PHASE TWO

VTRANS ON-ROAD BICYCLE PLAN

SPRING 2018

VERMONT
Agency of Transportation

RSG

alta
PLANNING + DESIGN

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Jess Devlin	*Agency of Transportation*
Amy Bell	*Agency of Transportation*
Erin Parizo	*Agency of Transportation*
Chad Allen	*Agency of Transportation*
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Joe Segale	*Agency of Transportation*
Lou Brisee	Green Mountain Bicycle Club
Josh Donabedian	Addison County Regional Planning Commission
John Adams	*Agency of Commerce and Community Development*
David Ellenbogen	*Local Motion*
Lucy Gibson	*American Council of Engineering Companies*
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Doug Morton	*Northeastern Vermont Development Association*
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Chapter 1. Executive Summary

1.0 Introduction

This report presents findings from Phase Two of the Vermont Agency of Transportation (VTrans) On-Road Bicycle Plan. The On-Road Bicycle Plan is a multi-phase project. The overall goal of the effort is to improve the condition of state roads* to enhance safety and better accommodate the needs of all bicyclists. The Plan's emphasis is on those roads designated as high-use priority bicycle corridors. The Plan will assist VTrans in understanding where to focus limited resources towards bicycle improvements and allow better integration into Agency projects and activities.

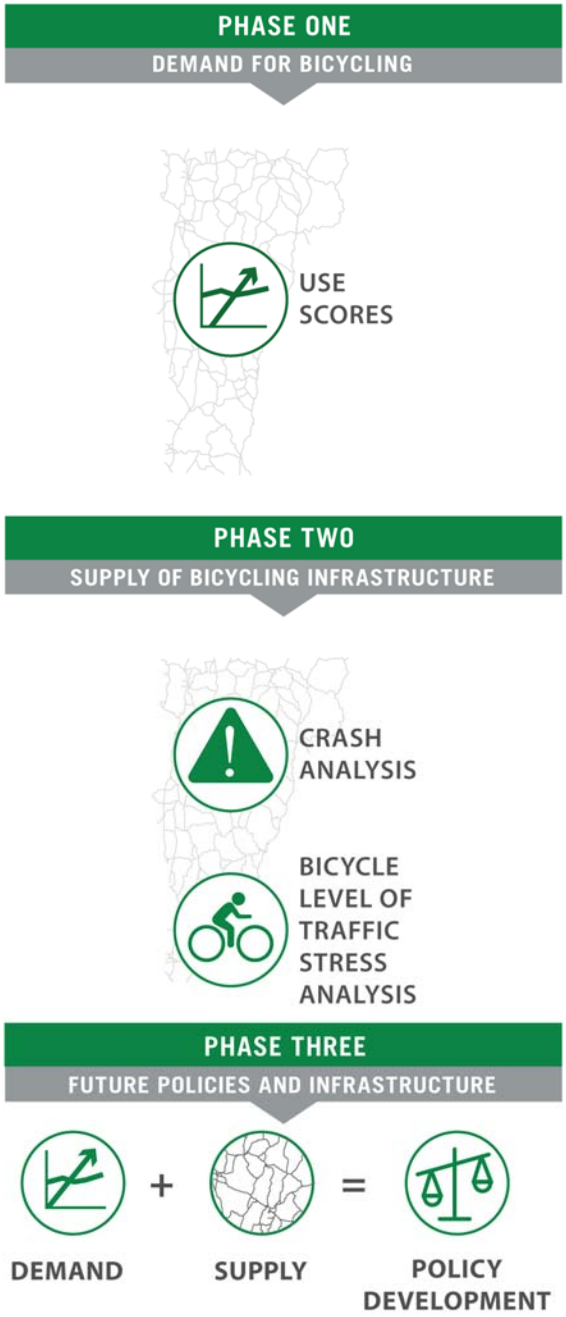
Phase One of the VTrans On Road Bicycle Plan began in 2015 and focused on identifying demand for bicycling on state roads. The product of this analysis categorized state roads into high-, moderate- and low-use corridors, based on current and potential bicycle use. Bicycle use was influenced by land use patterns, bicycle access to state roads, and current and potential bicycle use through a combination of public outreach and quantitative analysis. Once VTrans determined the demand for bicycling on state roads, the next step was to evaluate the conditions, or supply, of these roadways for bicycling.

Phase Two included two primary task elements, a detailed bicycle crash analysis (on state roadways) and the development of a methodology to assess how comfortable state roads are to bicycle. The crash analysis resulted in an understanding of statewide bicycle crash patterns. A Bicycle Level of Traffic Stress methodology, which is a national methodology, was used and adapted to Vermont's context to assess how comfortable Vermont's state roads are for bicycling. These two tasks evaluated the supply of bicycling facilities along state roads and identified where investments can be made to improve both safety and comfort. This report summarizes the steps involved with Phase Two and presents key findings.

Phase Two will directly inform Phase Three. Phase II results will be used for project prioritization, Project Identification and Definition, and corridor planning. The goal of Phase III is to understand how Phase II results could be used as input into project development and to define policies in the VTrans' Bicycle and Pedestrian Policy Plan Update.

This Executive Summary provides an overview of the major elements of Phase Two, including stakeholder and public engagement. Chapter 2 provides a detailed overview of the bicycle crash analysis, and Chapter 3 summarizes the steps taken to develop the VTrans roadway comfort analysis.

Figure 1.1 On-Road Bike Plan Phase Overview



*State roads include roads under VTrans jurisdiction. For the purpose of this analysis, State roads include Class 1 Town Highways, which are managed by the municipality with joint jurisdiction with VTrans. Additionally, most limited access highways are excluded, because bicycles are prohibited from riding on them by state law. However, some state-managed limited access roads are included, such as VT 289 and the St. Albans State Highway, because a suitable adjacent alternative bicycle facility does not exist in those locations.

1.1 Engagement Summary

VTrans Policy, Planning and Research Bureau led a collaborative stakeholder and public outreach process for the development of the Phase Two report. The process included one statewide public meeting, an online question-and-answer survey, and multiple stakeholder meetings. These stakeholder meeting included internal VTrans staff, as well as a larger stakeholder committee comprised of staff, advocates and transportation professionals. Feedback collected from these groups was synthesized and used to improve the approach of the analysis and the final level of comfort methodology. This page summarizes the key engagement activities that occurred during Phase Two.

Statewide Meeting

VTrans and the consultant team led a statewide public meeting for Phase Two on December 1, 2016. The meeting was streamed live from Montpellier to 11 locations at Regional Planning Commission offices throughout the state. Attendees could also participate via live stream from their homes, or other places where they had internet access. The meeting provided an overview of the process, and the key findings from the bicycle crash analysis. The meeting was successful in gaining input for the project and generating interest in the online survey.

1 STATEWIDE PUBLIC MEETING

11 LOCATIONS THE MEETING WAS STREAMED TO

Online Survey

After the statewide meeting, an online survey was launched that asked specific questions about bicycling on Vermont's state roads. Questions focused on understanding what roadway variables influence bicyclist comfort when riding in either urban (downtowns, village centers, populated areas) and rural contexts. The survey also included demographic questions to understand the types of people responding to the survey. More than 1,000 people responded to the survey. The results of the survey were informative and influenced the development of the BLTS methodology to assess how comfortable Vermont's state roads are for bicycling.

9 QUESTIONS

1,025 RESPONSES

Stakeholder Meetings

Stakeholder engagement was critical to the development of the Phase Two analysis and findings. Two primary stakeholder groups were established to inform the development of the report. This included a stakeholder group comprised of external members and VTrans staff, as well as an internal working group (IWG) comprised exclusively of VTrans staff. The external stakeholder group was engaged at key milestones in the development of Phase Two. The IWG convened more regularly to ensure broad Agency support for task work and deliverables.

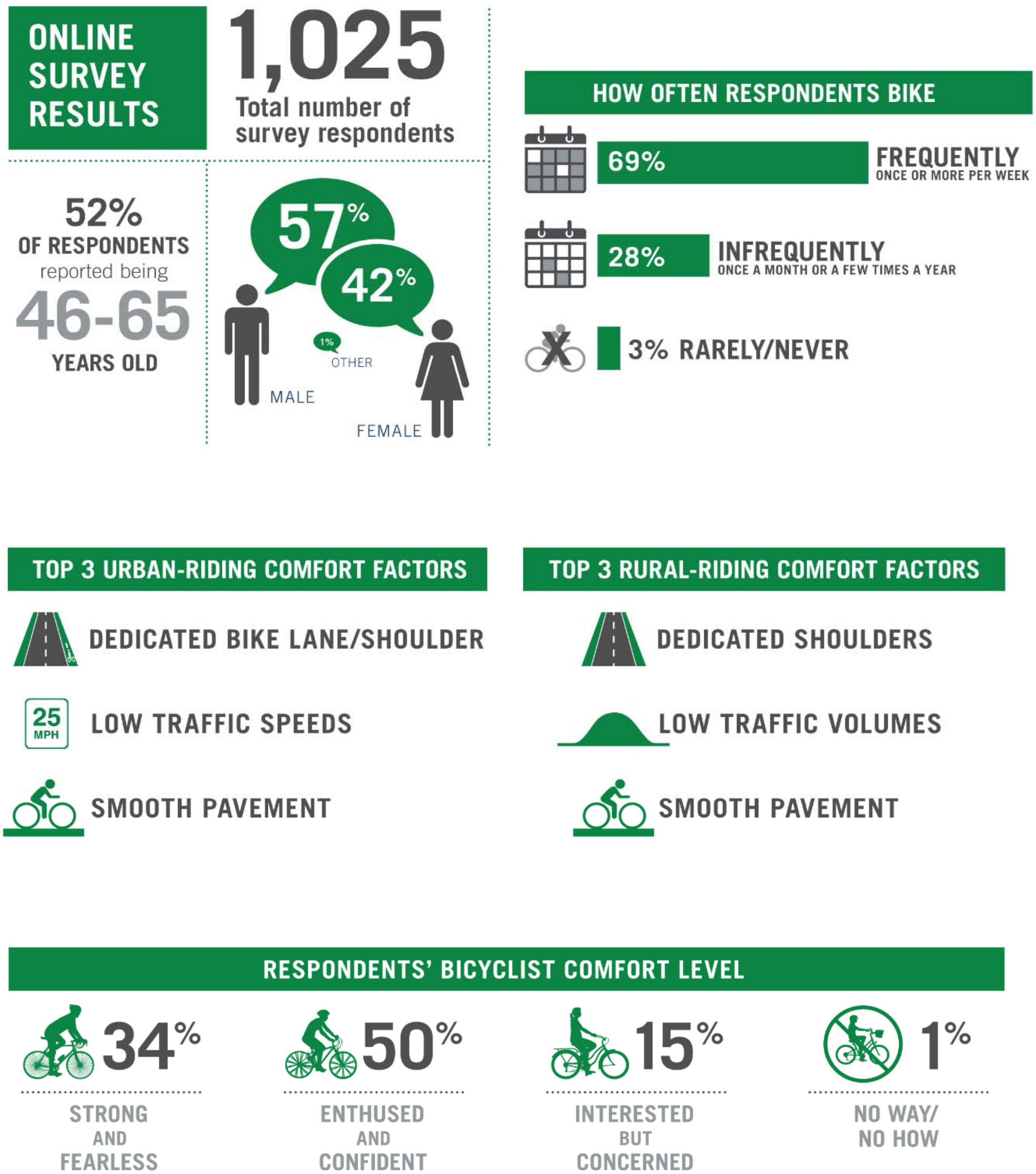
3 STAKEHOLDER MEETINGS

5 INTERNAL WORKING GROUP MEETINGS

1.2 Online Survey Summary

The online survey for Phase Two was open from February 9th to March 10th 2017. The survey was posted on the VTrans web-page for the On-Road Bike Plan and sent to a large list-serve that included people interested in bicycling in Vermont. The survey was successful in gaining responses from more than 1,000 people. Figure 1.2 provides a snap-shot of the key survey findings. The information gathered from the survey informed the development of the methodology to evaluate how comfortable Vermont's roads are for bicycling, which is described in Chapter 3. Complete results of the survey are provided in Appendix D.

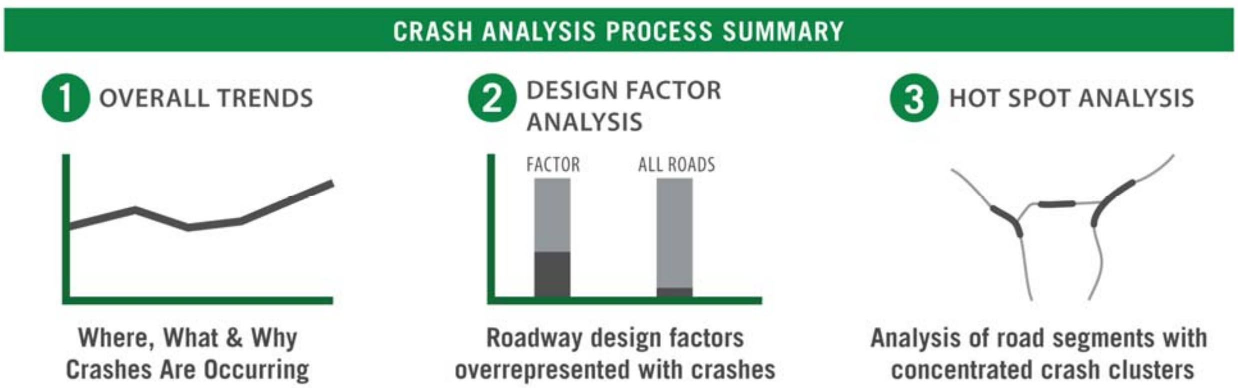
Figure 1.2 Online Survey Summary



1.3 Crash Analysis

The crash analysis involved three primary steps. A total of ten years of reported bicycle crashes on state roadways were analyzed, with crashes occurring between March 2006 and December 2015. Raw crash data for the state roads was provided by VTrans (collected initially from police reports). The first step evaluated overall trends in crashes, such as the time of day the crashes occurred, and if total crashes over the ten-year period increased or decreased. The second step analyzed roadways where crashes occurred, and compared design characteristics of these roads to the design characteristics of all state roads . This analysis was intended to isolate design factors that may be influencing crashes. The final step involved assigning a Hot Spot score to each state road segment, which corresponded to the total number of crashes and difficult bicycling location data recorded along it. The difficult bicycling location data came from the online input map developed for Phase One. The Top 10 Hot Spots were then evaluated in detail. Figure 1.3 provides an overview of this process. Chapter 2 presents the bicycle crash analysis and potential solutions to reduce crash rates.

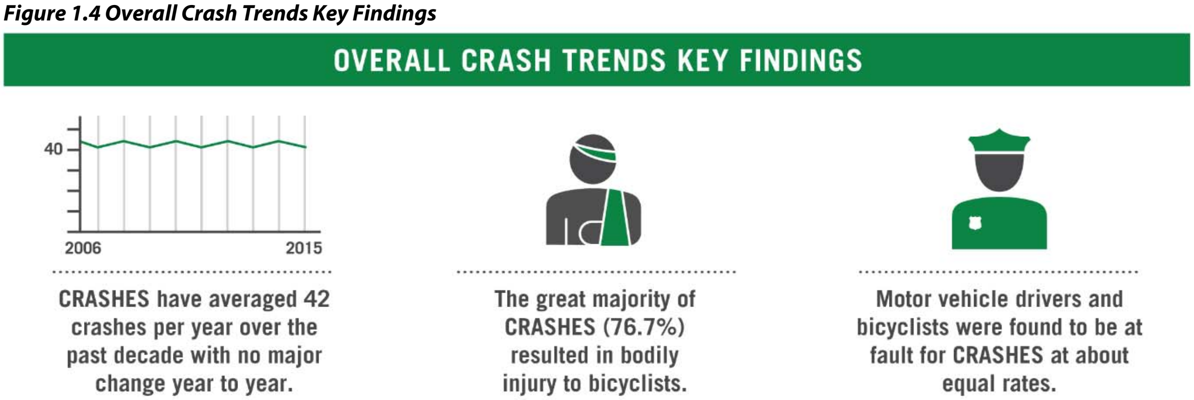
Figure 1.3 Crash Analysis Process



1.3.1 Overall Crash Trends Key Findings

The overall crash trends analysis evaluated the reported bicycle crash data to determine where, when, and why crashes are occurring. Key findings from this analysis were that the frequency of reported bicycle-vehicle crashes has not changed significantly over the ten years analyzed. Approximately half of crashes were due to improper action of the bicyclist or motor vehicle drivers,[1] highlighting the need for both drivers and bicyclists to exercise more caution. Additionally, crashes were concentrated on a relatively small portion of state roads in terms of lane miles.[2] Focusing efforts on identifying safety issues along these roads and improving conditions could be a cost-effective method to reduce the total number of crashes. Figure 1.4 presents findings from the overall trends analysis.

Figure 1.4 Overall Crash Trends Key Findings

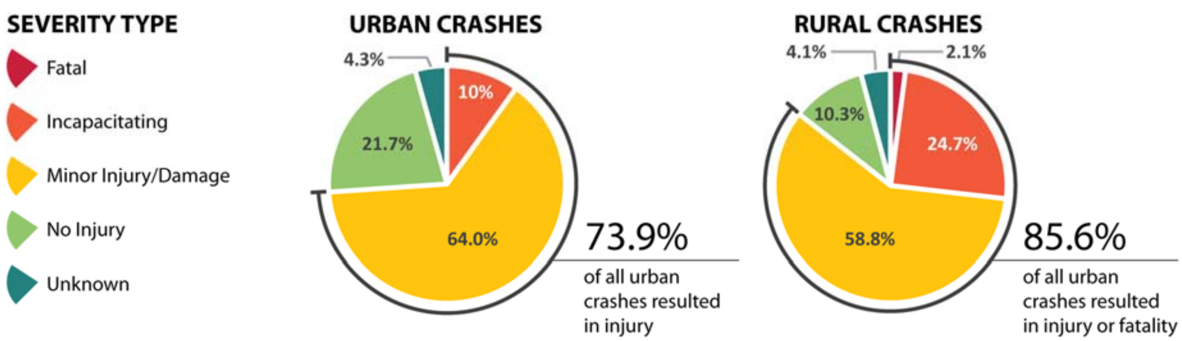


[1] Crashes were coded with who, the bicyclist or motor vehicle, made an improper action prior to the crash, which was found to result in the crash occurring

[2] About 60% of crashes occurred along the five state roads (Alternative US-7, US-5, VT-15, US-2 and US-7). These roads represent about 25% of the total miles of state roads

Another key finding from this analysis is that the majority of bicyclists involved in crashes sustain some form of bodily injury. When controlled for location, urban vs. rural, it was found that crashes occurring on rural roads more frequently resulted in injury, as shown in Figure 1.5.[3] This is likely due to higher posted speeds on rural roadways, and that higher speeds are typically associated with more severe injuries and fatalities.

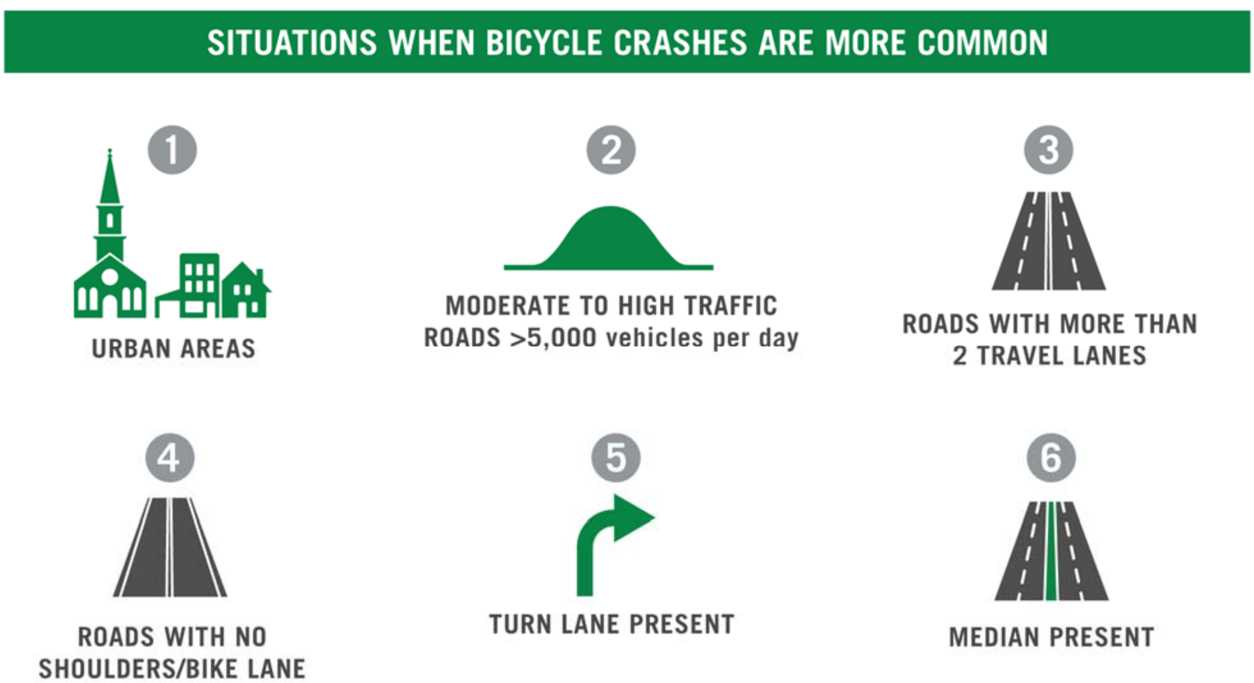
Figure 1.5 Crash Location and Injury Comparison



1.3.2 Design Factor Analysis

In addition to assessing general crash trends, the consultant team analyzed roadways where crashes occurred compared to all the state roads, to isolate design factors that may be influencing crashes. For this analysis, the prevalence of design factors where bicycle-vehicle crashes occurred was compared to the prevalence of these factors on all state roads. Comparing this information showed the relative influence different design factors have on crash frequency. Factors that were found to be overrepresented in locations where crashes occurred are presented in Figure 1.6. Generally, urban locations and more complex traffic patterns were found to be contributing factors with bicycle-vehicle crashes.

Figure 1.6 Design Factors Analysis – Key Findings



[3] The urban boundaries used in the crash analysis were defined by Federal Aid Urban (FAU). VTrans developed these FAU boundaries based upon FHWA guidance and Census data of urban clusters. There was coordination with the RPCs and smoothing of the boundaries to ensure that appropriate FAU boundaries were defined.

