes	43.13772	-72.4887
Pownal	Niles School Road	Class 3 TH	ON	road with minimal or no shoulder	no	42.78065	-73.2029
Brattleboro	Fairground Road	Class 3 TH	ON	road with minimal or no shoulder; sidewalk	yes	42.83795	-72.5624
Manchester	Mt Aeolus Drive	Class 3 TH	ON	road with marked shoulder	yes	43.19835	-73.0533
Rutland	North Street Ext	Class 3 TH	ON	road with minimal or no shoulder	yes	43.61944	-72.9681
Hancock	Texas Falls Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.9358	-72.9027
Grafton	Putnam Forest Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.19887	-72.6237
Randolph	Mountain Avenue	Class 3 TH	ON	road with minimal or no shoulder	yes	43.92901	-72.6638
Hartland	Shute Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.56186	-72.4055
Troy	River Road	Class 3 TH	ON	road with minimal or no shoulder	yes	44.916	-72.3966
Danville	North Shore Road	Class 4 TH	ON	road with minimal or no shoulder	no	44.41735	-72.218
Guilford	TH-55	Class 4 TH	ON	road with minimal or no shoulder	no	42.79989	-72.6109
Northfield	Falls Mobile Home	Private	ON	road with minimal or no shoulder	yes	44.16851	-72.6523
Hartford	Catamount Road	Private	ON	road with minimal or no shoulder	yes	43.64581	-72.4355
Warren	Stony Hill Road	Private	ON	road with minimal or no shoulder	no	44.11011	-72.8898

In addition, a second round of site locations were selected using the same methodology, but targeting a total of 3000 hours of observation at representative sites to be added to the database. The 20 sites in Table D1 along with the 23 additional sites in Table D2 would provide over 3000 hours of observation at representative sites, expanding to other facility classes including National or State Forest Highway and Multiuse Path facilities. It is important to note that because a geographic data repository for non-motorized facilities does not yet exist, the multiuse path inventory assembled as part of this effort was used to select the count site on the multiuse path. The multiuse paths that had not yet been counted as part of the existing data set were assigned indices and a random number generator was used to select the candidate site included below. The secondary sites would be the next set of locations that should be pursued for counting efforts. Included in Table D2 are the relevant site attributes and in Figure D1 a map of the current and new count sites, including the 20 target sites and the additional 23 count locations to target 3000 hours of observation.

Table D2. Details for Additional New Count Sites – Target 3000 Hours

Town	Facility Name	Facility Class	Segment Type	Facility Type	Paved	Latitude	Longitude
Waitsfield	VT-100	State Highway	ON	road with marked shoulder; sidewalk	yes	44.18393	-72.8371
Springfield	VT-10	State Highway	ON	road with marked shoulder	yes	43.33629	-72.5353
Shaftsbury	Airport Road	Class 2 TH	ON	road with minimal or no shoulder	no	42.96828	-73.1913
Stratton	Brazers Way	Class 2 TH	ON	road with unimproved shoulder	yes	43.10562	-72.8891
Orwell	Mt Independence Road	Class 2 TH	ON	road with minimal or no shoulder	yes	43.79608	-73.3241
Woodstock	Covered Bridge Road	Class 2 TH	ON	road with minimal or no shoulder	yes	43.63069	-72.4683
Guilford	Baker Cross Road	Class 3 TH	ON	road with minimal or no shoulder	no	42.74282	-72.6122
Dorset	Cross Road	Class 3 TH	ON	road with minimal or no shoulder	yes	43.22698	-73.0773
Benson	Stage Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.72496	-73.3134
Brandon	Basin Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.81795	-73.046
Wardsboro	Hemlock Hill Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.0498	-72.8277
Londonderry	Goodaleville Road	Class 3 TH	ON	road with minimal or no shoulder	yes	43.16628	-72.8226
Townshend	Back Windham Road	Class 3 TH	ON	road with minimal or no shoulder	yes	43.08467	-72.7096

Town	Facility Name	Facility Class	Segment Type	Facility Type	Paved	Latitude	Longitude
Braintree	Peth Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.99081	-72.6805
Randolph	South Randolph Road	Class 3 TH	ON	road with minimal or no shoulder	yes	43.93229	-72.5925
Vershire	Taylor Valley Road	Class 3 TH	ON	road with minimal or no shoulder	no	43.95216	-72.3377
Charleston	Mad Brook Road	Class 4 TH	ON	road with minimal or no shoulder	no	44.79646	-71.9873
Topsham	Downing Road	Class 4 TH	ON	road with minimal or no shoulder	no	44.15413	-72.2624
Westmore	Westside Lane	Private	ON	road with minimal or no shoulder	no	44.77082	-72.0809
Williston	Walnut Walk	Private	OFF	sidewalk	yes	44.44567	-73.1099
Newfane	Kenolie Campground	Private	ON	road with minimal or no shoulder	no	42.98325	-72.638
Bristol	Beaver Meadow Spur	Forest Highway	ON	road with minimal or no shoulder	no	44.05195	-73.0506
Dover	Valley Trail	Multiuse Path	OFF	multiuse path	yes	42.94239	-72.8599

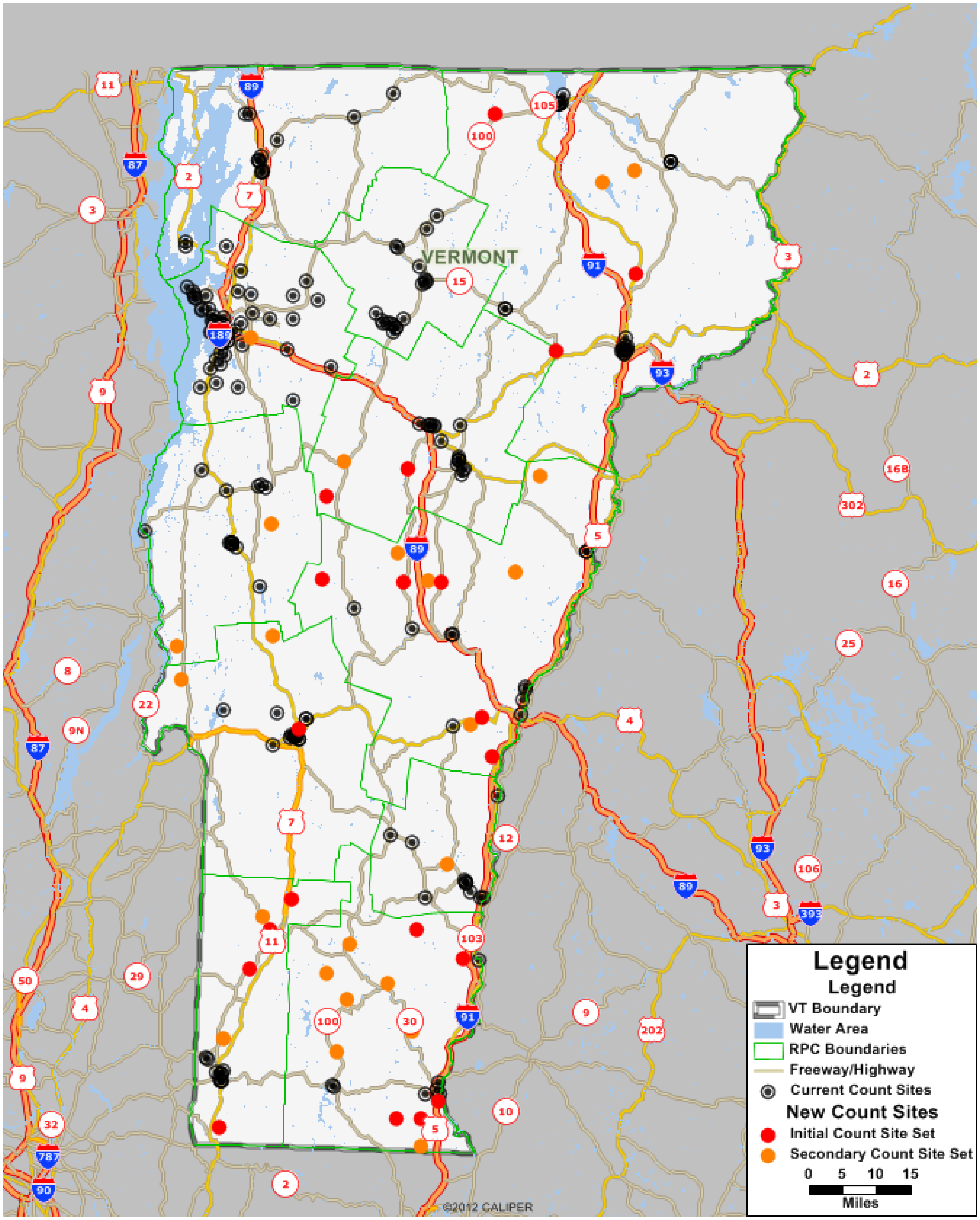


Figure D1. Map of the current and new count site locations, red indicating the initial set of sites to be counted and orange representing the secondary set of sites.

Appendix E: Data Dictionary for Data Input Tool

The data input tool questions and response options designed and implemented in LimeSurvey align with the desired fields in the non-motorized database and provided the appropriate data field name. The sections, questions, and response options from the field data sheet are consistent with the question handles, questions, and response options in the data input tool. The field names, question handles, input questions, and response options that users will interact with through the data input tool are listed in the data dictionary in Table E1.