1.3.3 Hot Spot Analysis

The final step in the crash analysis involved assigning a Hot Spot score to each state road segment, which corresponded to the total number of crashes and difficult bicycling location data recorded along it.[4] These Hot Spot Scores were then sorted to determine the Top 10 Hot Spots, or the corridors/locations with the greatest number of crashes/difficult bicycling location data. Crash report narratives for the Top 10 Hot Spots were then evaluated to determine crash trends. Figure 1.7 presents the factors that were consistently found to contribute to the crashes. Table 1.1 lists the 10 Hot Spots, and Figure 1.8 and 1.9 show the general location of the Hot Spots in Vermont.[5]

Figure 1.7 Hot Spot Analysis Key Findings

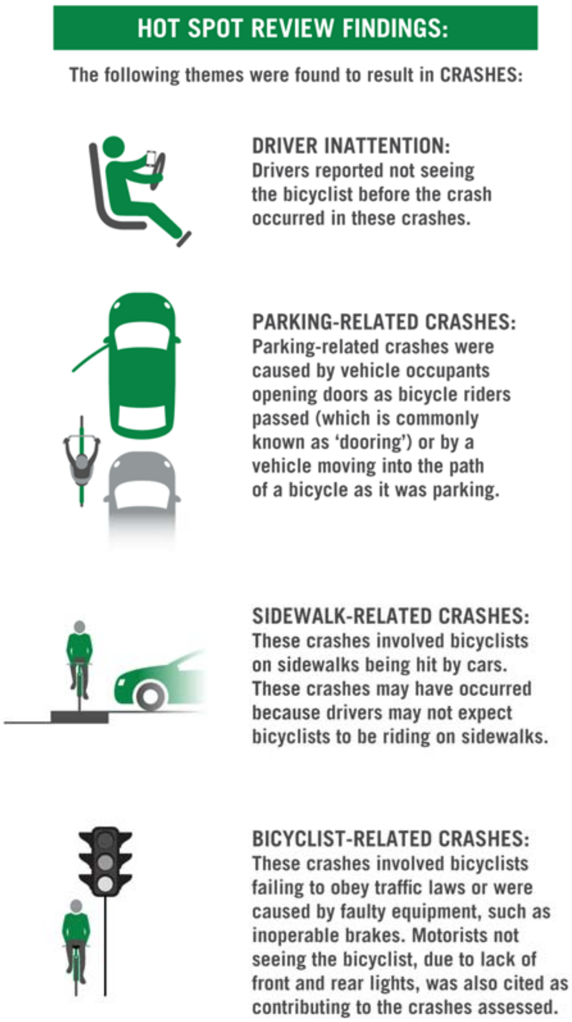
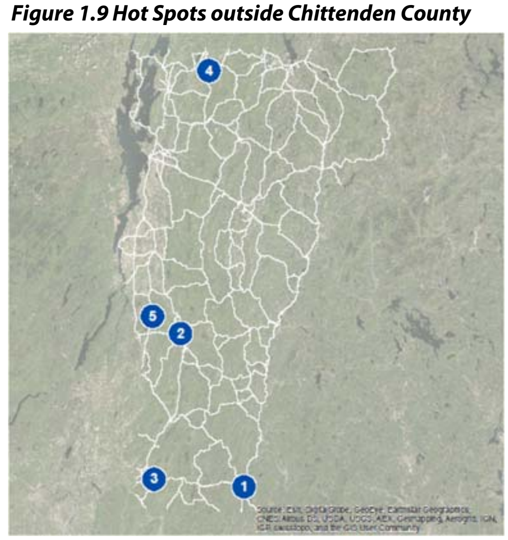


Table 1.1 Top 10 Hot Spot Locations

Hot Spot Locations					
#	City/Town	Road Name(s)	Length (mi)	# of Crashes	# of Votes
CC.1	Burlington	So. Winooski Ave.	0.52	27	27
CC.2	South Burlington	Williston Rd.	0.51	9	74
CC.3	Essex Junction	Pearl St.	0.27	7	0
CC.4	Burlington	Riverside Ave.	0.41	9	16
CC.5	Burlington	Colchester Ave. Bridge	0.05	0	32
OC.1	Brattleboro	Main St.	0.08	4	0
OC.2	Rutland	State St.	0.12	3	0
OC.3	Bennington	North St. & Main St.	0.54	8	6
OC.4	Enosburg	Elm St.	0.17	2	0
OC.5	Castleton	VT 30	0.12	2	0

Figure 1.8 Hot Spots in Chittenden County

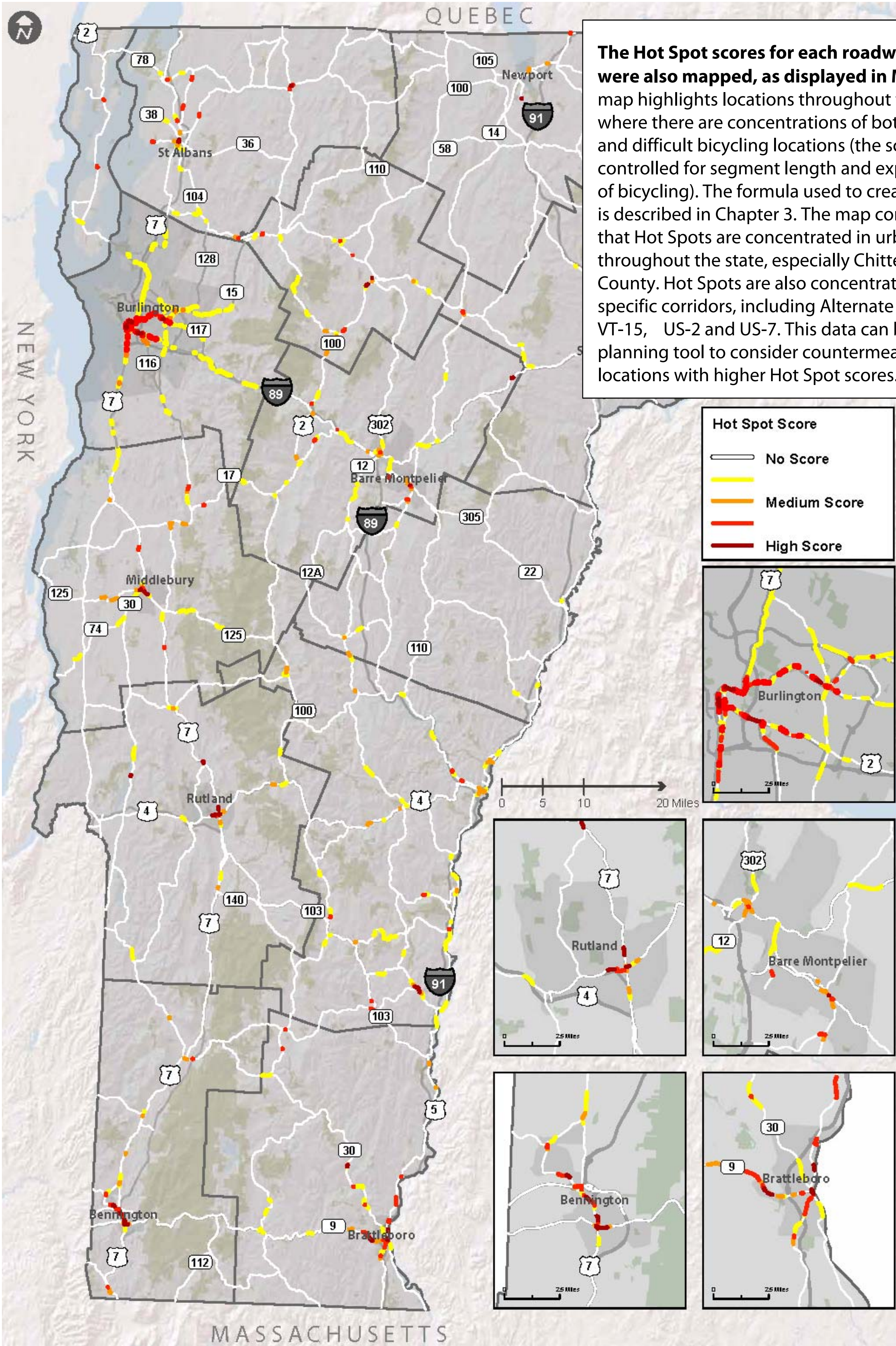
Figure 1.9 Hot Spots outside Chittenden County



[4] The difficult bicycling location data came from the online input map developed for Phase One

[5] Since most of the crashes were concentrated in Chittenden County, the Top 5 Hot Spots within Chittenden County and the Top 5 Hot Spots outside Chittenden County were selected for evaluation. This method provided better geographic distribution of the Hot Spots. Additional detail is provided in Chapter 3.

Map 1.1 – Mapping Hot Spot Scores



The Hot Spot scores for each roadway segment were also mapped, as displayed in Map 1.1. This map highlights locations throughout the state where there are concentrations of both crashes and difficult bicycling locations (the scores are controlled for segment length and expected rate of bicycling). The formula used to create the scores is described in Chapter 3. The map communicates that Hot Spots are concentrated in urban areas throughout the state, especially Chittenden County. Hot Spots are also concentrated along specific corridors, including Alternate US-7, US-5, VT-15, US-2 and US-7. This data can be used as a planning tool to consider countermeasures at locations with higher Hot Spot scores.

1.4 Analysis of Roadway Comfort for Bicycling

The second objective of the Phase Two effort was to evaluate how comfortable it is to bicycle along state roads in Vermont. Different methodologies exist to evaluate roadway comfort for bicycling. These methodologies have different data requirements and applications where they are most effective. The consultant team researched alternative methodologies, and ultimately selected the Bicycle Level of Traffic Stress (BLTS) as the tool to evaluate how comfortable Vermont's roads are for bicycling. The primary benefit of this tool is that it can be calibrated to urban and rural contexts, which is especially important given that the majority of state roads are located in rural areas. This section describes how the methodology was developed and presents key results. Additional detail on the development of this methodology is included in Chapter 3.

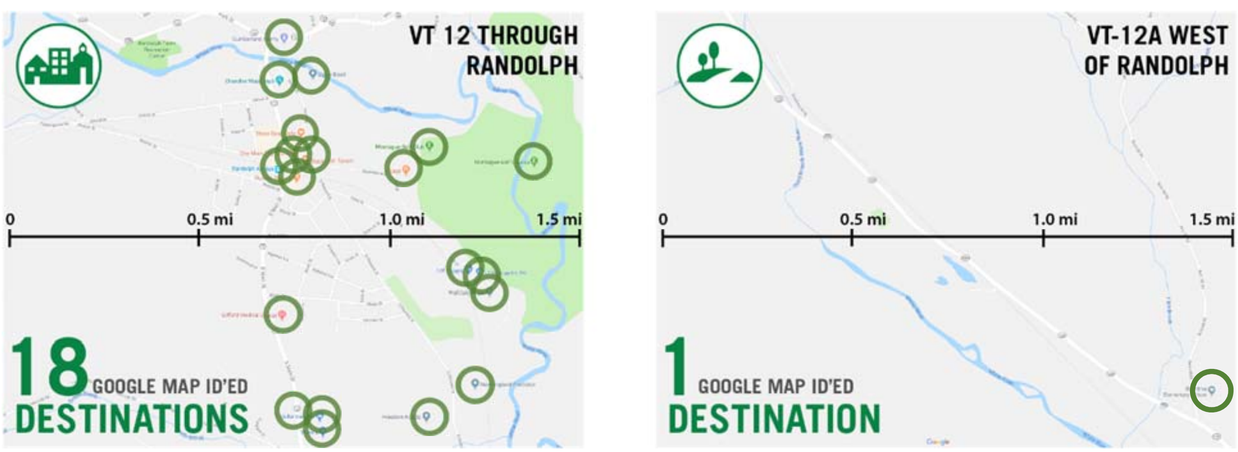
1.4.1 Types of Bicyclists

Research into bicycling habits has found that bicyclists typically can be grouped into two broad categories; utilitarian and recreational bicyclists. Utilitarian bicyclists ride to complete destination-oriented trips, while recreational bicyclists ride for fitness, the state's scenic qualities and enjoyment of bicycling. These two different categories of bicyclists have different roadway design needs due to their level of experience bicycling, and the land-use context is an important determinant of where these bicyclists are most likely to ride. Research suggests utilitarian trips are concentrated in urban areas, while recreational trips are most frequently along rural roadways.[6]

Land use patterns in urban areas support bicycling for a wide range of trip types, with significant emphasis on utilitarian trips. This is due primarily to the close proximity of trip generators and destinations, along with higher population densities. Therefore, roads in urban areas should be designed to be comfortable for a range of bicyclists, including novice l bicyclists.

Conversely, in rural areas, destinations are spread out and population density is much lower. Due to this, rural roads attract more recreationally-focused riders who ride long distances for exercise, training and/or general enjoyment. Because these riders do so as a choice, they tend to be more experienced and comfortable bicycling on roads with higher posted speed limits and more narrow shoulders. Figure 1.10 illustrates the relationship between land-use and expected bicyclist type. Due to the differences in bicyclist type, distinct Urban and Rural BLTS models were developed.

Figure 1.10 Destinations in Urban vs Rural Areas **(***Map source: Google Maps)*



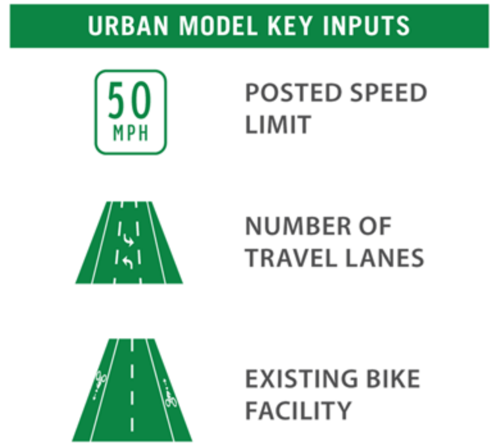
Google Maps includes icons representing destinations in communities. The comparison of destinations in a typical small-town (urban area) to a typical rural area in Vermont can be used to communicate how context can influence bicycling trips. In Randolph, VT, 18 Google Map ID'ed destinations are located within a 1.5-mile radius of downtown, which corresponds to a bicycle trip that can be completed in about ten minutes. In this context, bicycling represents a relatively convenient option to access multiple destinations. Conversely, the rural section of VT-12A west of Randolph has one destination within a 10-minute bike ride. Along this rural section of road, bicycling does not represent a very convenient mode of transportation. Due to low densities and few destinations, most bicycle trips in rural areas are expected to be recreationally focused.

[6] The Oregon Dept. of Transportation and Colorado Department of Transportation have developed methodologies to assess the level of comfort of roadway networks in urban and rural areas of the states. These assessments are sensitive to rider type: novice riders are expected to bicycle in urban areas, while more experienced riders are most expected to bicycle along rural roadways.

1.4.2 Urban Model Development

The urban model assesses bicycling conditions along state roads within defined urban areas.[7] The urban model is consistent with the standard BLTS methodology[8], and is calibrated to be sensitive to a range of bicyclist types, including novice bicyclists. Based on research, posted speed, number of general travel lanes, and presence/absence of a dedicated bicycle facility has been shown to have *the most influence* on bicyclist stress levels in urban areas. At the time of this study, existing bicycle lane data was unavailable. Therefore, the VTrans BLTS Urban model of roads within urban areas is assumed to be mixed-traffic roadways, where bicyclists and motor vehicles share the road. In this model, speed and number of travel lanes are used to assess how comfortable a roadway is for novice level bicyclists within Urban Areas assuming mixed traffic conditions. Chapter 3 provides additional scoring tables that can be used if additional data, such as dedicated bicycle facility data, becomes available in the future.

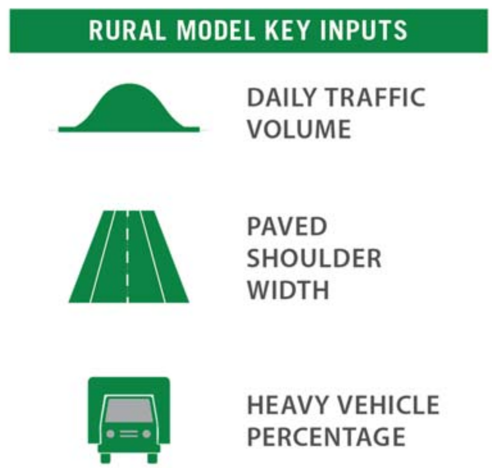
Figure 1.11 Urban Methodology Inputs



1.4.3 Rural Model Development

The rural model assesses bicycling conditions along state roads outside defined urban areas. The model is calibrated to be sensitive to more experienced, recreational bicyclists. This type of bicyclist is more stress-tolerant due to their level of riding experience. The rural model uses traffic volumes, the presence/absence of a shoulder, and heavy vehicle percentages to determine comfort level. These factors have been found to have *the most influence* on bicyclist comfort levels when riding in rural areas. The VTrans Rural Model was modified based upon rural BLTS models used by other State Departments of Transportation, and revised to reflect bicycling and roadway conditions in Vermont. Chapter 3 provides additional details describing the process for the development of the custom VTrans Rural BLTS methodology.

Figure 1.12 Rural Methodology Inputs



1.4.3 Definitions and Results

The BLTS model produces scores according to a four-point scale, from BLTS 1, representing the highest comfort roadways, to BLTS 4, representing the least comfortable roadways. A single set of score definitions was developed to be used for both the urban and rural model results. VTrans will use the definitions to develop policy strategies in Phase Three. For instance, VTrans may choose to use the definitions to set goals for target BLTS score in urban and rural contexts, as well as BLTS targets for high-use, medium-use and low-use corridors.

For the Vermont BLTS model, VTrans has defined the BLTS classification as follows.[9]

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[7] The urban and rural boundaries used in the comfort analysis were defined by VTrans as follows: urban boundaries defined as Federal Aid Urban (FAU) boundaries and ACCD designated downtown and villages centers .VTrans developed these FAU boundaries based upon FHWA guidance and Census data of urban clusters. There was coordination with the RPCs and smoothing of the boundaries to insure that appropriate FAU boundaries were defined.

[8] *Low-Stress Bicycling and Network Connectivity*. The Mineta Transportation Institute, 2012. <http://transweb.sjsu.edu/PDFs/research/1005-low-stress-bicycling-network-connectivity.pdf>.

[9] These definitions are based on best practices, and modified to be consistent with the context and design goals of VTrans.

Roadways whose design and character are:


BLTS 1: Welcoming to most types of bicyclists.


BLTS 2: Comfortable for most adult bicyclists.


BLTS 3: Comfortable for experienced and confident bicyclists.


BLTS 4: Uncomfortable for most bicyclists.

Once the model parameters were established for urban and rural roadways, the model was run on all state roads, and separately, on the "high use" roads, as designated during Phase One of this study. While VTrans efforts to improve bicycling conditions will be focused on the high-use corridors, preparing the results for all state roads can inform bicycle improvements along medium-use and low-use corridors as opportunities arise. The percentage of roads grouped into each category is displayed in Figure 1.13 (All Roads) and 1.14 (High-Use Corridors Only). In the future, VTrans will collect additional data and make modifications to the parameters of the BLTS model. The models are developed to be flexible to these changes and are able to produce new results quickly to inform decision-making. The BLTS results are displayed in Map 1.2

Figure 1.13 Percentage of Roads by BLTS Category – All Roads

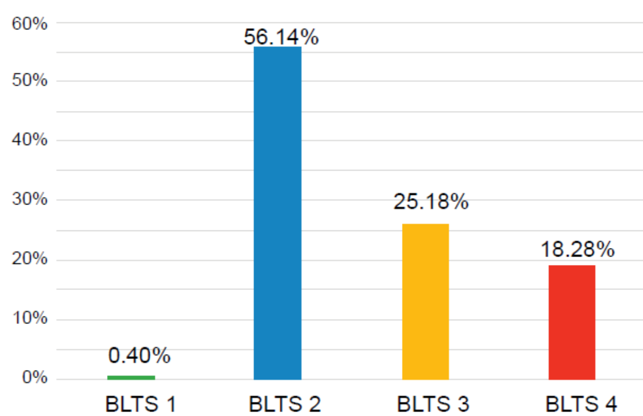
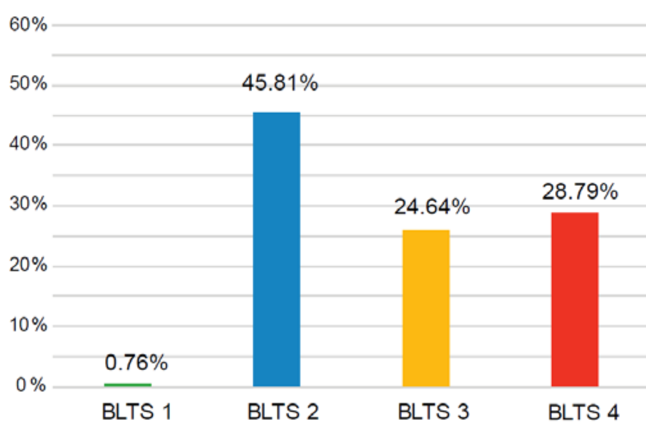
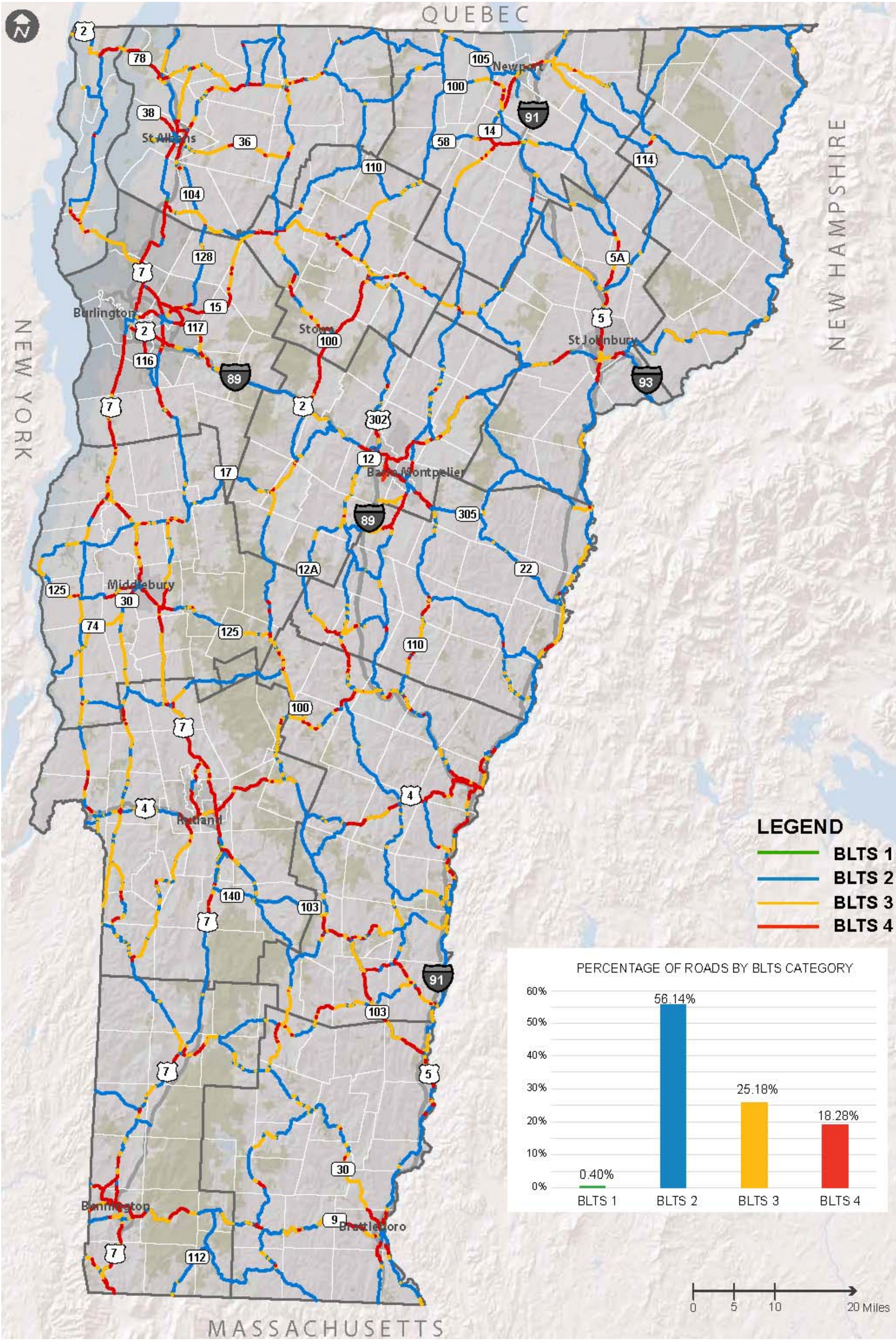


Figure 1.14 Percentage of Roads by BLTS Category – High-Use Corridors Only



Map 1.2 BLTS All Roads Results



1.5 Conclusion and Next Steps

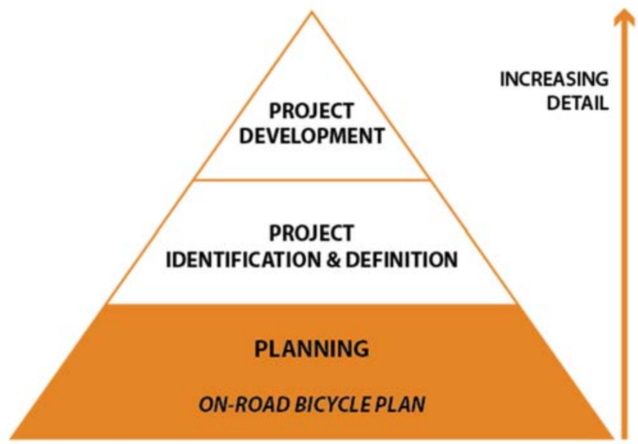
VTrans goal in developing the On-Road Bicycle Plan is to improve the condition of state roads to enhance safety and better accommodate the needs of all bicyclists with emphasis on those roads designated as high-use priority bicycle corridors.. Phase One of this plan categorized roads into high-, moderate- and low-use/priority corridors based on current and potential bicycle use, reflecting demand for bicycling on state roads. Phase Two focused on understanding the supply of bicycling facilities state-wide, evaluating where crashes are concentrated and how comfortable state roads are to bicycle.