Table E1. Data Dictionary for the Data Input Tool

Field Name	Question Handle	Data Input Tool Question	Response Options
INPUT_ORG	DataInput1	What organization are you affiliated with?	Vtrans ACRPC BCRC CCRPC CVRPC LCPC NRPC NVDA RRPC SWCRPC TRORC WRC Other
INPUT_CONTACT	DataInput2	What is your contact information?	
		What is your name (first and last)?	*open response*
		What is your email address?	*open response*
		What is a phone number to reach you or your organization?	*open response*
NEW_SITE	NewSite1	Was the new count data collected at a new site location or was the new count collected at an existing site location where counts have been collected in the past?	New Site Location Existing Site Location
OLD_SITE_ID	NewSite2	What is the Site ID for the location where a new count was conducted?	*List of pre-existing 10-digit Site Location IDs*
NEW_INFRA	NewSite3	Were there any significant infrastructure changes to the site since the last bicycle and pedestrian count was conducted that might affect the count?	*open response*
TOWN	Site1	In what city or town is the count site located?	*List of 255 Towns in Vermont*

Field Name	Question Handle	Data Input Tool Question	Response Options
RPC	Site2	Which RPC is the count site located in?	ACRPC BCRC CVRPC CCRPC LCPC NVDA NRPC RRPC SWCRPC TRORC WRC
LAT_LONG	Site3	Where is the count site located?	*pin on interactive map designates town, latitude, and longitude*
FACILITY_NAME	Site4	What is the name of the facility on which the count was taken?	*open response*
LOCATION	Site5	What is the nearest cross street or landmark to the count site?	*open response*
DESCRIPTION	Site6	What other descriptive information is pertinent to locating this count site?	*open response*
SEGMENT_TYPE	Site7	Is the counted facility on or off of the road network?	ON OFF

Field Name	Question Handle	Data Input Tool Question	Response Options
ROAD_CLASS	Site8	What is the road classification type?	Interstate Highway US Highway State Highway Class 1 Town Highway Class 2 Town Highway Class 3 Town Highway Class 4 Town Highway National or State Forest Highway Private
SPEED_LIMIT	Site9	What is the posted speed limit on the road segment?	25 mph or less 30 mph 35 mph 40 mph 45 mph 50 mph 55 mph 60 mph 65+ mph

Field Name	Question Handle	Data Input Tool Question	Response Options
FACILITY_TYPE	CountSite1	What type of facility were bicyclists and pedestrians counted on? Please check all that apply.	road with minimal or no shoulder road with unimproved shoulder road with unmarked shoulder road with marked shoulder road with signed bike route and/or sharrows standard bike lane buffered bike lane cycle track (physical barrier) multiuse path sidewalk trail nonmotorized bridge nonmotorized tunnel crosswalk
FACILITY_PAVED	CountSite2	Are the count facilities paved?	yes, all are paved no, none are paved both paved and unpaved
FACILITY_NOCOUNT	CountSite3	Are there facilities available at the count site that were NOT included in the count?	YES NO

Field Name	Question Handle	Data Input Tool Question	Response Options
FACILITY_NOCOUNT_TYPE	CountSite4	What type of facilities were available and NOT included in the count of bicyclists and pedestrians?	road with minimal or no shoulder road with unimproved shoulder road with unmarked shoulder road with marked shoulder road with signed bike route and/or sharrows standard bike lane buffered bike lane cycle track (physical barrier) multiuse path sidewalk trail nonmotorized bridge nonmotorized tunnel crosswalk
COUNT_DIRA	CountSite5	What is the direction of travel for the count in direction A (IN)?	N S E W NE SE NW SW

Field Name	Question Handle	Data Input Tool Question	Response Options
COUNT_DIRB	CountSite6	What is the direction of travel for the count in direction B (OUT)?	N S E W NE SE NW SW
COUNT_TYPE	Count1	How was the count data collected?	manually by a person observing automatically by a bicycle/pedestrian counting device video-based with a person manually reviewing video-based with automated count tallying

Field Name	Question Handle	Data Input Tool Question	Response Options
COUNT_DEVICE	Count2	What type of device was used to collect the count data?	Diamond EcoCounter EDI FLIR GTT Jamar MetroCount Miovision Reno A&E Road Sys Sensys Networks TimeMark TRAFx TrailMaster Other
COUNT_DEVICE_DETAIL	Count3	Please specify the following information about the device:	
		Device Model (e.g. PYRO for EcoCounter PYRO)	*open response*
		Device Serial Number	*open response*
		Device Nickname (e.g. UVM TRC Eco2)	*open response*
COUNT_CONTACT	Count4	Who was responsible for observing and/or tallying the count data?	*open response*

Field Name	Question Handle	Data Input Tool Question	Response Options
COUNT_ORG	Count5	With what organization is this person affiliated?	Vtrans ACRPC BCRC CCRPC CVRPC LCPC NRPC NVDA RRPC SWCRPC TRORC WRC Other
COUNT_START	Count6	At what date and time did the count data collection start?	*calendar and clock selection*
COUNT_DURATION	Count7	What was the duration of the count?	*open numeric only response*
COUNT_UNITS	Count8	(define units for previous question)	hours days weeks years continuous
COUNT_FREQ	Count9	At what frequency was the count tallied or recorded?	15-minute hourly daily total (for reported duration)
MAN_FILE_NAME	Manual10	Please upload your manual data file here:	*data file upload*
AUTO_FILE_NAME	Auto1	Please upload the data file from your automated count device here:	*data file upload*