The crash analysis involved three primary components, including understanding general trends in reported bicycle-vehicles crashes during the past ten years, and evaluating roadway design factors that are overrepresented where crashes occurred. The final step used a Hot Spot analysis to assess specific locations with demonstrated patterns of crashes. Chapter 2 presents findings from this analysis, including recommendations and potential counter measures that VTrans and its partner agencies can advance to reduce crash rates in the future.

The bicycle comfort analysis used an industry standard methodology, Bicycle Level of Traffic Stress, to calculate how comfortable Vermont's state roads are to bicycle given different roadway factors. This analysis was divided into two methodologies, one applicable to urban areas and one for rural roads. The models are designed to be flexible and can be updated as new data becomes available. The thresholds established in the model can also be adjusted to meet VTrans' policy goals, should they change in the future. The development of this methodology is described in detail in Chapter 3.

The results of Phase One and Two provide planning level information that can guide decisions and assist VTrans in identifying areas where improvements could be focused. More detailed analysis is required during the identification and development stages of projects, as displayed in Figure 1.15.

Figure 1.15 Context of On-Road Bicycle Plan



With both demand and supply information available, VTrans can evaluate where to focus investments to improve bicycling conditions on state roads. Policies and strategies to use the Results of Phase One and Two include:

- Establish minimum target BLTS score on High, Medium, and Low-Use Corridors, and seeking opportunities to meet these targets through project identification and development for the High-Use Corridors. The target scores for these Medium and Low-Use Corridors may be different, since demand for bicycling along these corridors is less than in the High-Use corridors.
- Review crash analysis and Hot Spot data to determine if counter-measures to reduce crashes can be incorporated during planning, project identification and project development phases of projects.
- Continue to work with partner agencies to improve bicycling conditions state-wide; This could include establishing policies to work with local agencies to identify parallel bicycling routes to state roads, if the state road cannot be improved to accommodate bicyclists to an acceptable level. Also, continue to work with municipalities to improve bicycle conditions on Class 1 Highways, and other roadways that VTrans does not have jurisdiction for (given than 9 out of 10 Hot Spots were located along Class 1 Highways)
- Update design guidance to improve roadways for bicycling in urban and rural contexts.
- Continue to advance and refine design practices that impact bicycling comfort and safety, including rumble strip design practices, maintenance practices, speed assessments and shoulder width standards.
- Continue to collect state-wide data on roadway factors that influence bicycling comfort, such as pavement data, accurate shoulder data, and dedicated bicycle facility information.
- Continue to work with the law enforcement community on bicycle-vehicle crash data collection, and continue to use data to influence roadway design decisions that could mitigate crash rates and severity
- Continue to advance and formalize policies that improve bicyclist safety, such as driver/bicyclist awareness and behavior campaigns and education programs.

Chapter 2. Crash Analysis

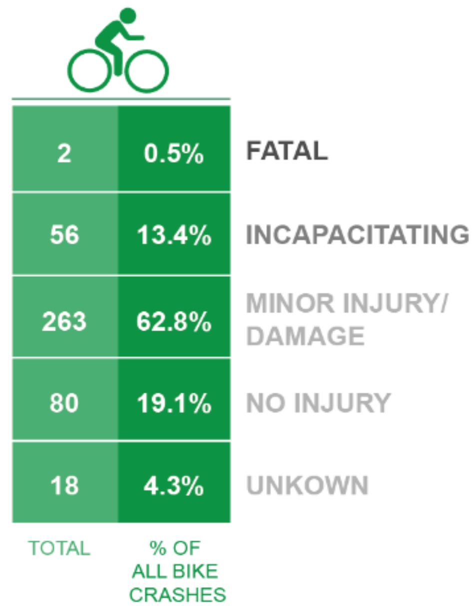
2.0 Introduction

This chapter focuses on identifying potential safety hot spots along state roads. For the purposes of this report, state roads are defined as state roads and Class 1 Town Highways.[10] The chapter summarizes overall findings related to bicycle-motor vehicle crashes in Vermont. The analysis then goes a step further to identify the Top 10 Hot Spots along state roads, or segments of road with a high concentration of both reported bicycle crashes and where the public concentrated feedback regarding where potential bicycle safety issues exist. The identification of the Safety Hot Spots included the following cumulative steps:

1. Mapping reported bicycle crashes
2. Analyzing overall crash trends
3. Analyzing roadway design factors that contributed to the crashes
4. Developing a hot spot scoring methodology
5. Analyzing the Top 10 Hot Spots

The final step in the analysis included the review of crash reports for the Top 10 Hot Spots. This review assessed what factors contributed to the crashes. This research served as the basis for the development of potential policy and engineering recommendations that could help mitigate the frequency of crashes at these locations. These interventions can also be implemented at other locations with similar characteristics along state roads.

Figure 2.1: Severity of Crashes



2.1 Mapping Bicycle Crashes

The first step in the crash analysis process involved mapping reported bicycle crashes along state roads. A total of ten years of bicycle crash data was analyzed, with crashes occurring between March 2006 and December 2015.[11] This analysis did not account for collisions or near-collisions that were not reported to law enforcement. Map 2.1 displays the location of collisions across the State Highway system.

During the ten-year study period, police recorded a total of 419 total bicycle-vehicle crashes. During this period, two fatalities occurred on state roads. Both fatalities occurred along rural roadway segments, on the outskirts of urban areas. The majority of bicycle-vehicle collisions, or about 75 percent, resulted in some form of bodily injury to the bicyclist. Figure 2.1 displays the total number of crashes, and the type of injury sustained by the bicyclist involved. This map illustrates that the majority of collisions, 77 percent, occurred in urbanized areas around the state, even though the majority of the state roads, or 86 percent, are in rural areas.

Figure 2.2 displays the relationship between where crashes occurred (urban vs. rural area) and the impact on crash severity. Of all crashes that occurred in urban areas, 9.9 percent resulted in severe injury or death, compared to 26.8 percent of crashes in rural areas resulting in severe injury or death. More severe injuries in rural areas may be linked to the fact, that generally, rural roadways have higher posted speed limits[12], and higher speeds are correlated with more severe injuries.

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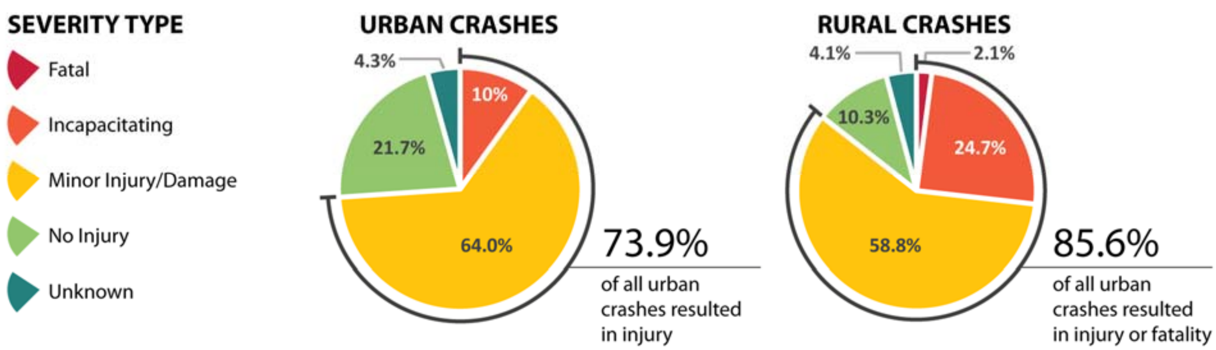
[11] Raw crash data for the state roads was provided by VTrans (collected initially from police reports).

[12] The mean speed of the urban State roads is 35 miles per hour. The mean speed of the rural State roads is 45 miles per hour

Figure 2.2 Severity of Crashes by Context



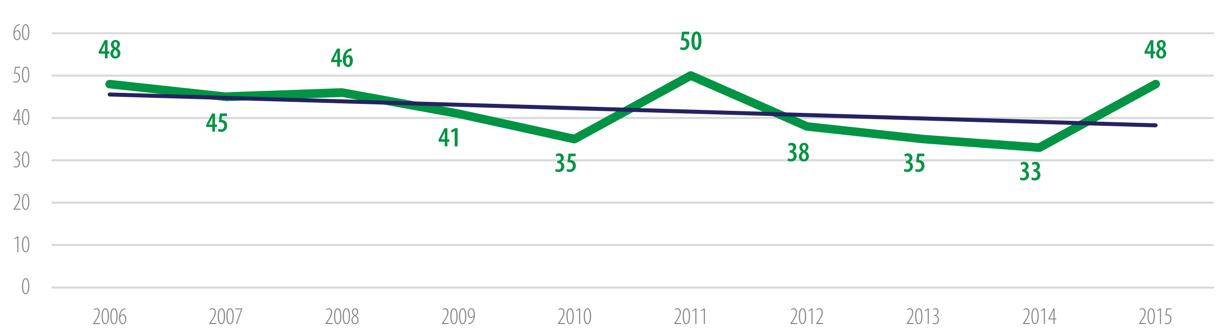
2.2 Analysis of Overall Crash Trends

Additional details associated with the crashes were also assessed to evaluate environmental and demographic trends. In total, nine factors were assessed, including:

1. Severity of Collisions
2. Annual Number of Reported Bicycle Crashes
3. Time of Day Crash Occurred
4. Day of the Week Crash Occurred
5. Age of Bicyclist
6. Gender of Bicyclist
7. Location of Collision
8. Traffic Control Present at Location
9. Roadways with Most Crashes
10. Weather Conditions at Time of Collision

The frequency of reported bicycle-vehicle crashes decreased slightly over the ten years analyzed**, but no discernable long-term pattern emerged.** Crashes averaged 42 crashes per year. Crashes peaked in 2011 at 50 crashes, and then declined for the next three years, before rising again in 2015 to 48. Figure 2.3 displays the Annual Number of Crashes, as well as the trend line of the crashes.

Figure 2.3 Annual Number of Reported Bicycle Crashes



Key finding from the trends analysis are included in Table 2.1. The column *Percent Data Point Not Coded* how frequently the data was left blank by the reporting officer. Graphs summarizing each of the data points are provided in Appendix A: Overall Crash Trends.

Map 2.1: Reported Crash Locations

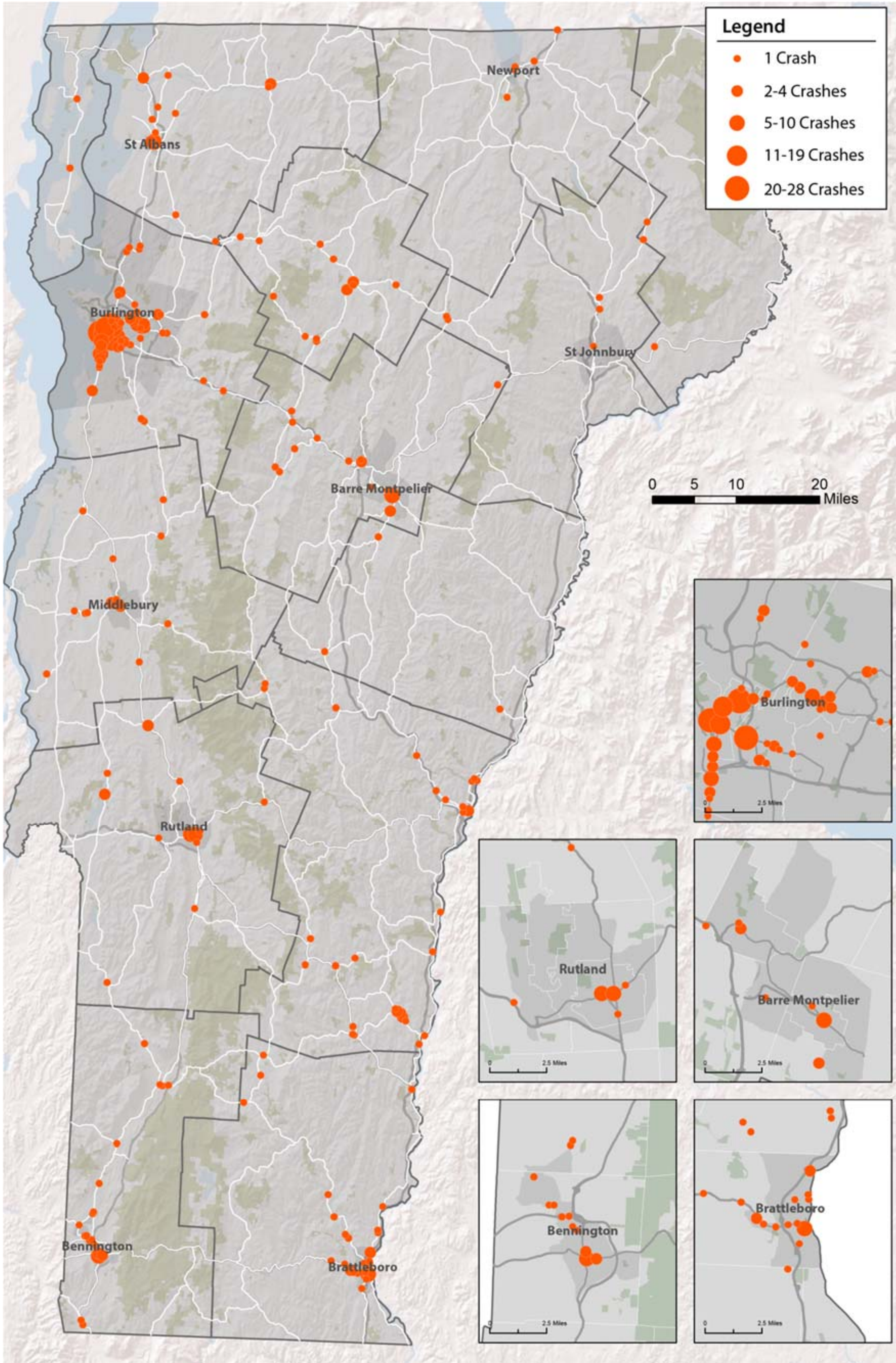


Table 2.1: Overall Crash Trends Analysis Findings

Factor	Key Finding	Percent Data Point Not Coded[13]
Severity of Collisions	Three of four crashes resulted in some form of bodily injury to the bicyclist (76.7%); The most common type of injury was Minor Injury/Damage (62.8%). Crashes were found to be more severe, generally, in rural vs urban areas.	4.3%
Annual Bicycle Collisions with Motorists	Crashes per year have not changed significantly over the past decade, and no long-term discernable pattern has emerged. The average crashes per year equal 42 crashes.	0%
Time of Day	Most crashes occur during the day (75.4%).	.7%
Day of Week	Crashes happen more frequently during the weekdays than the weekends (average of 65 crashes per weekday compared to average of 46 crashes per weekend day).	0%
Age of Bicyclist	17 to 34-year-olds represented the largest number of crashes for all age groups, or 39%. The second largest group was 35 to 54-year-olds, representing 25% of all crashes. Together, these two age groups represented nearly 65% of all crashes.	6%
Gender of Bicyclist	4 of 5 crashes involved a male bicyclist. 1 in 5 involved a female bicyclist.	1.2%
Location of Crashes	About half of all collisions occurred at intersections (49.4%).	4.7%
Traffic Controls Present at Crash Location	Of crashes where the type of traffic control was reported, most collisions (55.0%) occurred where no traffic control device was present, indicating crashes occurred at intersections where two lanes merged, or other unsignalized intersection types.	5.8%
Bicyclist Action Preceding Crash	Of crashes where the bicyclist action preceding the crash was coded, 47% were due to improper bicyclist action and 14.3% had no improper bicyclist action. The remainder were either not coded (19.8%) or require review of the crash narrative to determine preceding action (18.9%). The top three most commonly reported Improper Bicyclist Actions were Improper Crossing (14.6%); Darting (8.1%) and Failure to Yield Right of Way (6.9%)	19.8%
Motorist Action Preceding Crash	Of crashes where the motorist action preceding the crash was coded, 44.6% were due to improper motorist action and 32.5% had no improper motorist action. Data was not provided for the remainder (22.9%). The top three most commonly reported Improper Motorist Actions were Failure to Yield Right of Way (16.2%); Inattention (11.9%) and Visibility Obstructed (4.3%)	22.9%
Roadways with the Most Crashes	Approximately 60% of crashes occurred along five roads, while these roads represent about 25 percent of the total miles of state roads. These roads include Alternate US 7, US-5, VT-15, US-2 and US-7.	0%

2.2.1 Overall Crash Trends Analysis Findings

The crash trend analysis provides insight into where, when and why crashes are occurring. The majority of crashes resulted in some form of bicyclist injury. The frequency of reported bicycle-vehicle crashes decreased slightly over the ten years analyzed, but no discernable long-term pattern emerged. Most of the crashes analyzed occurred at intersections. Intersections are where conflicts exist and where the probability of a crash occurring is higher. Approximately half of crashes were due to improper action of the bicyclist or motor vehicle drivers,[14] highlighting the need for both drivers and bicyclists to exercise more caution when using the roads. The top three Improper Bicyclist Actions that caused crashes were Improper Crossing, Darting and Failure to Yield Right of Way. For motorists, the top three were Failure to Yield Right of Way, Inattention and Visibility Obstructed. Since these precipitating factors represent over a quarter of improper actions for bicyclists and pedestrians, education campaigns aimed at bicycle

[13] Percentage indicates the percent of the time that the officer did not record the specific data point.

[14] A crash could be coded with both a bicyclist and driver action contributing to the crash

safety could be developed to focus on these actions to help reduce them. Additionally, crashes were concentrated on a relatively small portion of state roads in terms of lane miles. Focusing efforts on identifying bicycling issues along these roads and improving conditions along them could be a cost-effective method to reduce the total number of crashes.

Analysis of the data points consistently reported by police officers also provides beneficial insights. Environmental factors, such as day of the week or time of day, were consistently reported across all of the crash records. This is to be expected, since these inputs are relatively easy to document. Inputs that had more choices and required a clear understanding of what precipitated the crash were less frequently reported, such as the bicyclist and the motorist actions preceding the crash, each of which were recorded for about 80 percent of the time. Potential reasons for omitting this information could be that the bicyclist was injured and could not describe the crash, the motorist may not have seen the bicyclist before the crash, there may have been no witnesses, or other reasons. Recording this information is critical to helping analysts to understand the causes of the bicycle crashes and recommend counter measures. VTrans has a good working relationship with law enforcement. As this relationship continues, working with law enforcement to collect bicycle crash data could help this information to be coded more frequently. While the intent is not to make the crash reporting form bicycle-centric, continuing to work with law enforcement could help to create more useful data about bicyclist crashes in the State of Vermont.[15]

2.3 Contributing Factors Analysis

In addition to analyzing general crash trends, the Consultant Team analyzed roadway design features associated with bicycle crash patterns. This section summarizes the methodology and describes the findings.

For this analysis, the prevalence of design factors where bicycles and vehicles crashed is compared to the prevalence of these factors on all state roads. Comparing the prevalence of crashes for a particular design factor to its prevalence on all state roads shows the relative influence particular design factors have on crash frequency. Figure 2.4 displays how this information was compared for the Density variable. The design factors assessed are listed below (roadway data provided by VTrans).

- Land Use Density (urban vs rural)
- Number of Lanes
- Lane Width
- Shoulder Width
- Typical Speed
- Annualized Average Daily Traffic (AADT)
- Turn Lane Present
- Median Type

Figure 2.4: Density Factor Comparison Chart

2.3.1 Contributing Factors Analysis Findings

Table 2.5 summarizes design factors where bicycle crashes are overrepresented. The factors with the highest contributions to crashes are urban areas and higher volume roads (5,000 vehicles or more per day). These are places with high potential for motor vehicle-bicycle interaction due to the higher rates of travel. More than two lanes, lanes 12 feet or wider, and the presence of turn lanes are also overrepresented in crash prevalence. Similarly, crashes were more common on slower roads (35 mph or less), which tend to be in denser, urban areas, places where more bicyclists

[15] Municipalities and States across the country are recognizing the need to collaborate with police officers to collect more accurate bicycle crash data. Michigan DOT updated its crash form in 2016, and through this update, made changes to improve bicycle crash data collection. The City of Boston's Transportation Department and Seattle Department of Transportation are working on this issue as well.

are prevalent due to the higher concentration and proximity of origins and destinations. Crashes were also overrepresented on roads with a raised median, which tend to be higher volume roads. Appendix B includes detailed findings from the Contributing Factors Analysis. The presence of shoulders appears to have a significant impact on reducing crashes, as crashes are more likely on roads without a shoulder.

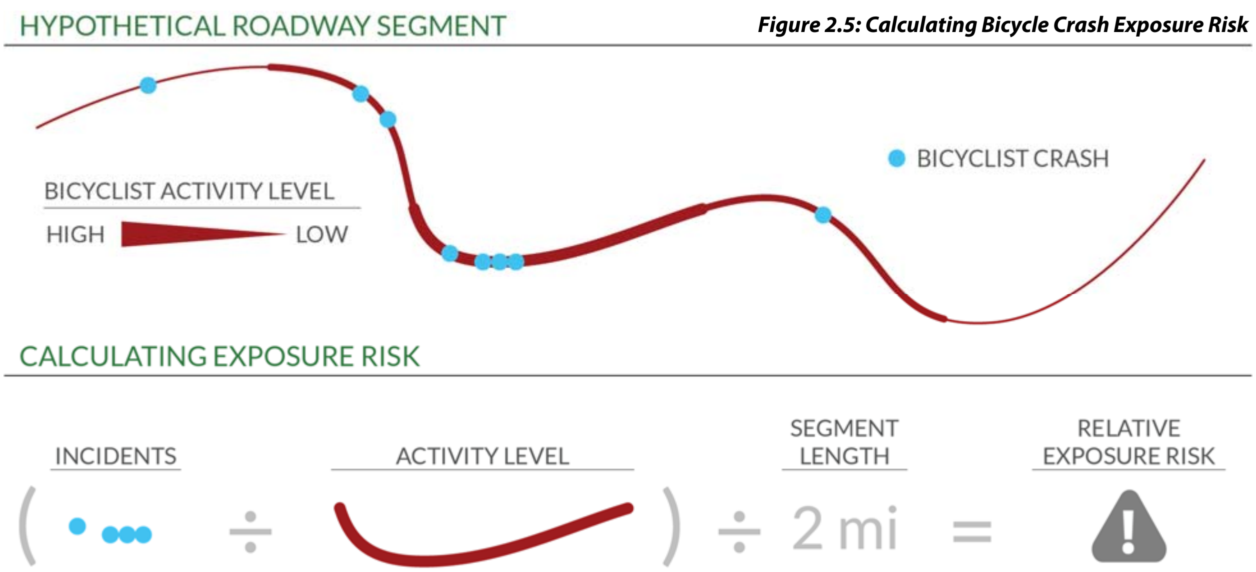
Table 2.5: Overall Crash Trends Analysis Findings

Factor	Overrepresented In:
Density	Urban Areas
Annualized Average Daily Traffic	Roads with more than 5,000 vehicles per day
Number of Lanes	More than two Lanes
Lane Width	12 feet wide or more
Shoulder Width	No shoulder present
Typical Speed	Slower speed roads (35 mph or less)
Turn Lane Present	Presence of a turn lane
Median Type	Presence of a median

2.4 Hot Spot Scoring Methodology

The next step in the crash analysis was to create a hot spot score for the state roads. This score reflected bicyclist *exposure risk* and was used to determine the Top 10 Hot Spots. For the purpose of this analysis, *exposure* represents a quantification of the opportunity for a bicycle crash to occur. As exposure increases, so too does the number of crashes. *Risk* represents the probability of any given exposure event, such as a bicyclist riding along a State Highway segment, resulting in a crash. As exposure increases, the number of crashes is expected to increase as well. To develop the hot spot scoring methodology, a literature review of formulas used to calculate bicycle exposure risk was conducted. From this review, the Consultant Team concluded that typically, exposure risk is calculated using incident (bicyclist crash) and activity level (bicyclist volume) data. When both these data sets are available, incidents of crashes can be divided by bicyclist volumes, and then normalized by the segment length, to determine relative exposure risk, as seen in Figure 2.5.

Figure 2.5: Calculating Bicycle Crash Exposure Risk



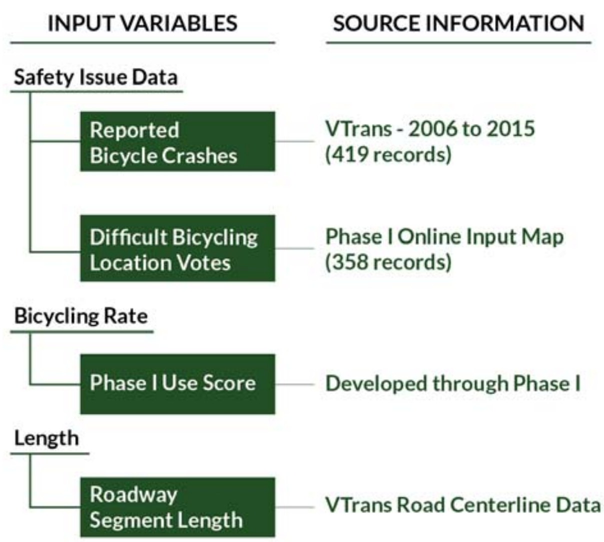
The research concluded that to study bicycle crash risk and identify high risk hot spots in the network, an estimation of levels of activity (exposure) is needed. Exposure is typically represented using bicycle traffic volumes. Since this data was not available across the whole state road network, the team researched if bicycle volumes could be estimated to serve as a proxy for actual bicycle counts. The research found that bicyclist activity levels across a roadway network have been estimated using two methods:

1. Using count data and extrapolating it across the roadway network
2. Using other variables, such as land-use data, to estimate bicyclist activity levels, which is consistent with the method used in Phase One of this project to develop the Use Scores

Based on these findings, the team developed a hot spot scoring methodology with the input variables shown in Figure 2.6, which used the Phase One Use Scores to represent relative level of bicycle activity. The source for each input variable is noted in Figure 2.6 as well.

Equation 1 shows how the hot spot scores were determined, and Equation 2 shows how the raw hot spot score was used to create a Hot Spot Index Score.

Figure 2.6: Hot Spot Scoring Methodology Inputs



Equation 1

$$((C_t + (DBV_t * .2)) / L) / US = \text{Hot Spot Score}$$

Where:

C_t = Total Number of Crashes per Segment

DBV_t = Total Number of Difficult Bicycling Locations per Segment (Defined in Section 1.4.2)

L = Length of segment

US = Phase One Segment Use Score

Equation 2

$$(\text{Hot Spot Score} / HS_m) * 100 = \text{Hot Spot Index Score}$$

Where:

HS_m = Maximum Hot Spot Score

Equation 2 resulted in a Hot Spot Index Score for each segment of roadway from 0 to 100, with 0 being the lowest score and 100 being the highest. All other segments were assigned scores within this range, enabling the relative Hot Spot scores to be ranked.

2.4.2 Difficult Bicycling Location Input

One of the key inputs for the Hot Spot Scoring Methodology was Difficult Bicycling Locations derived from the Phase One Crowdsourced Interactive Map (Wikimap). During Phase One, the Wikimap was used to collect information from the public about bicycling in Vermont. One of the requested actions was for the public to identify locations that were perceived as difficult for bicycling. The public was also given the opportunity to vote (e.g. agree) for Difficult Bicycle Locations that were placed by other users.

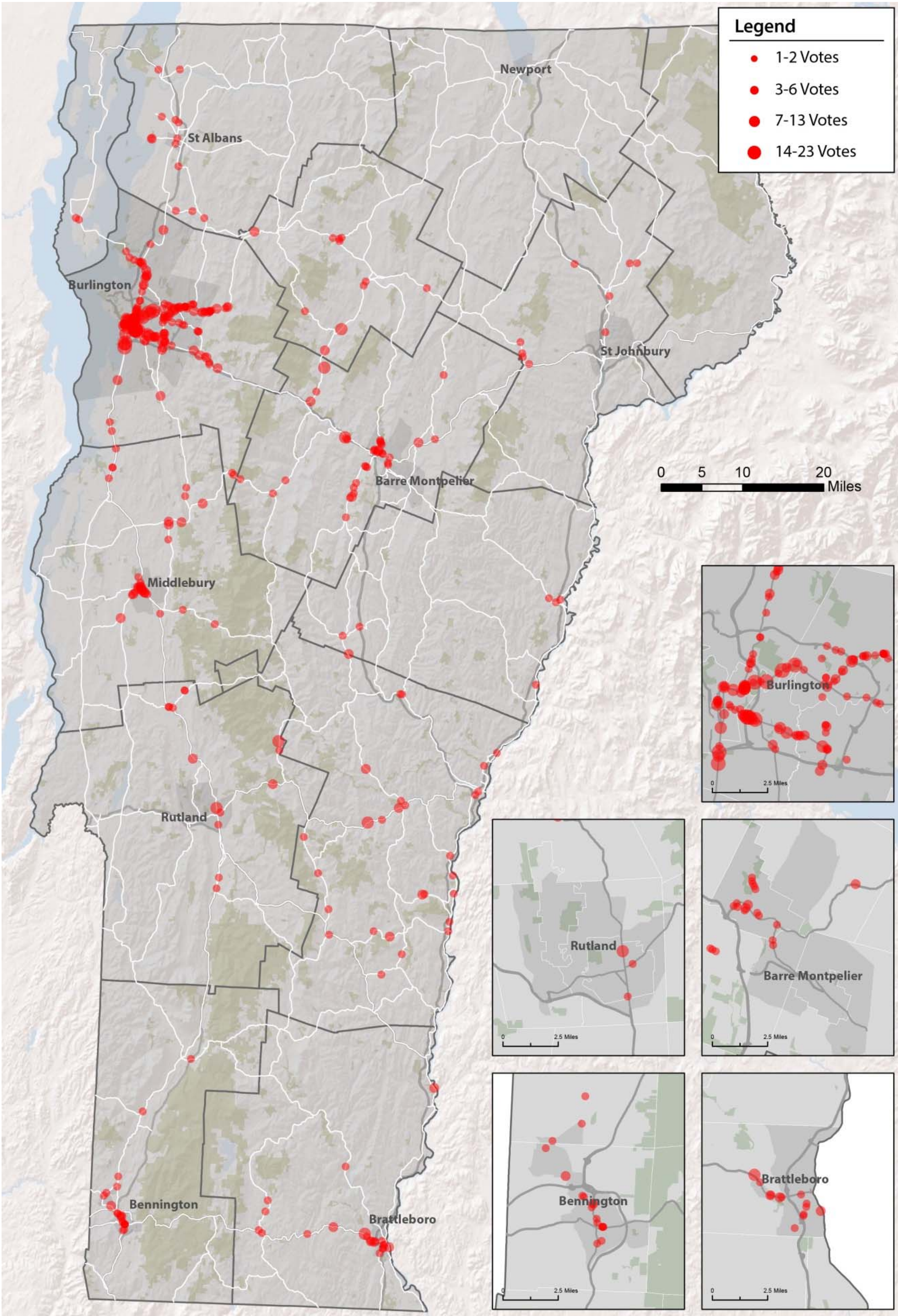
The consultant team isolated the Difficult Bicycling Locations to only the state roads, and then summed the vote scores for each location. This resulted in a complimentary data set to the reported crashes, which acted as another proxy for potential safety issues across the roadway network. Importantly, it provided additional data in locations where no or few crashes occurred, potentially because people do not feel comfortable riding in these locations. Despite few crashes occurring, these locations still represent potential safety hot spots for bicyclists. If only reported crashes were used in the methodology, the hot spot locations may not have been identified. In total, 358 Difficult Bicycling Locations were included in the methodology, with a sum total of 845 votes. These Difficult Bicycling Locations, including votes, can be seen in Map 2.2: Difficult Bicycling Locations Map.

2.4.1 Employing the Hot Spot Scoring Methodology

Once the Hot Spot Scoring Methodology was finalized, scores were created for the State Highway segments. The Hot Spot scores for each roadway segment were then mapped, as displayed in Map 2.3. This map highlights locations throughout the state where there are concentrations of both crashes and difficult bicycling location data (segment scores were created using the equation described previously in Section 4). The map communicates that Hot Spots are concentrated in urban areas throughout the state, especially Chittenden County. Hot spots are also concentrated along specific corridors, including Alternate US-7, US-5, VT-15, US-2 and US-7. This information can be used by VTrans to consider countermeasures at locations with higher Hot Spot scores.

Since crashes were concentrated in Chittenden County, it was important to perform the analysis on roads within Chittenden County, and then separately on roads outside of Chittenden County. This helped to create a geographic distribution of the Top 10 Hot Spots. In total, five Hot Spots were identified in Chittenden County, and five were identified on all other analysis roads outside Chittenden County. The analysis was successful in isolating roadways where a potential safety issue is present. While the Top Ten Hot Spots represented 0.11% of the total miles of State Highway, together they accounted for 16% of reported bicycle crashes statewide and 18% of difficult bicycling locations statewide (as reported via the Phase One Wikimap).

Map 2.2: Difficult Bicycling Location Votes– State Roads



Map 2.3: Hot Spot Scores – State Roads

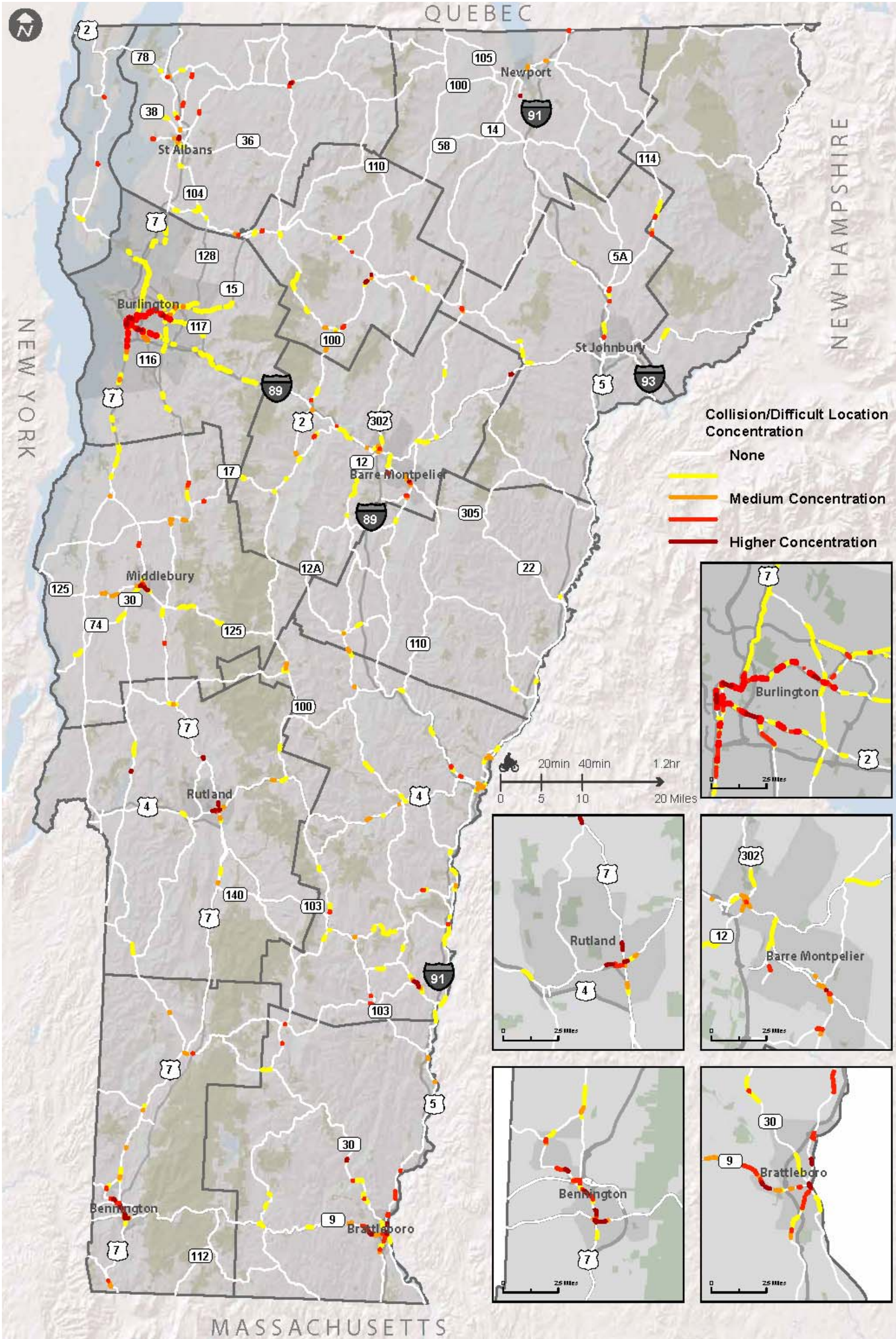


Table 2.6 provides information about each of the Top Ten Hot Spots, including the number of crashes and difficult bicyclist location votes per Hot Spot. The code 'CC' indicates that the Hot Spot was located in Chittenden County, while the code 'OC' indicates that the Hot Spot was located outside of Chittenden county. Figure 7 displays the location of the 5 Chittenden County Hot Spots, and Figure 8 displays the location of the 5 Hot Spots outside Chittenden County. A detailed review of the Hot Spot locations is provided in Appendix C.

Table 2.6: Hot Spot Location Summary

Hot Spot Locations					
#	City/Town	Road Name(s)	Length (mi)	# of Crashes	# of Votes
CC.1	Burlington	So. Winooski Ave.	0.52	27	27
CC.2	South Burlington	Williston Rd.	0.51	9	74
CC.3	Essex Junction	Pearl St.	0.27	7	0
CC.4	Burlington	Riverside Ave.	0.41	9	16
CC.5	Burlington	Colchester Ave. Bridge	0.05	0	32
OC.1	Brattleboro	Main St.	0.08	4	0
OC.2	Rutland	State St.	0.12	3	0
OC.3	Bennington	North St. & Main St.	0.54	8	6
OC.4	Enosburg	Elm St.	0.17	2	0
OC.5	Castleton	VT 30	0.12	2	0

Figure 2.7: Chittenden County Roadways - Top 5 Hot Spots*

1. S Winooski Ave (ALT-7), Burlington
2. Williston Rd (Rt. 2), South Burlington
3. Pearl St (Rt. 15), Essex
4. Riverside Ave. (Rt. 2), Burlington
5. Colchester Ave (Rt. 2), Burlington

**Note: The majority of Chittenden County Hotspots occur on municipally owned roads.*

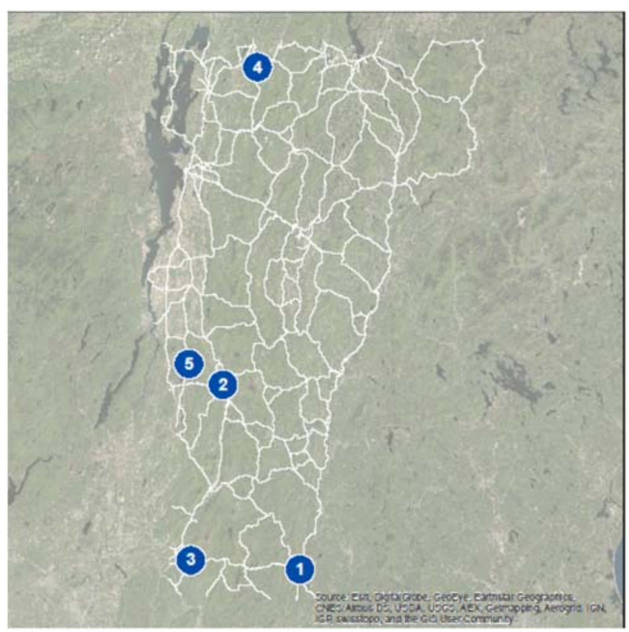


Figure 2.8: Roadways Outside Chittenden County – Top 5 Hot Spots

1. Main St (Rt. 5), Brattleboro
2. State St (BUS-4), Rutland
3. North St. (Rt. 7) & Main St (Rt. 9), Bennington
4. Elm St (Rt. 105), Enosburg
5. Route 30N, Castleton

2.5 Hot Spot Analysis

The Hot Spot Scoring Methodology enabled the Consultant Team to identify locations in the state that had a high concentration of crashes and difficult bicycling locations, when controlled for length and estimated bicycling activity level. Once the Top Ten Hot Spots were identified, five located within Chittenden County and five located outside of it, the next step was to examine the crash reports and difficult bicycling location data for the Hot Spots. The intent of this analysis was to identify roadway design factors that may have contributed to the crashes at each location. From this analysis the Consultant Team developed general crash-themes across all Hot Spot locations (identified in Figures 2.7 and 2.8). These themes were consistently noted in crash report narratives as potentially contributing to the bicycle crashes. Section 2.5.1 includes general conclusions developed through the Hot Spot Analysis . Based on these conclusions, it also includes general roadway design changes and specific engineering improvements that could be implemented to improve bicycling conditions across the state roads. Details for this material can be found in Appendix C.

Appendix C includes findings from the Hot Spot Analysis for each Hot Spot location. For the ten sites, the location is identified, and existing roadway conditions are summarized. A map of the Hot Spot extents is included, as is a summary of the crashes and difficult bicycling locations at the site, and what factors contributed to the crashes. Potential spot improvements are provided for each site. **Figure 2.9** shows the Hot Spot summary for CC.1 South Winooski Avenue, Burlington, from Grant Street to King Street, which was the highest scoring Hot Spot in the state (with 27 reported crashes and 27 total Difficult Bicycling Location votes).

Figure 2.9: Example Hot Spot Summary

CC.1 - Winooski Avenue, Burlington

CC.1 is located on North and South Winooski Avenue. The section extends from Grant Street to King Street (Figure 1). The road is generally two lanes of vehicular traffic in each direction, but the northern portion (above Pearl Street) is one lane, one-way southbound with a dedicated bicycle lane. Vehicular lane widths are approximately 10 feet in the four-lane sections, and there is no shoulder. Table 2 summarizes the location characteristics

FIGURE 1: CC.1 LOCATION - WINOOSKI AVENUE, BURLINGTON

TABLE 2: CC.1 - WINOOSKI AVENUE LOCATION CHARACTERISTICS

CC.1 – So. Winooski Avenue, Burlington	
Total crashes	27
Total Dif. Bicycling Location Votes	27
Average Use Score	16.0
Posted Speed (mph)	25
Typical Speed (mph)	35
AADT (vehicles/day)	3,600 - 13,000
Land Use	Urban, Mixed-use
Vehicle Lane Width (ft)	10 - 12
Bicycle Lane Present	North of Pearl Street
Shoulder Width (feet)	None South of Pearl Street
Parking	No Parking

2.5.1 Hot Spot Analysis General Conclusions

The themes that emerged from the different crash locations generally fell into five categories:

1. Vehicle driver inattention
2. Parking related
3. Sidewalk-use related
4. No roadway shoulder
5. Bicyclist related
    - Failure to obey traffic laws
    - Faulty equipment, e.g. inoperable brakes, no light at night

Based on these general themes, Table 2.7 includes strategies for safety improvements that can be implemented based on the themes. It is important to note that VTrans is already advancing policies related to these themes and has several programs in place that help to improve bicyclist safety on the state roads. The improvements represent opportunities to continue to strengthen existing and new programs.

Table 2.7: Strategies to address bicycle safety on state roads

Theme	Potential Counter Measures
Driver Inattention	**Issue**: Driver reported to not have seen the bicyclist before the crash occurred. This theme was found to contribute to more crashes when complicated traffic patterns, more than two travel lanes, and a high density of curb cuts were present. **Spot/System Safety Improvements**: *Increase the visibility of bicyclists* on roadways through the installation of facilities that dedicated space for bicyclists (such as bike lanes) and signage. This will help to communicate to motorists that bicyclists will be using the road, and increase driver awareness of bicyclists. *Improve intersection design*. Of all crashes, nearly 50 percent occurred at intersections. Intersection design for bicyclists has improved considerably in recent years. Intersections should be designed according to the following principles: *Increase Conspicuity* of bicyclists, by positioning riders in highly visible locations; *Increase Awareness* of potential conflicts through defined conflict areas, markings and signs; *Isolate Conflicts* so that they can be negotiated separately from the intersection itself; *Reduce or remove conflicts* through geometry, signaling and other treatments; *Clearly Assign Priority* so that all road users understand who has the right-of-way; *Minimize Speed* to increase reaction times and reduce the consequences of mistakes. Where possible, *consider implementing access management practices* by consolidating driveways and reducing the total number of curb cuts. VTrans, as a policy, has been addressing this issue.
Parking Related Crashes	**Issue**: Parking-related crashes were caused by vehicle occupants opening doors as bicycle riders passed (which is commonly known as 'dooring') or by a vehicle moving into the path of a bicycle as it was parking. **Spot/System Safety Improvements**: *Install buffered bike lanes* where space allows creating a buffered space between parked cars and bicyclists. In areas where there is high parking turnover, the buffer should be placed on the right side of the bike lane, and be wide enough so that bicyclists ride outside of the door lane. In instances where the road is not wide enough, angled markings extending into the bike lane can be installed to encourage bicyclists to ride outside of the door zone. *Shared Lane Markings* can be installed on roadways that are too narrow for the installation of bike lanes. The center of the chevron suggests lane positioning for bicyclists. In town center contexts, shared lane markings should be placed in the center of the travel lane (as opposed to the minimum MUTCD required curb off-set of 11 feet). Placing shared lane markings here encourages bicyclists to ride outside of the door zone.

Theme	Potential Counter Measures
Sidewalk Related Crashes	**Issue:** Sidewalk related crashes were caused by bicyclists riding on sidewalks and being hit by drivers. There is a common perception that riding on sidewalks is safer than riding on roadways. However, the data indicates that drivers may not expect bicyclists to be riding on sidewalks, and that this factor may be causing these crashes. Poor site lines were found to contribute to this type of crash. **Spot/System Safety Improvements**: *Install dedicated bicycle facilities*. Bicyclists may choose to ride on sidewalks because they perceive it to be safer than riding on-road. By installing on-street bicycle facilities in areas where there is demand for bicycling, it could help to reduce sidewalk riding by providing a dedicated space on-road for riding. This could encourage more people to ride on-road and reduce sidewalk riding. *Improve Site Distances.* At locations where sidewalk riding is prevalent, site lines at driveways and crosswalks should be clear without visual obstructions. Where possible, *consider implementing access management practices* by consolidating driveways and reducing the total number of curb cuts to reduce the number of driver/bicyclist conflicts. VTrans has policies in place that are aimed at access management. *Install signage* that reinforces that motorists should yield to pedestrians and bicyclists when crossing the driveway/crosswalk.
No Roadway Shoulder	**Issue:** Roadways without shoulders were found to be overrepresented in the number of crashes. In the rural section of road analyzed (OC. – VT 30 – Castleton) a bicyclist may have been pushed off the road by a truck, but the crash report was not conclusive. **Spot/Safety Improvement:** Install minimum shoulder widths per the VT State Standards. 4' minimum shoulders enable vehicles to pass bicyclists without needing to cross the roadway centerline. Wider shoulders are appropriate as speeds increase. The AASHTO Guide for the Development of Bicycle Facilities recommends a minimum shoulder clear-width of 4' to accommodate bicyclists in shoulders. AASHTO states that shoulders wider than 4 feet are desirable if higher bicycle usage is expected or if motor vehicle speeds exceed 50 miles per hour; if use by heavy trucks, buses, or recreational vehicles is considerable; or if static obstructions exist at the right side of the roadway.

2.6 Crash Analysis Overall Conclusions

The analysis of reported bicycle crashes along the state roads identifies opportunity areas that can be considered to reduce crashes and improve bicyclist safety statewide. The general findings from the analysis include:

- The total number of crashes per year over the period analyzed have remained relatively consistent, at 42 reported crashes per year. Of all the reported crashes, approximately one in four resulted in some form of bodily injury to the bicyclist, which is consistent with national findings. This highlights the risk bicyclists face if they are involved in a crash and emphasizes the need to reduce them. The total economic costs of these crashes over the period studied equal more than $27 million dollars.[16]
- Anecdotally, bicyclists are thought to disobey traffic laws at higher rates than motor vehicle drivers. The data indicates that this is not the case, with bicyclists and motor vehicles being cited for improper actions preceding the crashes at roughly equal rates.

[16] Total based on the average economic costs as reported in the 2014 VTrans High Crash Location (HCL) Report. Over the period studied, 2 bicycle fatalities were recorded on the State roads, and there were 319 recorded bicycle injuries. The HCL Report estimates a fatality equates to $1,410,000 in average economic costs, and that an injury equates to $78,900 in average economic costs (2 fatalities X $1,410,000 + 319 injuries X $78,900 = $27,989,100 in Total Average Economic Costs).

- The analysis found that 1 in 5 crash reports did not include either the bicyclist or motorist action preceding the crash. Having this data coded more consistently would provide additional insight into where and why crashes are occurring. VTrans should continue building its positive relationship with law enforcement to continually improve crash data collection.
- The analysis exposed consistent themes in the crashes, actions that could potentially be reduced through targeted safety and awareness campaigns. These themes included:
    - Motorists not seeing the bicyclist before the crash
    - Specific motorist and bicyclist actions were found to represent a large percentage of improper actions. For bicyclists, this includes improper crossings and failure to yield right of way. For motorists, this includes failure to yield right of way and inattention.
    - Dooring and distracted driving were also found to contribute to crashes
    - Bicyclists not wearing lights, and making improper maneuvers prior to the crash, were linked to causing the crashes
    - Crashes were concentrated in urban areas, particularly within Chittenden County
- The analysis exposed consistent themes in roadway design that are potentially contributing to crashes. These themes included:
    - Lack of dedicated bicycle facility or roadway shoulder
    - High concentration of crashes at both signalized and unsignalized intersections
    - Roads with more than two lanes, medians, and complicated traffic patterns had a higher prevalence of reported crashes
    - The presence of curb cuts was also found to contribute to crashes.

  A small number of state roads, by mileage, exhibited high rates of crashes. For example, approximately 60 percent of crashes occurred along five roads, while these roads represent about 25 percent of the total miles of roadways analyzed. These roads include Alternate US 7, US-5, VT-15, US-2 and US-7.

Chapter 3. Bicycle Level of Traffic Stress Analysis

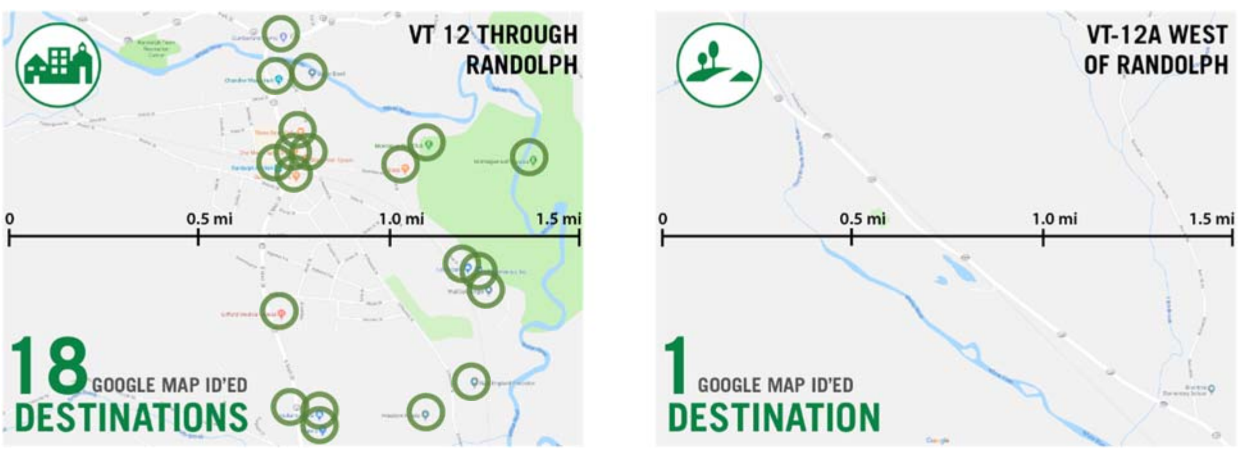
3.0 Introduction

This chapter presents the evaluation criteria used to assess how comfortable Vermont's state roads are for bicycling, and how this methodology was developed.

Research into the subject of roadway comfort for bicycling suggests that land use patterns in urban areas support bicycling for a wide range of trip types, with significant emphasis on utilitarian trips. This is due primarily to the close proximity of trip generators and destinations, along with higher population densities. Therefore, roads in urban areas should be designed to be comfortable for a range of bicyclists, including novice bicyclists who might be using the roadways. In addition, improving bicycling in an urban setting could invite people who have an interest in bicycling that do not bicycle, due to lack of facilities.

Conversely, in rural areas, destinations are more spread out and population density is much lower. Due to this, rural roads attract more recreationally-focused riders who ride long distances for exercise, training and/or general enjoyment. Because these riders do so as a choice, they tend to be more experienced and comfortable bicycling on roads with higher posted speed limits and more narrow shoulders. The Transportation and Recreation Use Scores developed in Phase One of the On-road Bicycle Plan substantiate this assumption. Phase One showed that roads with higher transportation use scores are concentrated in urban areas, while roads with higher recreation use scores are dispersed between urban and rural areas. The evaluation criteria developed is sensitive to the differences in user types for urban and rural areas. This difference is important since 86% of the analysis roadways are located in rural areas.

Figure 3.1: Destination in Urban vs Rural areas (map source: Google Maps)



Google Maps includes icons representing destinations in communities. When comparing a typical small-town (urban area) to a typical rural area in Vermont, this information can be used to communicate how context can influence bicycling trips. In Randolph, VT, 18 Google Map ID'ed destinations are located within a 1.5-mile radius of downtown, which corresponds to a bicycle trip that can be completed in about ten minutes. In this context, bicycling represents a relatively convenient option to access multiple destinations. Conversely, the rural section of VT-12A west of Randolph has one destination within a 10-minute bike ride. Along this rural section of road, bicycling does not represent a very convenient mode of transportation. Due to low densities and few destinations, most bicycle trips in rural areas are expected to be recreationally focused.

The consultant team researched what other municipalities and states have done to assess the comfort levels of roadways under their jurisdiction and determined that two primary methodologies exist: Bicycle Level of Service (BLOS) and Bicycle Level of Traffic Stress (BLTS). Both models use evaluation criteria to create scores for roadway segments that assess how comfortable they are for bicycling along roadways and through intersections. The primary benefit of the BLTS methodology is that it can be calibrated specifically to both urban and rural areas and can be made sensitive to various rider types, while the BLOS criteria does not change based on roadway context or design user (cyclist).

Due to the benefits of using the BLTS model, the methodology was selected as the tool to evaluate the comfort of bicycling along Vermont's state roads. This chapter presents background on how the framework was developed for urban and rural areas, scoring tables and score definitions, and key findings from the analysis.

3.0.1 Bicycle Level of Traffic Stress Background

Bicycle Level of Traffic Stress has become the planning industry standard for assessing how comfortable, or stressful, a roadway is for bicycling. Built on the goal of creating a bicycle network that is accessible to novice bicyclists, the analysis uses three key inputs and other supporting inputs that are readily available and can easily translate into network recommendations. The BLTS methodology was originally proposed by The Mineta Institute in 2012[17] and was subsequently tested in urban San Jose, CA. Since that time dozens of local, regional and state agencies, including the States of Colorado and Oregon, have employed this methodology to evaluate the comfort of bicycling on roadways.

Using the BLTS model has advantages over other tools available, such as Bicycle Level of Service. BLTS is less data intensive, which is particularly important for a state-wide tool, since state-wide datasets are time consuming to obtain. Additionally, practitioners are able to easily link a segment's score to underlying roadway factors that are causing the score. This is helpful when projects are being planned and designed, as the practitioner can quickly understand what roadway factors could be changed to improve the roadway's score. Additionally, BLTS can be calibrated specifically to both urban and rural areas and is therefore beneficial in scenarios where both types of conditions are present. These benefits make BLTS a useful planning framework for identifying network gaps and determining opportunities for improvement along Vermont's state roadways.

3.0.2 Bicycle Level of Traffic Stress Definitions

BLTS presents relative stress levels according to a four-point scale, with lower number indicating lower stress/higher comfort level, and higher number indicating higher stress/lower comfort level. For the Vermont BLTS model, VTrans has defined the BLTS classification as follows.[18]

Roadways whose design and character are:

- BLTS 1: Welcoming to most types of bicyclists.
- BLTS 2: Comfortable for most adult bicyclists.
- BLTS 3: Comfortable for experienced and confident bicyclists.
- BLTS 4: Uncomfortable for most bicyclists.

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[17] *Low-Stress Bicycling and Network Connectivity*. The Mineta Transportation Institute, 2012. <http://transweb.sjsu.edu/PDFs/research/1005-low-stress-bicycling-network-connectivity.pdf>.

[18] These definitions are based on best practices, and modified to be consistent with the context and design goals of VTrans.

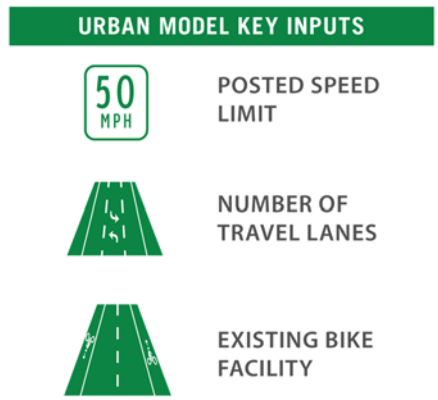
3.1 Urban and Rural BLTS Criteria and Scoring Framework

For Phase Two of the VTrans On-road Bicycle Plan, the consultant team used one set of evaluation criteria for roads in urban areas, and another for roads in rural areas.[19] This method is sensitive to the type of bicyclist—utilitarian vs. recreational, respectively — that is expected to be using roadways in the two different contexts. The criteria used in this study are based upon research conducted to develop the BLTS methodology, which determined the criteria that have *the most* influence on bicycle stress levels in the different roadway contexts**.** While other criteria have an influence, based on the Mineta Institute's research and others, and substantiated by a survey conducted for this plan, the criteria presented below are the MOST important for determining a roadway's level of comfort for bicycling in urban and rural areas.

For the BLTS Model, roads that are within defined urban boundaries are defined as urban roadways. For these roadways, the **Urban BLTS methodology** is used, which includes the following scoring criteria:

- Posted Speed
- Total Number of Travel Lanes
- Presence/absence of a bikeway facility, and if this data is used, parking conditions adjacent to the bikeway

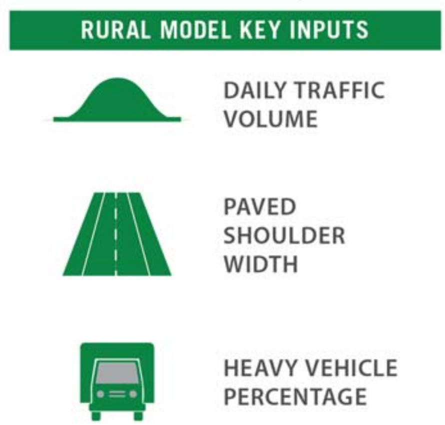
Figure 3.2: Urban Methodology Inputs



For roadways outside of defined urban boundaries are scored using the **Rural BLTS Methodology**. This methodology includes the following scoring criteria.

- Average Daily Traffic (ADT)
- Shoulder width
- Heavy Vehicle Percentage

Figure 3.3: Rural Methodology Inputs



Each model is calibrated to the primary type of bicyclist that is currently or could be expected to ride in each context. More novice bicyclists are expected to ride in urban areas, while recreational bicyclists are most likely to be found riding in rural areas. The type of rider dictates the scoring criteria used. Section 2.3 describes why different criteria are used for the rural model.

3.2 Urban Methodology

Based on research, posted speed and the number of general travel lanes have been shown to have *the most influence* on bicyclist stress levels in urban areas. This conclusion is substantiated by an online survey developed for this study. Respondents were asked to rank the factors that influence their comfort when riding in urban area. As Figure 3.3 displays, respondents reported that dedicated bike lane/shoulder, low traffic speeds and smooth pavement have the most influence on their comfort when riding in urban areas. For this study, neither existing bicycle lane nor parking data are available. Therefore, the consultant team's modelling of roads within urban areas is assumed to be mixed-traffic roadways, where bicyclists and motor vehicles share the road. In the VTrans BLTS Urban model, speed and

[19] The urban and rural boundaries used in this analysis were defined by VTrans as follows: urban boundaries for BLTS purposes were defined as Federal Aid Urban (FAU) boundaries and ACCD designated downtown and villages centers .VTrans developed these FAU boundaries based upon FHWA guidance and Census data of urban clusters. There was coordination with the RPCs and smoothing of the boundaries to insure that appropriate FAU boundaries were defined.

number of travel lanes are used to assess how comfortable a roadway is for novice level bicyclists within Urban Areas assuming mixed traffic conditions.

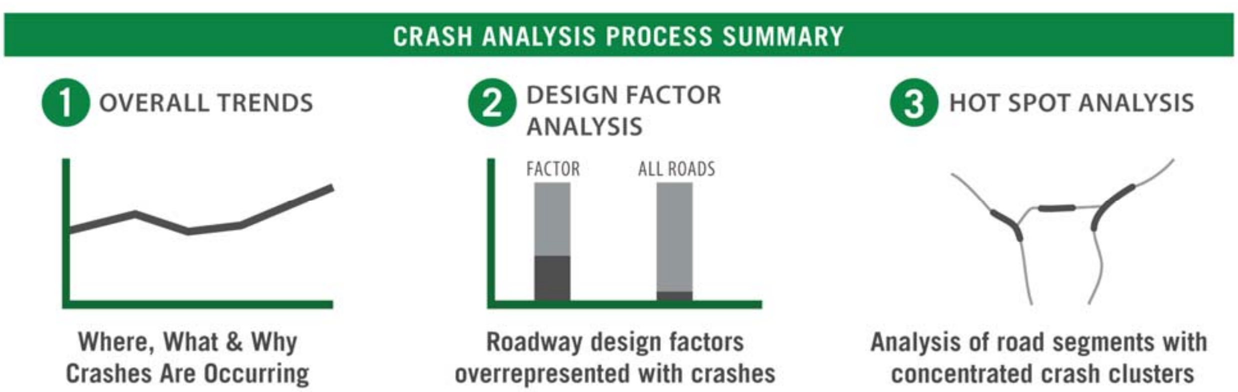
Table 3.1 presents the current scoring methodology for Vermont's Urban state roads. Again, because a comprehensive set of statewide data is not available, this methodology assumes that no dedicated bicycle facility is present, and that bicyclists are sharing the roadway with motor vehicles. Given this condition, BLTS scores are influenced by the number of travel lanes and posted speed. Roadways with a posted speed of 35 mph or greater are automatically classified as BLTS 4 (high stress/low comfort) facility, as are roadways with three or more lanes per direction. Lower speed limits and fewer lanes improve the BLTS score of roadways. For example, a BLTS 1 roadway is achieved on 25 mph, local roadways with no marked centerline; however, this condition likely does not exist along the state roads. [20]

Figure 3.4: Survey Results – Most Important URBAN Comfort **Factors**

Table 3.1: Proposed Urban Roadway Section Methodology – Mixed Traffic

Apparent Travel Speed	Total Lanes Per Direction			
	Unmarked Centerline	1 lane per direction	2 lanes per direction	3+ lanes per direction
≤ 25 mph	BLTS 1	BLTS 2	BLTS 3	BLTS 4
30	BLTS 2	BLTS 3	BLTS 4	BLTS 4
≥ 35	BLTS 3	BLTS 4	BLTS 4	BLTS 4

Figure 3.5: VTrans Rural BLTS Methodology



Tables 3.2 and 3.3 reflect the methodology that **would be used if** bicycle facility and parking location data were available. These tables should be used to inform Urban BLTS scores if there are future efforts to collect this data for state roadways.

[20] The presence of dedicated bicycle infrastructure, such as a bike lane, could improve the BLTS score for a given roadway segment. However, since this data is not available, this condition cannot be modeled. Tables 2 and 3 reflect the scoring table if this data were available.

Table 3.2: Urban Roadway Section Methodology – Bike Lane with Adjacent Parking

1 Lane per direction				**≥2 lanes per direction**	
Prevailing or Posted Speed	**≥ 15' travel lane and bike lane + parking**	**14' – 14.5' travel and bike lane + parking**	**≤ 13' travel and bike lane or frequent blockage**	**≥ 15' travel and bike lane + parking or frequent blockage**	**≤ 14.5' travel and bike lane**
≤25 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
30 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
≥35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 3
≥40 mph	LTS 2	LTS 4	LTS 4	LTS 3	LTS 4

[1]Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Table 3.3: Urban Roadway Section Methodology – Bike Lane without Adjacent Parking

1 Lane per direction					**≥2 lanes per direction**	
Prevailing or Posted Speed	**≥ 7' (Buffered bike lane)**	**5.5' – 7' Bike lane**	**≤ 5.5' Bike lane**	**Frequent bike lane blockage1**	**≥ 7' (Buffered bike lane)**	**<7' bike lane or frequent blockage[1]**
≤30 mph	LTS 1	LTS 1	LTS 2	LTS 3	LTS 1	LTS 3
≥35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 2	LTS 3
≥40 mph	LTS 3	LTS 4	LTS 4	LTS 4	LTS 3	LTS 4

[1]Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

With the urban methodology, separated facilities always score as an BLTS 1. According to the original Mineta Report, this includes roadways where cyclists are either physically separated from traffic or are in an exclusive bicycling zone next to a slow traffic stream with no more than one lane per direction. Separated facilities therefore include shared use paths running adjacent to roadways, as well as separated bikeways, which provide dedicated space for bicyclists to ride, visually or physically separated from motor vehicle traffic by flexible posts, curbs, parked vehicles or other vertical elements.

3.3 Rural Methodology

The Urban BLTS methodology presented in the previous section is calibrated for urban areas, and roadways with speeds greater than 35 miles per hour receive 'high stress' scores. This standard methodology provides little variation in scores along Vermont's state roads in rural areas, which primarily have speeds greater than 35 miles per hour; approximately 86 percent of state roads outside of defined urban boundaries have posted speeds greater than 35 mph. If the urban methodology was used for these roads, the great majority would automatically receive 'higher stress' scores of BLTS 3 or 4. This would not accurately reflect the comfort level of the type of bicyclist that would be expected to be using these roadways, which research suggests tend to be more experienced and more stress-tolerant recreational bicyclists.

Figure 3.6: Survey Results – Most Important RURAL Comfort **Factors**

Reacting to this constraint, state agencies have modified the Urban BLTS methodology to more-accurately represent the type of bicyclists that ride in rural contexts, those who tend to be more confident, recreational riders. The Oregon Department of Transportation (ODOT) outlines their modified methodology in Chapter 14 of their Analysis Procedures Manual[21]. In developing this methodology, ODOT determined that most reported crashes on rural roadways involved a vehicle attempting to overtake a bicyclist on roadways with limited paved shoulder width. A paved shoulder provides additional operating space for a bicyclist that is not in the path of a vehicle. With the exception of high-volume roadways (>7,000 vpd), a wide paved shoulder can significantly increase the comfort level of a bicyclist. This assumption is consistent with the Vermont State Design Standards, which recommends wider shoulders as vehicle speeds and volumes increase, and findings from the online survey developed for this study.

3.3.1 CDOT Rural BLTS Methodology

A report from the Colorado Department of Transportation (CDOT), Region 2 builds on the methodology presented in the ODOT report. It includes an adjustment factor based on percentage of heavy truck traffic. Their research found that truck traffic representing 10% or more of the traffic stream will influence bicyclist stress levels on roadways with1,500 vehicles per day or more. This threshold is consistent with the Vermont State Design Standards, Table 3.7 which indicates that one additional foot of paved shoulder width is recommended where truck traffic exceeds 10% of the roadways ADT.

The research is based on percentage of medium and heavy trucks, rather than the volume of trucks. The percentage is used because the BLTS model is built on the framework of bicyclist perception of comfort. The model uses data as proxies to indicate these subjective feelings, and one indicator of stress is the presence of trucks. Specifically, the 10 percent figure is used because research suggests at this level, a road starts to feel like it carries many trucks, when compared to all vehicles within the traffic stream. Since presence of trucks increases a rider's risk of severe injury and wind blast, bicyclists tend to avoid roads that feel like truck routes, or may choose to ride on them, but feel uncomfortable doing so. Using the 10 percent figure, the model is able to identify roadways that 'feel' like there is a dominance of trucks for lower and higher-volume roadways.

3.3.2 Calibrating the Rural BLTS Methodology for Vermont

The consultant team scored the rural roadways using the CDOT Rural BLTS Methodology (described in Section 3.3.1), and assessed the results to determine how well the scores reflected bicyclist experience. The purpose of this exercise was to identify model factors that might benefit from adjustment to more accurately represent Vermont. The assessment involved two steps. First, analysts compared the BLTS scores developed through CDOT Methodology for frequently bicycled roadways to the experiences of bicyclists who ride on these roads.

Secondly, a more data-driven review of the state-wide BLTS scores was conducted. Road segments with various criteria were identified in GIS, and their scores examined. For example, all rural roads with daily traffic volumes of 1500 vpd were identified and reviewed, then roads with daily traffic volumes of 1600, etc. Shoulder width and speed were similarly considered. The VTrans Bicycle Crash Analysis results were evaluated as well to determine if roadway variables that were over-represented in crashes should influence the scoring table[22]. A detailed summary of the findings from this review is included in Appendix E. As a result of this assessment, the following modifications to the shoulder and volume categories (referred to in Table 4) were recommended to better reflect bicyclist experiences in Vermont:

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[21] *Analysis Procedures Manual.* Chapter 14. Oregon Department of Transportation, 2016.

[22] The VTrans Bicycle Crash Analysis detail is available as a separate technical memo and focused on identifying potential safety hot spots along the State Roadways. This included mapping reported bicycle crashes, analyzing overall crash trends, analyzing roadway design factors that contributed to the crashes, developing a hot spot scoring methodology and analyzing the Top 10 Hot Spots.

- Adjust shoulder categories to the following:
    - Shoulder Category 1: Roadways with shoulders less than 2' wide or none at all. These roads provide no dedicated space for bicyclists on the roadway.
    - Shoulder Category 2: 2 to less than 3' shoulders. These roads do not provide enough separation for bicyclists to ride completely outside the travel lane.
    - Shoulder Category 3: 3 to less than 6' shoulders. These roads provide enough space for bicyclists to ride separated from motor vehicle traffic, or to ride in the travel lane and maneuver into a separated space when motor vehicles pass.
    - Shoulder Category 4: 6' or more. Shoulders over 6' wide provide a space wide enough for bicyclists to travel, and exceed the recommended bike lane width defined by AASHTO
- Adjust volume thresholds to the following categories:
    - 0-500, 500-1500, 1500-5000, 5000-7000 and greater than 7,000 vehicles per day (vpd)
    - Justification for these changes include:
        - The crash analysis indicated that roadways with more than 5,000 vpd are over-represented in bicycle/motor vehicle crashes
    - Additional changes to the volume criteria included:
        - Low volume roadways (<1500 vpd) with wide shoulders (>6') are to receive a BLTS score of 1, since vehicles pass bicyclists infrequently
        - Roadways with more than 7,000 vpd that do not have wide shoulders (>6 feet) will always receive a BLTS score of 4

3.3.3 Rural BLTS Methodology for Vermont

Based on this review, the CDOT BLTS Methodology was updated for Vermont with the modifications specified in Section 4.2. Roads that are outside of defined urban boundaries are defined as rural roadways. These state roads are scored using the VTrans Rural BLTS methodology. This methodology includes the following scoring criteria:

- Presence and Width of Shoulder
- Estimated Daily Traffic Volume
- Estimated Percentage of Truck Traffic[23]

The Rural BLTS Methodology, calibrated specifically for the State of Vermont, is presented in **Table 3.5.**

Table 3.5: VTrans Rural BLTS Methodology for Roadway Sections

Daily Volume (vpd)	Paved Shoulder Width			
	0 to < 2 ft	2 ft to < 3 ft	3 ft to < 6 ft	6ft or wider
< 500	BLTS 2	BLTS 2	BLTS 2	BLTS 1
500 to 1,500	BLTS 3	BLTS 2	BLTS 2	BLTS 1
1,500 to 5,000	BLTS 4	BLTS 3 – 4*	BLTS 2 – 3*	BLTS 2 – 3*
5,000 to 7,000	BLTS 4	BLTS 4	BLTS 3 – 4*	BLTS 3 – 4*
>7,000	BLTS 4	BLTS 4	BLTS 4	BLTS 3 – 4*

*For roadways where Truck % exceeds 10% of the traffic stream the higher score is assigned

[23] Truck is defined as FHWA Class 4-13 which includes full size school and transit busses, delivery type van and heavy duty pick up. The truck data is used in this analysis however the data is based on traffic counters and there are gaps the data available (in other words some roadway segments have 0% percent trucks).

3.4 BLTS Results

The BLTS model produced scores according to a four-point scale, from BLTS 1, representing the highest comfort roadways, to BLTS 4, representing the least comfortable roadways. A single set of score definitions was developed to be used for both the urban and rural model results. VTrans will use the definitions to develop policy strategies in Phase Three. For instance, VTrans can use the definitions to set goals for target BLTS score in urban and rural contexts, as well as BLTS targets for high-use, medium-use and low-use corridors. For the Vermont BLTS model, VTrans has defined the BLTS classification as follows.[24]

Roadways whose design and character are:

Once the model parameters were established for urban and rural roadways, the model was run on all state roads, as well as exclusively on the high-use roads.[25] While VTrans efforts to improve bicycling conditions in the near term will be focused primarily on the high-use corridors, preparing the results for all state roads can inform bikeway improvements along medium-use and low-use corridors as opportunities arise. The percentage of roads grouped into each category is displayed in Figure 3.7 (All Roads) and 3.8 (High-Use Corridors Only). In the future, VTrans may collect additional data and make modifications to the parameters of the BLTS model. The model is developed to be flexible to these changes and is able to produce new results quickly to inform decision making. The All Roads results of the BLTS model are displayed on Map 3.1, and the High Use Corridor Results are displayed on Map 3.2.

[24] These definitions are based on best practices, and modified to be consistent with the context and design goals of VTrans.

[25] A small percentage of roadways had shoulder widths that varied between the left and right shoulder. For this report, the narrower shoulder width was always modeled, as to represent the roadway's worst-case scenario for accommodating bicyclists. This method means that inevitably, some roadways are not correctly modeled, and bicycling on one direction of the road may be more comfortable that the model results indicate. VTrans is actively working on cleaning the shoulder width data so that it accurately reflects conditions on the ground. The BLTS results will be updated as new data become available.

Figure 3.7 Percentage of Roads by BLTS Category – All Roads

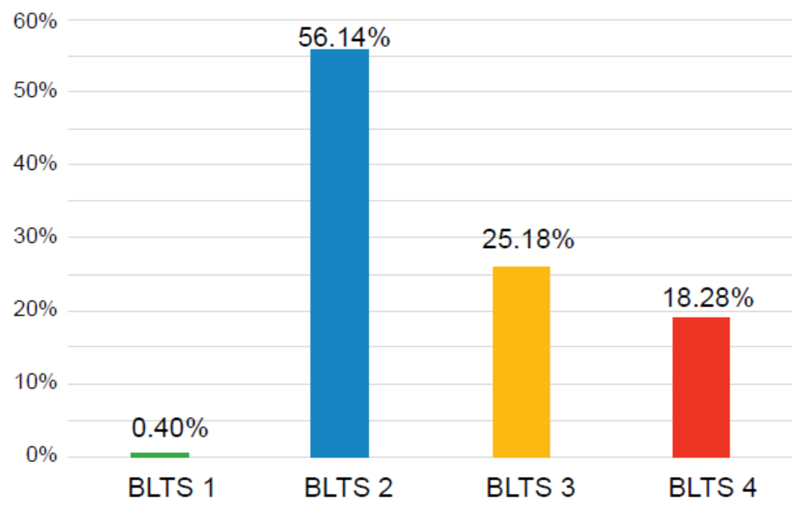


Table 3.6 Urban All Roadways – Miles and Percentages by BLTS Score

Score	Miles	Percent
BLTS 2	3.6	1%
BLTS 3	48.6	14%
BLTS 4	294.0	85%
Total	**346.2**	**100%**

Table 3.7 Rural All Roadways – Miles and Percentages by BLTS Score

Score	Miles	Percent
BLTS 1	23.0	1%
BLTS 2	1407.3	65%
BLTS 3	589.1	27%
BLTS 4	146.9	7%
Total	**2,166.3**	**100%**

Figure 3.8 Percentage of Roads by BLTS Category – High-Use **Corridors**

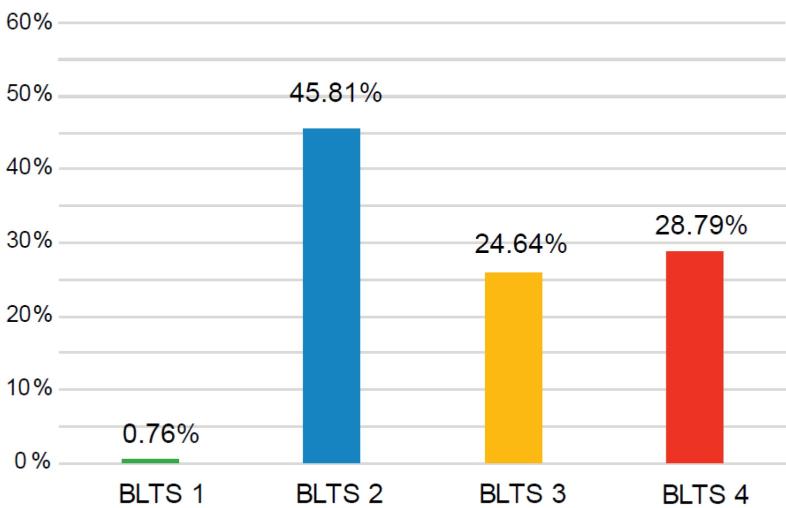


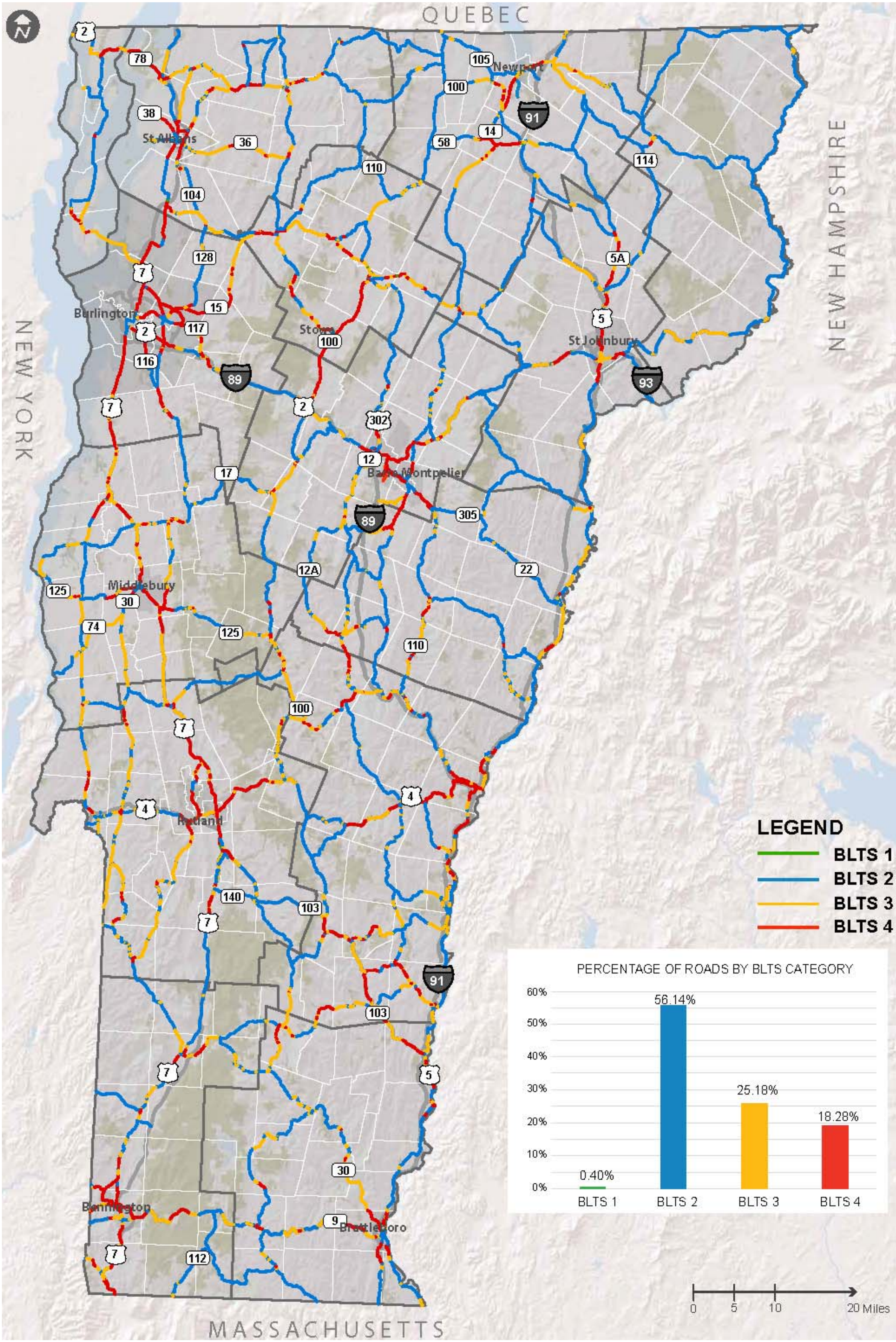
Table 3.8 Urban High Use Corridors – Miles and Percentages by BLTS Score

Score	Miles	Percent
BLTS 2	3.0	1%
BLTS 3	40.4	17%
BLTS 4	199.4	82%
Total	**242.8**	**100%**

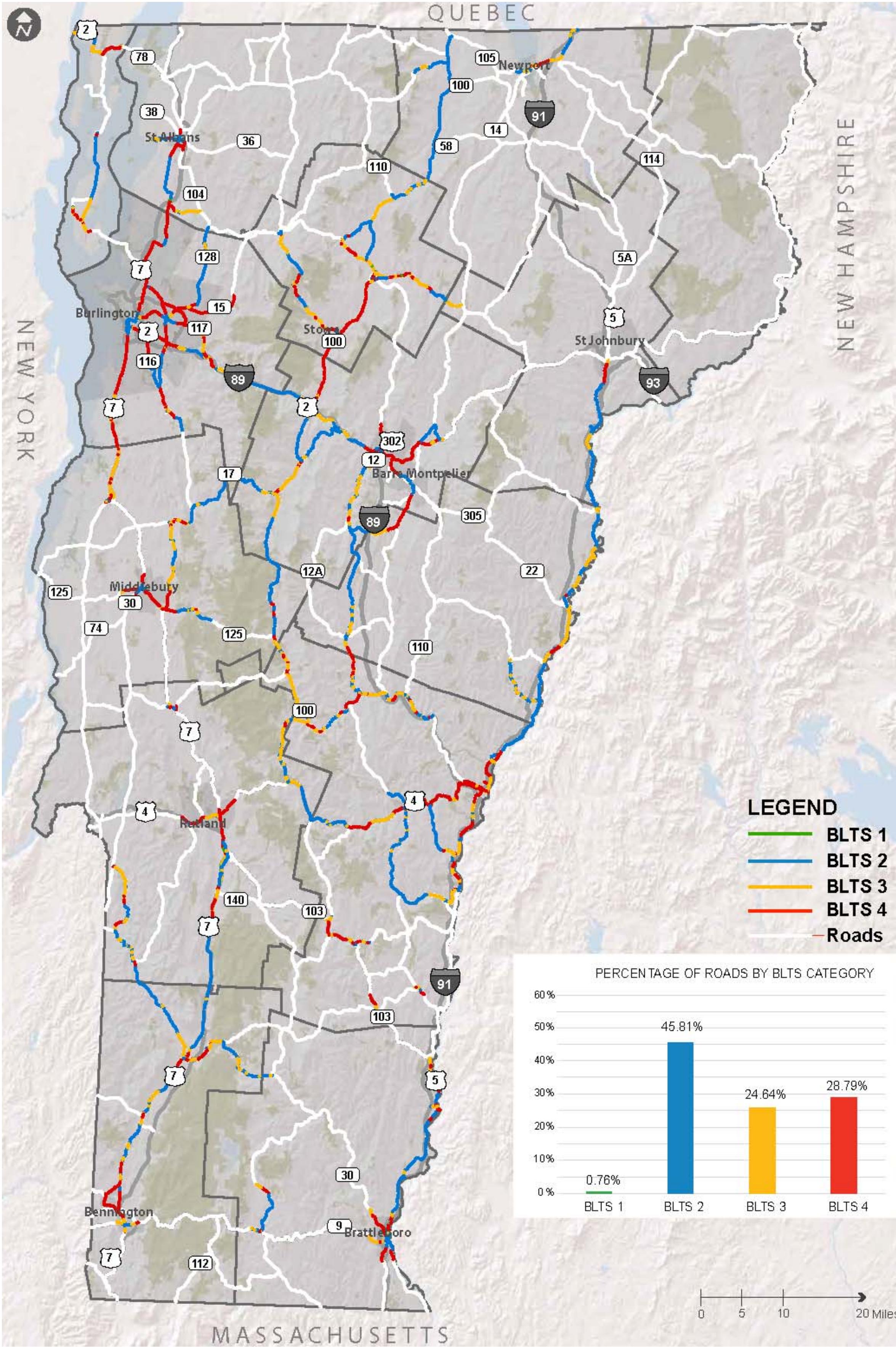
Table 3.9 Rural High Use Corridors – Miles and Percentages by BLTS Score

Score	Miles	Percent
BLTS 1	11.8	2%
BLTS 2	390.9	57%
BLTS 3	204.0	30%
BLTS 4	80.4	11%
Total	**687.1**	**100%**

Map 3.1 BLTS All Roads Results



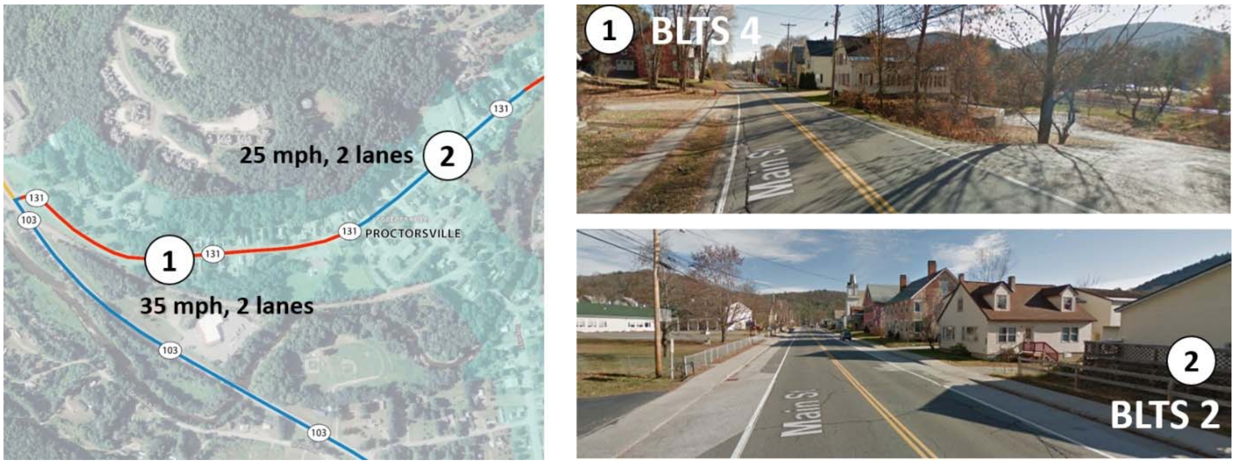
Map 3.2 BLTS High Use Corridor Results



3.4.1 Example Urban BLTS Results

The current Urban BLTS model relies on two primary factors to produce BLTS scores. These factors are speed and the number of travel lanes. Figure 3.9 shows an example of how the urban model produces scores. The example displays VT-131 as it passes east/west through Proctorsville. Two scores are produced for this urban roadway section. Both segments are two-lane roadways, as shown in the pictures at left. Segment 1 receives a BLTS score of 4 due to the posted 35 mph speed limit, while the segment to the east receives a BLTS score of 2 due to the posted speed limit of 25 mph. Lower speed roads are more comfortable to ride. The model results suggest that most bicyclists would find Segment 1 uncomfortable to ride for most bicyclists, while Segment 2 would be comfortable for most adult bicyclists.

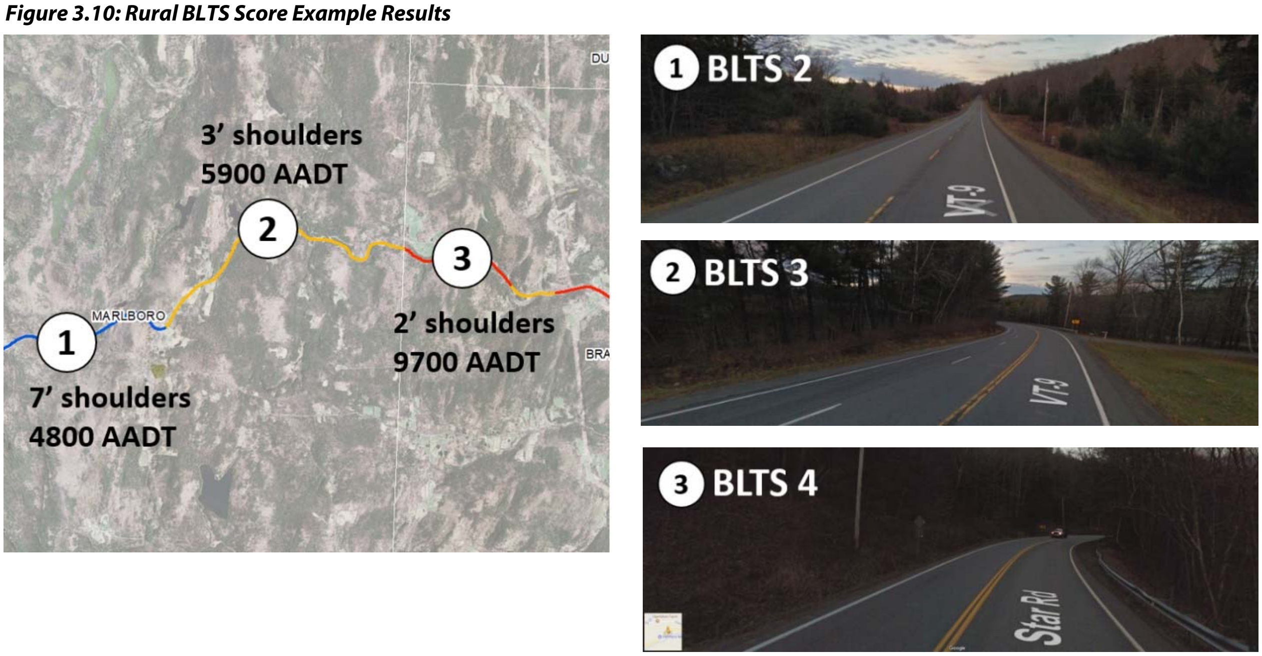
Figure 3.9: Urban BLTS Score Example Results



3.4.2 Example Rural BLTS Results

The Rural BLTS model relies on three primary factors to produce BLTS scores. These factors include the presence/absence of a shoulder, traffic volumes, and heavy vehicle percentage. Figure 3.10 shows an example of how the rural model produces scores. The example displays VT-9 east of Marlboro. Three scores are produced for the rural section shown. Traffic volumes and the width of the shoulder vary along this section of road. Segment 1 receives a BLTS score of 2, while Segment 2 receives a BLTS score of 3, and Segment 3 a BLTS score of 4. Lower volume roadways with wider shoulders are more comfortable to ride. The model results suggest that most adult bicyclists would find Segment 1 comfortable to ride, while Segment 2 would be comfortable for most experienced, confident bicyclists, and Segment 3 would be uncomfortable to ride for most bicyclists (due to the higher volumes and narrow shoulder).

Figure 3.10: Rural BLTS Score Example Results



3.5 Other Criteria Considered

In developing the Urban and Rural BLTS Methodologies, VTrans invested significant time to create a statewide data-set that includes the needed criteria listed in Table 3.1 and Table 3.5. The methodologies are developed, so that in the future, should data change or different data become available, the models can be updated and new results prepared quickly.

In localized (i.e. corridor and city-wide studies) BLTS analysis, intersection scores are typically prepared. With BLTS intersection analysis, where a lower-stress roadway intersects a higher stress roadway at an unsignalized intersection, the segment from the lower-stress roadway leading to the higher stress roadway generally 'picks-up', or assumes, the higher stress score. For the VTrans analysis, intersections have not been scored. The state roadways that comprise the analysis tend to be higher volume, higher speed roadways that overall receive higher stress scores. The primary impact of crossings would occur where local and collector roadways cross state roadways; local and collector roadways tend to have lower stress scores that will be affected by unsignalized crossings of high stress roadways. Since local and collector roadways are not included in the model, intersection scores are not provided as part of this analysis since the impact of scoring intersections would be minimal.

The criteria and scoring tables presented in this memorandum are based upon data that was readily available to the consultant team. Additional data could be incorporated into the Urban and Rural BLTS model to make it more robust. These data sets include:

- Presence/Absence of a bike lane
- Presence/Absence of on-street parking
- Pavement Condition

In order to conduct more robust analysis in the future, VTrans should consider collecting bike lane width and parking data. Bike lane width greatly impacts comfort level through provision of operating space and increased separation from traffic, and the presence or absence of parking impacts level of comfort for bicycling as well.

For this study, the online survey asked the public to rank factors that influence their comfort when riding in urban areas.[26] "Smooth Pavement" ranked as the third most important road characteristic that made people feel comfortable while riding in both urban and rural contexts. The planning team considered adding pavement condition as a factor in both the urban and rural model. VTrans assesses pavement condition from the centerline to the outside white line, and updates pavement scores every two years. The team identified a few shortcomings with incorporating pavement data.

First, for roadways that have shoulders, the condition of the shoulder may differ from the adjacent pavement condition rating. Although staff from VTrans roadway design indicated it is fair to assume the shoulder condition matches the travel lane conditions, in general. The only roads that the travel lane and shoulder may see different treatments (or treatment frequency) are those "wide roads" where we may do an edge line to edge line PM treatment. Even in those cases, most of the time, the shoulders are in at least "fair" condition if they are left untreated.

Second, the actual pavement condition may differ from the pavement database, since the database is updated every two years. This could mean the results of the model do not accurately reflect existing conditions.

Third, there is no research into how much pavement condition influences the BLTS score and therefore, pavement condition is not included in the final scoring tables or results.

3.6 BLTS Next Steps

The planning and consultant team have undergone many iterations to improve the dataset and create a model specific for Vermont. The results of the BLTS analysis is a planning tool and will serve as an input during project development and updating VTrans Bike/Ped Policy documents.

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[26] The primary purpose of the survey was to determine if the inputs proposed for use in the Rural and Urban Bicycle Level of Traffic Stress (BLTS) Model reflected the criteria that the public thought influenced their comfort levels while riding in urban and rural contexts. More detail will be available within the Phase Two final report.

PHASE TWO

VTRANS ON-ROAD BICYCLE PLAN

APPENDIX A: OVERALL CRASH TRENDS

alta PLANNING + DESIGN

RSG

APPENDIX A

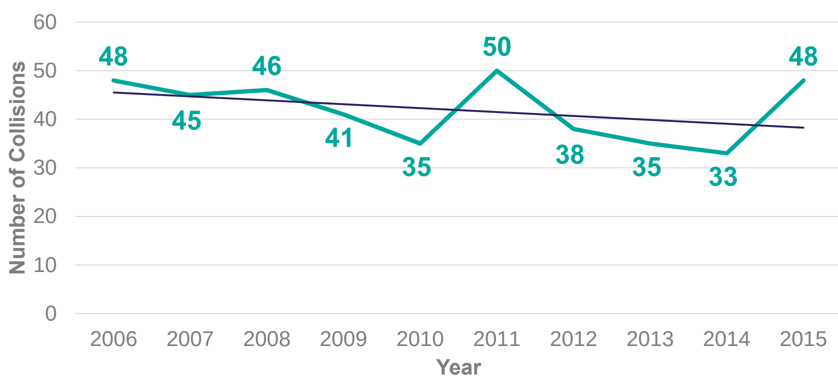
Overall Crash Trends (2006-2015)

Trends:

1. Severity of Collisions
2. Annual Bicycle Collisions with Motorists
3. Roads with Most Collisions
4. Time of Day that Collisions Occurred
5. Day of Week that Collisions Occurred
6. Age of Bicyclist Involved in Crash
7. Gender of Bicyclists Involved in Crash
8. Location of Collision
9. Traffic Controls at Collision Location
10. Weather Conditions at Time of Collisions

TOTAL	% OF ALL BIKE CRASHES	
2	0.5%	FATAL
56	13.4%	INCAPACITATING
263	62.8%	MINOR INJURY/ DAMAGE
80	19.1%	NO INJURY
18	4.3%	UNKOWN

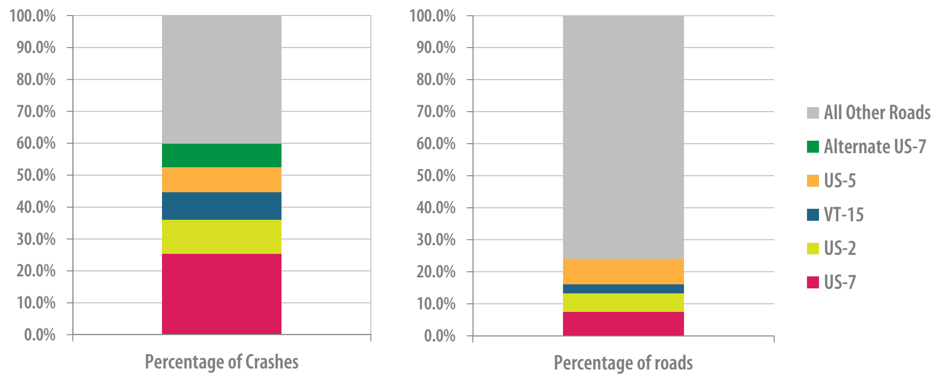
Annual Bicycle Collisions With Motorists



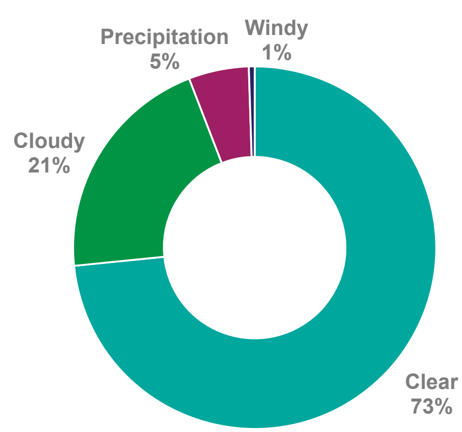
- On average, about 42 crashes have occurred per year
- The most crashes in a single year occurred in 2011, with 50 crashes
- The fewest crashes in a single year occurred in 2014, with 33 crashes
- Overall, crashes have been trending slightly down over the period studied

Roads with Most Collisions

About 60% of crashes occurred along the five roads identified in the charts below. These roads represent about 25% of the total miles of analysis roadways.

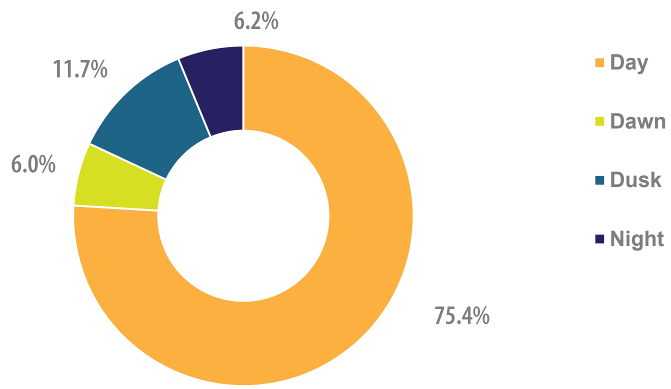


Weather Conditions at Time of Collisions

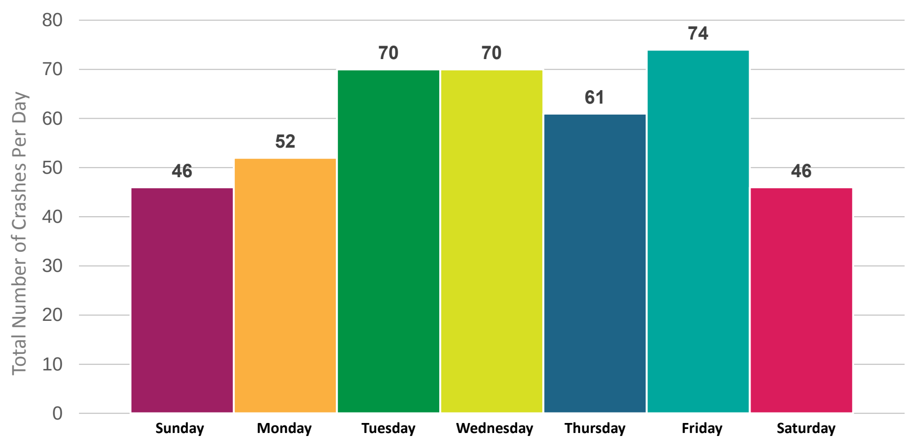


** For 6.7% of crashes, the weather condition was not noted in the crash report*

Time of Day that Collisions Occurred

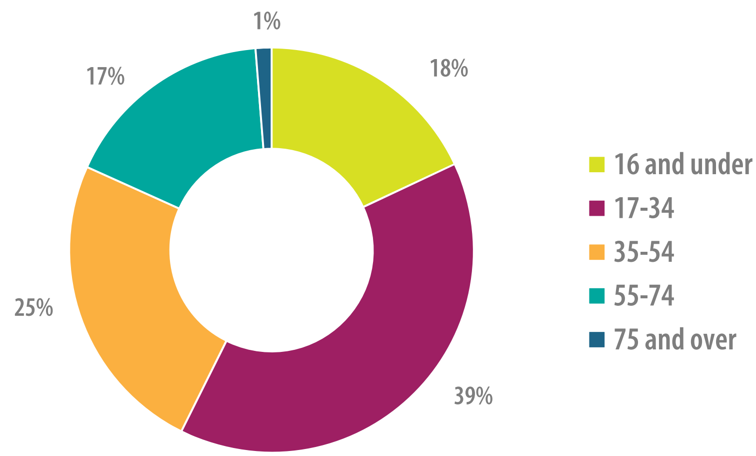


Day of Week that Collisions Occurred



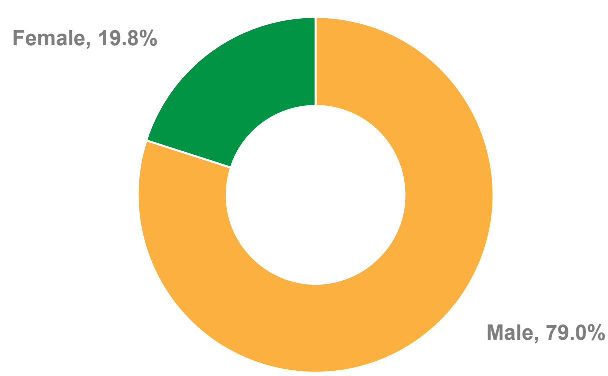
- The day with the most recorded crashes is Friday (74)
- Average of the weekday crashes = 65.4
- Average of the weekend crashes = 46

Age of Bicyclists Involved in Collision



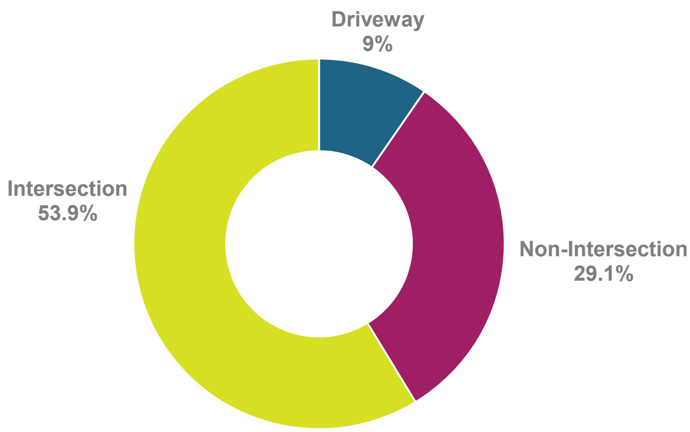
** For 6.0% of crashes, the age of the bicyclist was not noted in the crash report*

Gender of Bicyclists Involved in Collision



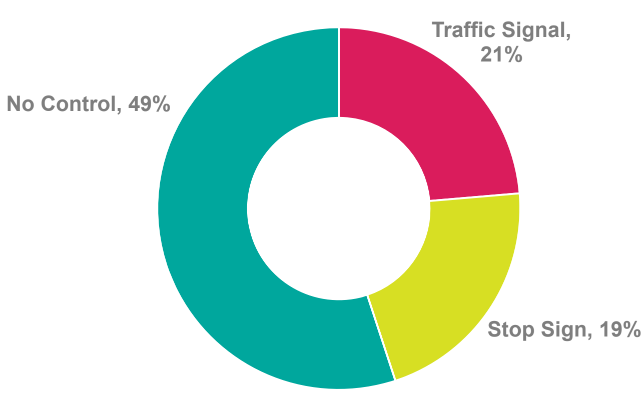
** For 1.2% of crashes, the gender of the bicyclist was not noted in the crash report*

Location of Collisions



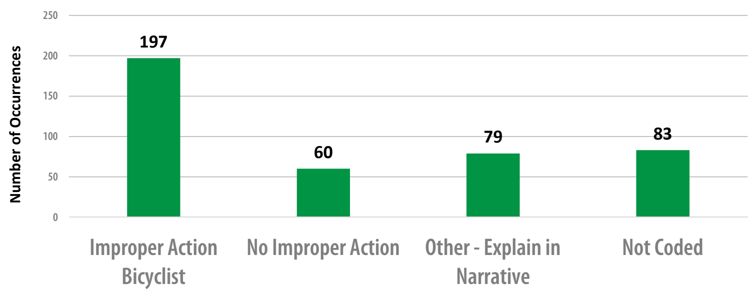
** For 8.1% of crashes, the location was unknown/not noted in the crash report*
Intersections included on-ramps, shared use path or trail, railway grade crossing, T-intersections, Y intersections, Four way intersections, traffic circle/roundabouts. Non-intersections were coded 'Not at a Junction' and Driveways were coded 'Driveways'

Traffic Controls at Collision Location



** For 11.2% of crashes, the presence/absence of a traffic control device was not coded in the crash report, or the traffic control device was a yield sign (4 crashes) or officer (2 crashes), or the type of intersection was explained in the narrative (14 crashes)*
Traffic signal includes Traffic Signal (normal operation), traffic signal (flashing), All-way flasher (red on cross street), all-way flasher (red on mainline); Stop Sign includes All-way stop signs, stop signs on cross street only, stop signs on main line only

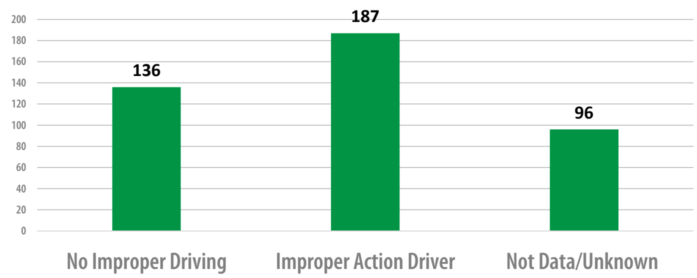
Bicyclist Action Preceding Crash



Top three most frequently reported Improper *Bicyclist* Actions:

- Improper Crossing (14.6%)
- Darting (8.1%)
- Failure to Yield Right of Way (6.9%)

Motorist Action Preceding Crash



Top three most frequently reported Improper *Driver* Actions:

- Failure to Yield Right of Way (16.2%)
- Inattention (11.9%)
- Visibility Obstructed (4.3%)

PHASE TWO

VTRANS ON-ROAD BICYCLE PLAN

APPENDIX B: CONTRIBUTING FACTORS ANALYSIS

Appendix B

The Planning Team has analyzed roadway design features associated with bicycle crash patterns for the Vermont On-Roads Bicycle Facilities project. This memorandum summarizes the methodology and describes the findings.

METHOD

This paper compares the prevalence of design factors in crashes involving bicycles with the factors' prevalence on the Vermont State roads network. For each crash, the Team associated roadway design factors to the crash. The Team also identified the prevalence of those design factors on the Vermont State road network. Comparing the prevalence of crashes for a particular design factor to its prevalence on the overall road network shows the relative influence particular design factors have on crash frequency. The specific design factors and their data source are identified in Tabl1 1. All data files were provided by VTrans.

TABLE 1: DESIGN FACTORS AND THEIR DATA LAYER (SOURCE: VTRANS)

Design Factor	Data File
Density	FAU_Boundaries_2014
Number of lanes	RoadWidth
Lane width	RoadWidth
Shoulder width	RoadWidth
Typical speed	Speed file from statewide regional model
Annualized Average Daily Traffic (AADT)	AADT_2015
Turn lane present	RoadWidth
Median type	RoadWidth

This methodology does not account for the number of bicycle riders on a segment nor the fact that an increase in the number of riders increases the exposure for crashes. For example, there may be more bicycles on the road in urban areas than rural areas, increasing the probability that a crash might occur in an urban area. Also, this methodology is not able to distinguish if higher crash rates result from other factors that could influence bicycle crash rates, such as the adjacent urban street scape or land use characteristics, and focuses exclusively on roadway design factors.

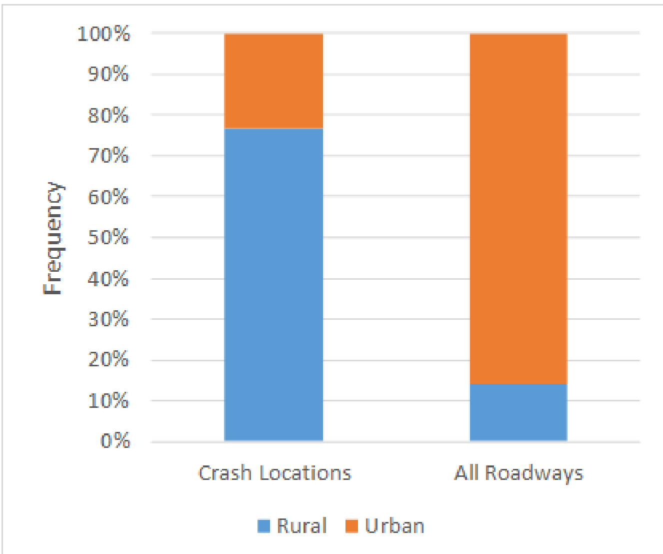
FINDINGS

For each factor, two stacked bar charts are displayed illustrating the frequency of crashes on the left and frequency of road miles in that category on the right.

Influence of Density on Bicycle Crashes

Figure 1 shows that most crashes happen in urban areas (77%) while most State roads in Vermont are in rural areas (86%).

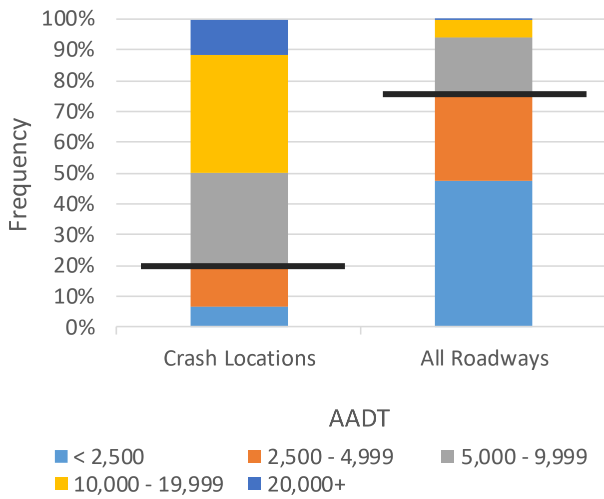
FIGURE 1: DENSITY



Influence of Traffic Volumes on Bicycle Crashes

As shown in Figure 2, roads with higher daily volumes (5,000 vehicles and above) are overrepresented in crashes. Roads with more than 5,000 vehicles per day account for 80% of crashes and 23% of road mileage. The presence of more vehicles increases the probability of bicycle-motor vehicle interactions.

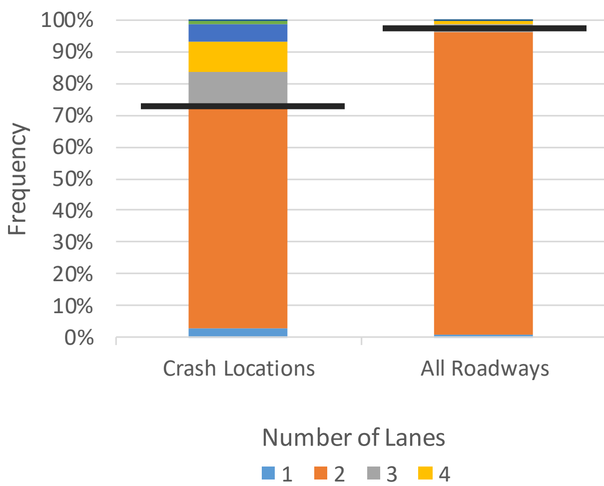
FIGURE 2: ANNUALIZED AVERAGE DAILY TRAFFIC (AADT)



Influence of Number of Lanes on Bicycle Crashes

Figure 3 indicates that roads with more than two lanes are overrepresented in crashes, accounting for 28% of crashes and 4% of road miles. More lanes are likely present where there is a higher vehicular volume.

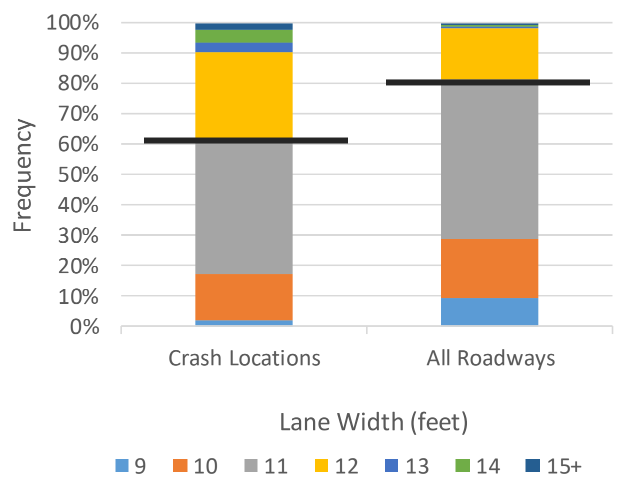
FIGURE 3: NUMBER OF LANES



Influence of Lane Width on Bicycle Crashes

Figure 4 shows lane width frequency in crashes and on roadways. Crashes are overrepresented on roads with 12-foot or wider lanes. Wider lanes likely are present where there are higher speeds or volumes.

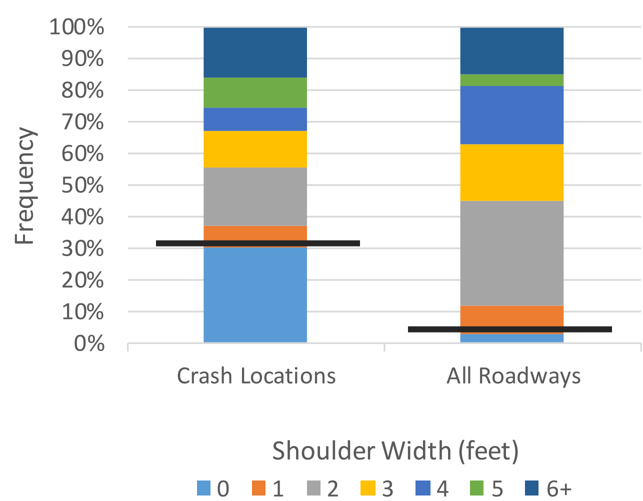
FIGURE 4: LANE WIDTH



Influence of Shoulder Width on Bicycle Crashes

Figure 5 shows shoulder width frequency in bicycle crashes and roadways. Roads without shoulders are overrepresented in crashes. Roads without shoulders comprise 30% of crashes and 3% of roads. Roads with shoulders five feet or more wide are also overrepresented.

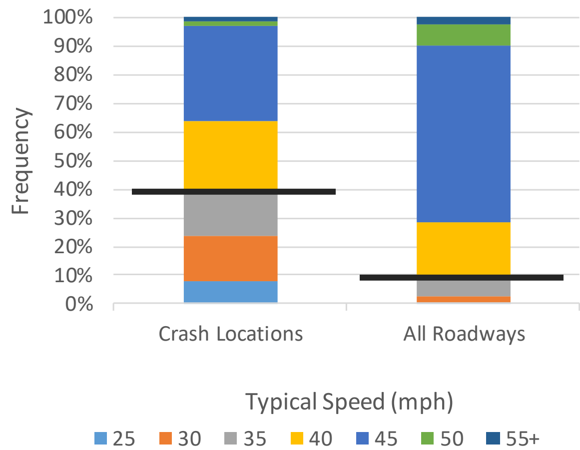
FIGURE 5: SHOULDER WIDTH



Influence of Speed on Bicycle Crashes

Typical speed is shown in Figure 6. Faster roads – 45 mph and above – are underrepresented in crashes, while slower roads – 35 mph and below – are overrepresented. This may be because more crashes occur in urban areas where roads tend to be slower and because cyclists prefer to ride on slower roads.

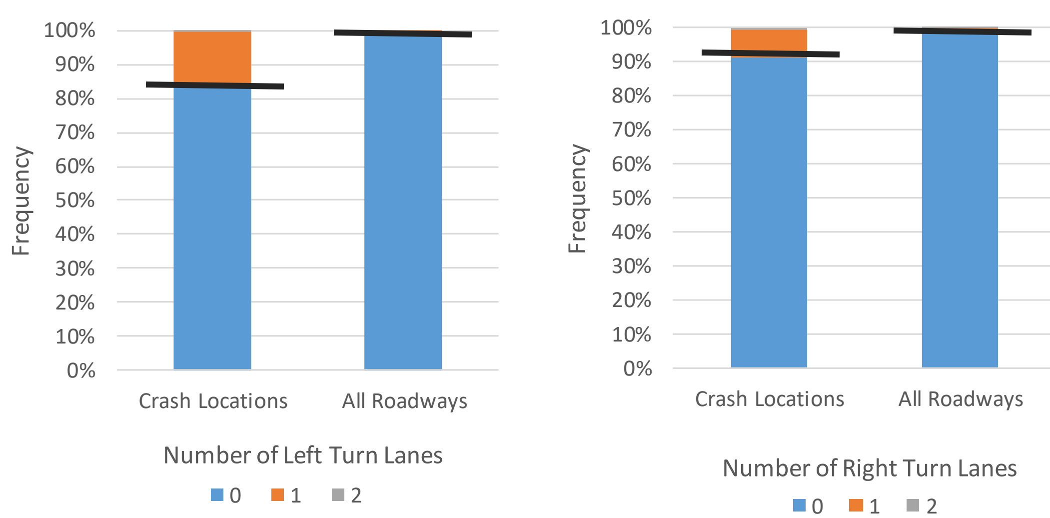
FIGURE 6: TYPICAL SPEED



Influence of Turn Lanes on Bicycle Crashes

Figure 7 shows the frequency of left and right turn lanes. Most road segments (about 99%) do not contain a turn lane. However, a significant number of crashes occurred on segments that contain a turn lane (16% and 8% on left and right crashes, respectively). It is not known if these crashes occurred in the turn lane or if they were on the same side of the road as the turn lane, only that they occurred on a road segment where a turn was present. The crash prevalence may be more a function of the number of vehicles at an intersection than the turn lane itself.

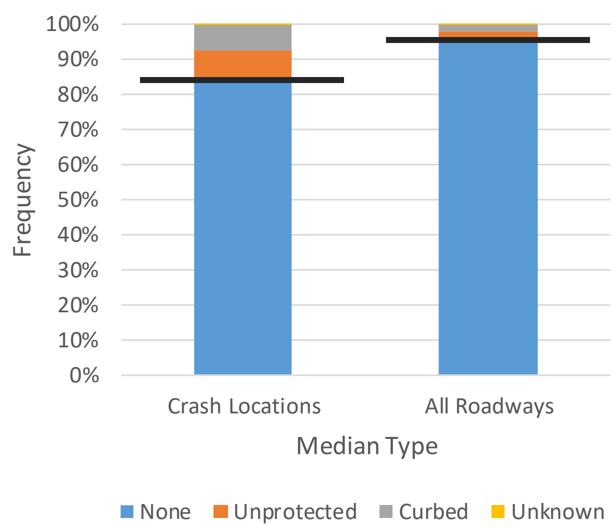
FIGURE 7: NUMBER OF TURN LANES



Influence of Presence of a Median on Bicycle Crashes

Median type frequency, shown in Figure 8, indicates that roads with some type of median are overrepresented in crashes – representing 15% of crashes and 4% of road miles. Since medians are often present on higher volume roads, the crashes may be related to the number of vehicles more than the median itself.

FIGURE 8: MEDIAN TYPE



SUMMARY OF RELEVANT FACTORS

Table 2 summarizes design factors where bicycle crashes are overrepresented. The factors with the highest contributions to crashes are urban areas and higher volume roads (5,000 vehicles or more per day). These are places with high potential for motor vehicle-bicycle interaction due to the higher prevalence of both modes. More than two lanes, lanes 12 feet or wider, and the presence of turn lanes are all overrepresented in crash prevalence. Similarly, crashes were more common on slower roads (35 mph or less), which tend to be in denser, urban areas and are more attractive to bicycles. Crashes were also overrepresented on roads with a median, which tend to be higher volume roads.

The presence of shoulders appears to have a significant impact on reducing crashes as crashes are more likely on roads without a shoulder. Roads with wider shoulders (5 feet and above) appear to have more crashes, but this may be a more a function of traffic volumes on these roads than the shoulders themselves.

TABLE 2: OVERREPRESENATION OF DESIGN FACTORS

Design Factor	Overrepresented in…
Density	Urban areas
Annualized Average Daily Traffic (AADT)	Higher volumes (5,000 vehicles or more per day)
Number of lanes	More than two lanes
Lane width	12 feet wide or more
Shoulder width	No shoulder present
Typical speed	Slower roads (35 mph or less)
Turn lane present	Presence of a turn lane
Median type	Presence of a median

PHASE TWO

VTRANS ON-ROAD BICYCLE PLAN

APPENDIX C: HOT SPOT LOCATION ANALYSIS

APPENDIX C

The Project Team determined 10 hot spots of bicycle crashes in Vermont – five in Chittenden Country and five outside it. In this memo, we describe each hotspot location and examine themes of the crashes and comments at each location. Crashes occurred between 2006 and 2015. Comments are from the crowdsourced interactive map effort as part of Phase 1 of this project. We note any road design factors that may be contributing to the crashes. Next, we describe general conclusions from the detailed crash analysis. Finally, we note general roadway design changes and specific engineering improvements that could improve bicycling conditions.

HOT SPOT SUMMARY

Hot spot locations within Chittenden County are numbered CC.1 to CC.5; locations outside are numbered OC.1 to OC.5. Table 1 summarizes these locations. The following sections describe each location, crash patterns at that location, and difficult biking comments at that location.

TABLE 1: HOT SPOT LOCATION SUMMARY

Hot Spot Locations						
#	City/Town	Road Name(s)	Length (mi)	# of Crashes	# of Votes	Average Use Score
CC.1	Burlington	Winooski Ave.	0.52	27	27	16.0
CC.2	South Burlington	Williston Rd.	0.51	9	74	16.1
CC.3	Essex Junction	Pearl St.	0.27	7	0	15.1
CC.4	Burlington	Riverside Ave.	0.41	9	16	17.1
CC.5	Burlington	Colchester Ave. Bridge	0.05	0	32	17.4
OC.1	Brattleboro	Main St.	0.08	4	0	13.4
OC.2	Rutland	State St.	0.12	3	0	10.3
OC.3	Bennington	North St. & Main St.	0.54	8	6	10.6
OC.4	Enosburg	Elm St.	0.17	2	0	8.9
OC.5	Castleton	VT 30	0.12	2	0	9.6

CC.1 - Winooski Avenue, Burlington

CC.1 is located on North and South Winooski Avenue. The section extends from Grant Street to King Street (Figure 1). The road is generally two lanes of vehicular traffic in each direction, but the northern portion (above Pearl Street) is one lane, one-way southbound with a dedicated bicycle lane.

Vehicular lane widths are approximately 10 feet in the four-lane sections, and there is no shoulder. Table 2 summarizes the location characteristics

FIGURE 1: CC.1 LOCATION - WINOOSKI AVENUE, BURLINGTON

TABLE 2: CC.1 - WINOOSKI AVENUE LOCATION CHARACTERISTICS

CC.1 - Winooski Avenue, Burlington	
Total crashes	27
Total Dif. Bicycling Location Votes	27
Average Use Score	16.0
Posted Speed (mph)	25
Typical Speed (mph)	35
AADT (vehicles/day)	3,600 - 13,000
Land Use	Urban, Mixed use
Vehicle Lane Width (ft)	10 - 12
Bicycle Lane Present	North of Pearl Street
Shoulder Width (feet)	None South of Pearl Street

The block north of Pearl Street to Grant street and the block south of Main Street to King Street contains parking on both side of the street. Most of the street abuts commercial land uses and parking areas, while the northern section above Pearl Street fronts on mostly residential lots. The distance between intersections is generally less than 0.1 miles, and curb cuts are frequent.

Of the 27 crashes recorded, 5 did not contain narrative information. Of the 22 crashes with officer narratives, about 60% involved the vehicle not seeing the bicyclist. Most of these crashes involved the car turning left (five crashes) or the vehicle and bicycle moving in crossing directions (six crashes). Three involved right-turn-on-red movements. About 30% involved the bicyclist not obeying the rules of the road. Three of the 22 crashes with narratives involved a bicyclist on the sidewalk or crosswalk, and in two cases the bicyclist did not have functioning brakes.

The comments and votes suggest this section feels uncomfortable for bicycling. Some comments advocate for protections for left turning bicyclists such as bike boxes, and others note the presence of pedestrians crossing the street "when they are not supposed to … makes it challenging for bikes and cars." One comment notes bicycles frequently disobey traffic laws in this location, running red lights or going the wrong way on the one-way section of the road. Another comment suggested this section of street should be a complete street.

Summary

A significant number of crashes involved bicyclist not obeying traffic laws, so increased education and enforcement, including about use of sidewalks for bicycles, may address some of the concerns in this section. The many curb cuts, four lanes of traffic, lack of bicycle lanes, and numerous intersections create a complicated traffic pattern for drivers and bicycle riders to navigate. Simplifying the road geometry by reducing travel lanes and curb cuts or adding protected space for bicycles could address the concerns in this section.

CC.2 - Williston Road, South Burlington

Hot spot CC.2 is located on Williston Road in South Burlington. This section extends from the bridge over I-89 to White Street (Figure 2). The road is generally two lanes in each direction, with two left-turn lanes on the westbound approach to the intersection with Dorset Street. Bicycle lanes are present on the bridge over I-89, but they do not continue east of the interchange. Land use in this area is mostly commercial and residential with one story retail fronting on the main line and residences on side streets. Table 3 summarizes the location characteristics.

TABLE 3: CC.2 - WILLISTON ROAD LOCATION CHARACTERISTICS

CC.2 - Williston Road, South Burlington	
Total crashes	9
Total Dif. Bicycling Location Votes	74
Average Use Score	16.1
Posted Speed (mph)	35
Typical Speed (mph)	40
AADT (vehicles/day)	24,000 - 37,000
Land Use	Mixed, Suburban
Vehicle Lane Width (ft)	11 - 12
Bicycle Lane Present	Only on Bridge
Shoulder Width (feet)	0 -3

FIGURE 2: CC.2 LOCATION - WILLISTON ROAD, SOUTH BURLINGTON

Of the nine crashes, five or six (the location of the bicycle was disputed in one of the crash narratives) involved a bicycle on the sidewalk or in a crosswalk. Two of these involved a vehicle leaving a driveway, and two involved a vehicle turning right. The others included a left-turning vehicle, the bicycle and vehicle moving in crossing directions, and a right-turn-on-red vehicle movement.

Comments on this section of Williston Road suggest it feels uncomfortable, and many comments also note it provides an important connection between the University, downtown, and South Burlington locations such as the airport and residences. One comment notes the shoulder is inadequate but the sidewalk will "destroy your bike." Another comment mentions the sharp swerve in the westbound travel lanes at the intersection with Dorset Street. When drivers do not see this swerve, they depart their lane unpredictably and risk colliding with a bicyclist.

Summary

The large number of bicycle crashes on the sidewalk suggests bicycle riders do not feel comfortable on the street or are unaware they are not permitted to ride on the sidewalk. Increased education could help drivers remember to look for people on bicycles and help bicycle riders understand sidewalks can be uncomfortable. The four travel lanes and two left-turn lanes at Dorset Street create a confusing traffic pattern for all users. In addition, the large vehicular volume exacerbates concerns for bicyclists. Dedicated space for bicyclists and frequent line striping to channelize drivers would address safety concerns at this location.

CC.3 - Pearl Street, Essex

Hot spot CC.3 is located on Pearl Street in Essex Junction proximate to the fair grounds. The section extends from Hillcrest Road to Willeys Court and consists of one travel lane in each direction and a center left-turn lane. A 1-foot shoulder is present proximate to the Essex Junction Shopping Center, and no shoulder is present to the east of it. Bicycle lanes begin at the west end of the Essex Junction Shopping Center and continue west. The land uses in the area are mostly single-story retail stores and shopping centers, and curb cuts are frequent. Additional locations characteristics are summarized in Table 4.

FIGURE 3: CC.3 LOCATION - PEARL STREET, ESSEX

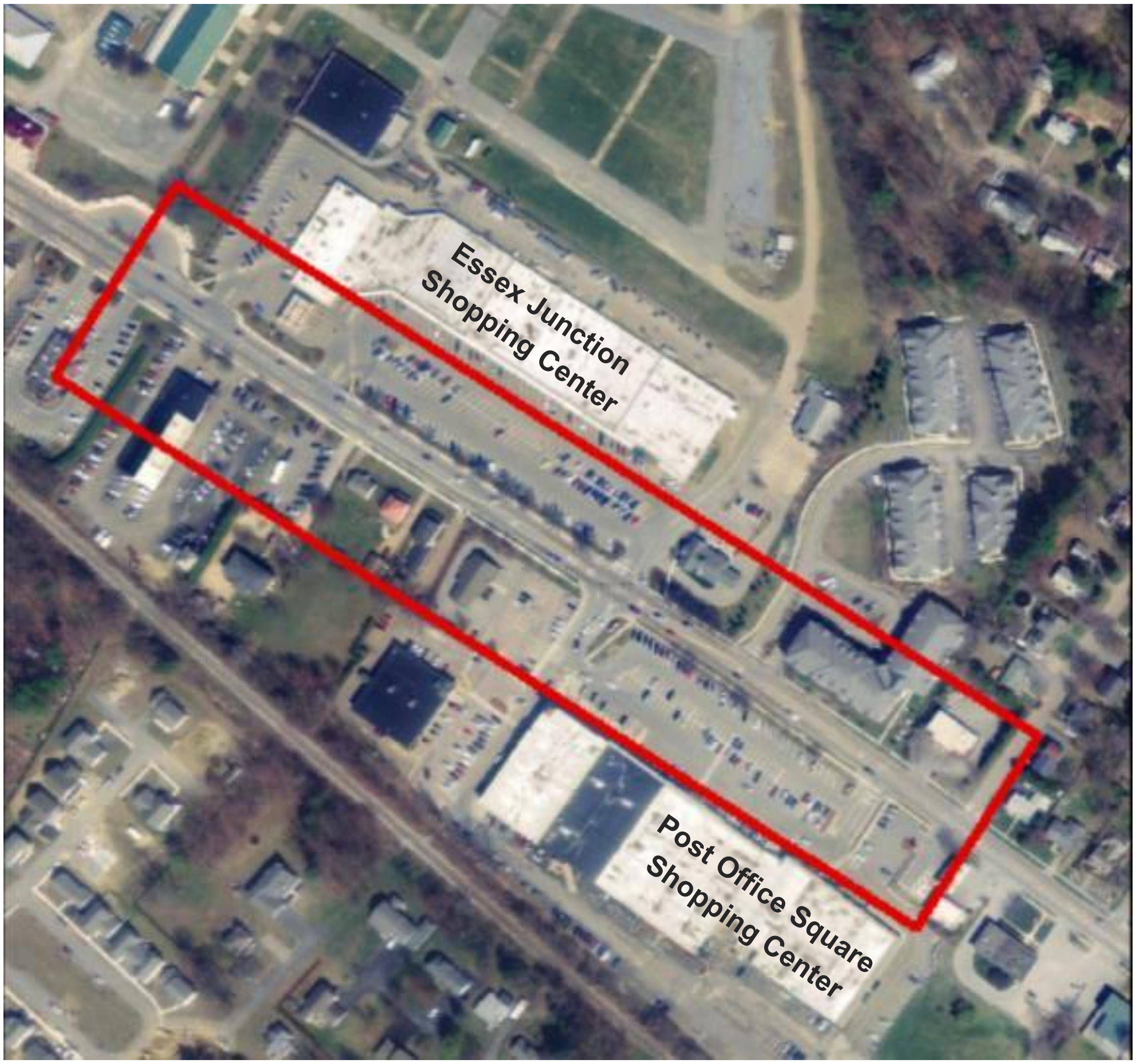


TABLE 4: CC.3 - PEARL STREET LOCATION CHARACTERISTICS

CC.3 - Pearl Street, Essex	
Total crashes	7
Total Dif. Bicycling Location Votes	0
Average Use Score	15.1
Posted Speed (mph)	25
Typical Speed (mph)	40
AADT (vehicles/day)	12,000 - 16,000
Land Use	Commercial, Suburban
Vehicle Lane Width (ft)	11-12
Bicycle Lane Present	Partial
Shoulder Width (feet)	0-1

Of the seven crashes, four involve a vehicle turning right into a driveway and colliding with a bicycle traveling in the same direction. Two crashes involve a vehicle turning and colliding with an oncoming bicycle, and one crash involves a right-turn-on-red. Two crashes involve a bicycle on the sidewalk or in a crosswalk.

There were no difficult bicycling location comments on this section from the crowdsourced interactive map.

Summary

Many crashes resulted from a driver not seeing a bicycle rider in the bicycle lane and turning into them. Increased education and enforcement could encourage bicycle riders and drivers to be more aware of who is around them and when they cannot be seen. Buffered bicycle lanes or green colored pavement to mark the conflict areas can provide increased visibility for bicycle riders, and reducing the number of curb cuts can reduce potential conflict points.

CC.4 - Riverside Avenue, Burlington

Hot spot CC.4 is located on Riverside Avenue in Burlington. The section extends from North Winooski Avenue to Hillside Terrace, and consists of one vehicular travel lane in each direction with left turn lanes at the intersections with North Prospect Street and with North Winooski Avenue. Bicycle lanes are present in the eastern half of the study area, and two-foot shoulders are present in the western half (Figure 4). The bicycle lane was installed prior to September 2008, but it is not clear exactly when. Two of the nine crashes in CC.4 occurred before September 2008, so it is not known if the bicycle lanes were present at the time of those crashes. Table 5 summarizes the location characteristics.

FIGURE 4: CC.4 LOCATION - RIVERSIDE AVENUE, BURLINGTON

TABLE 5: CC.4 - RIVERSIDE AVENUE LOCATION CHARACTERISTICS

CC.4 - Riverside Avenue, Burlington	
Total crashes	9
Total Dif. Bicycling Location Votes	16
Average Use Score	17.1
Posted Speed (mph)	25
Typical Speed (mph)	35
AADT (vehicles/day)	15,000
Land Use	Commercial, Suburban
Vehicle Lane Width (ft)	11-12
Bicycle Lane Present	Partial
Shoulder Width (feet)	2 (where no bicycle lane)

The crash narratives described the following:

- Nine total crashes, seven of which had officer narratives
- Five crashes (71% of crashes with narratives) involved a bicycle on the sidewalk or at a crosswalk

- Two crashes involved cars pulling out of driveways
- Two crashes involved right-turn-on-red movements

The comments focus on the difficulty of navigating the Riverside Avenue/North Winooski Avenue intersection on a bicycle and note the bicycle lanes do not carry through intersections.

Summary

Most crashes on this section of Riverside Avenue involve bicycles on the sidewalk. Bicycle riders and drivers do not expect to encounter each other in this context, so they are not looking for each other. Most of the bicycle crashes involving a sidewalk occurred where there is not a bicycle lane. Heightened education and enforcement may address this concern. Improving bicycle network connectivity would also address safety concerns at this location.

CC.5 - Colchester Avenue, Winooski River Bridge, Burlington

Hot spot CC.5 is located on the Colchester Avenue Bridge over the Winooski River in Burlington. The section extends from Winooski Falls Way to Riverside Avenue (Figure 5) and consists of two vehicular travel lanes in each direction with one of the southbound lanes becoming a right-turn lane at Riverside Avenue. Table 6 summarizes the location characteristics.

FIGURE 5: CC.5 LOCATION - COLCHESTER AVENUE BRIDGE, BURLINGTON

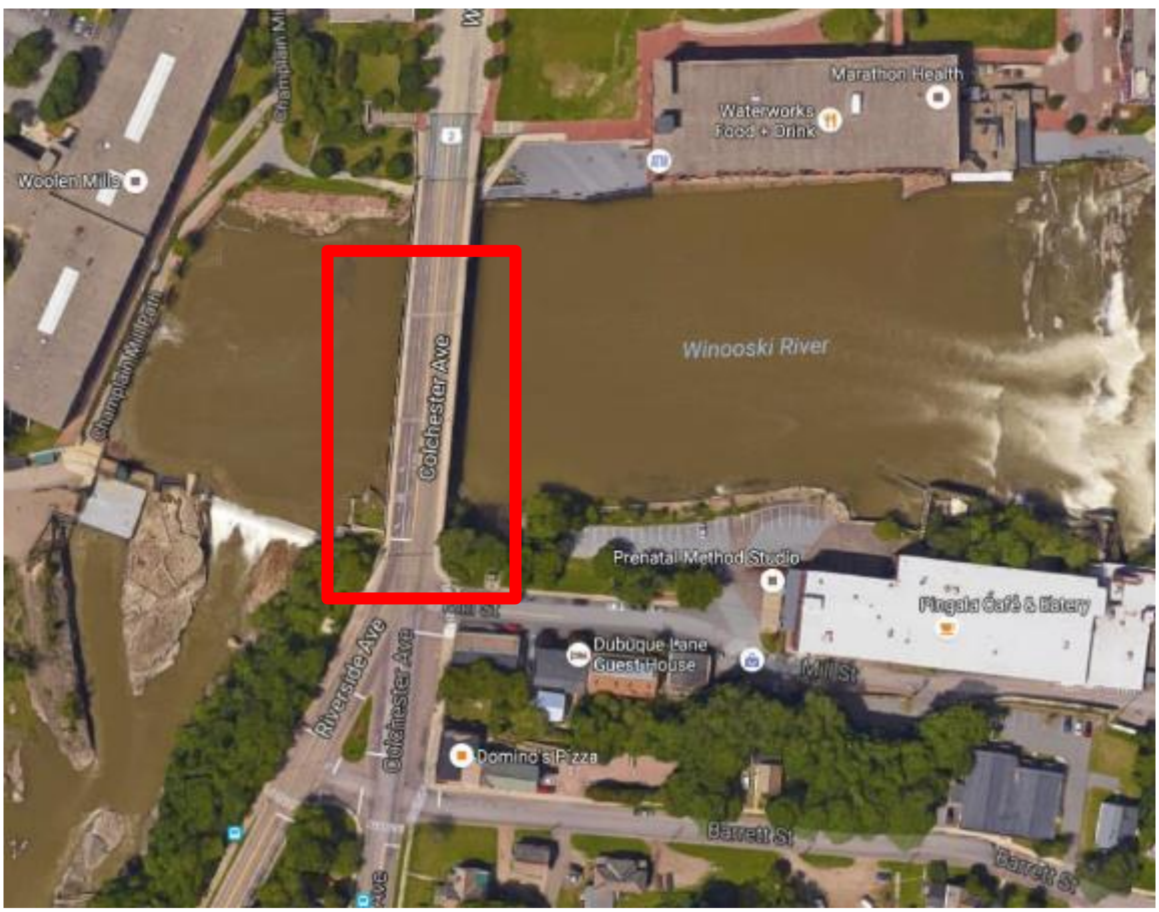


TABLE 6: CC.5 - COLCHESTER AVENUE BRIDGE LOCATION CHARACTERISTICS

CC.5 - Colchester Avenue Bridge, Burlington	
Total crashes	0
Total Dif. Bicycling Location Votes	32
Average Use Score	17.4
Posted Speed (mph)	25
Typical Speed (mph)	30-35
AADT (vehicles/day)	24,000
Land Use	Commercial, Urban
Vehicle Lane Width (ft)	10-14
Bicycle Lane Present	No
Shoulder Width (feet)	0

No crashes were documented at this location.

This location received many difficult bicycling location comments/votes on the crowdsourced interactive map. All comments noted the bridge is unsafe to cross on a bicycle, and many emphasized the need for bicycle lanes. Respondents also found the sidewalk on the bridge difficult to use due to poor maintenance, inadequate width, and difficulty getting back in the stream of traffic after they crossed. Respondents indicate this link is important due to its connection for commuters and the proximity of the bicycle path along the Winooski River.

Summary

Concerns at this location highlight the large number of vehicles moving in a constrained space, along with the many conflicting movements on either end of the bridge. Bicycles have trouble navigating with vehicular traffic and traveling between the vehicle lanes and the sidewalk. A dedicated space for bicycles would make it safer for cyclists to cross the bridge.

OC.1 - Main St., Brattleboro

Hot spot OC.1 is located on Main Street in Brattleboro. The section extends from High Street to Elliot Street (Figure 6) and consists of one vehicular travel lane in each direction with a right- or left-turn lane present at the intersections. On-street parking is present on both sides of the road. Table 7 summarizes the location characteristics.

FIGURE 6: OC.1 LOCATION - MAIN STREET, BRATTLEBORO

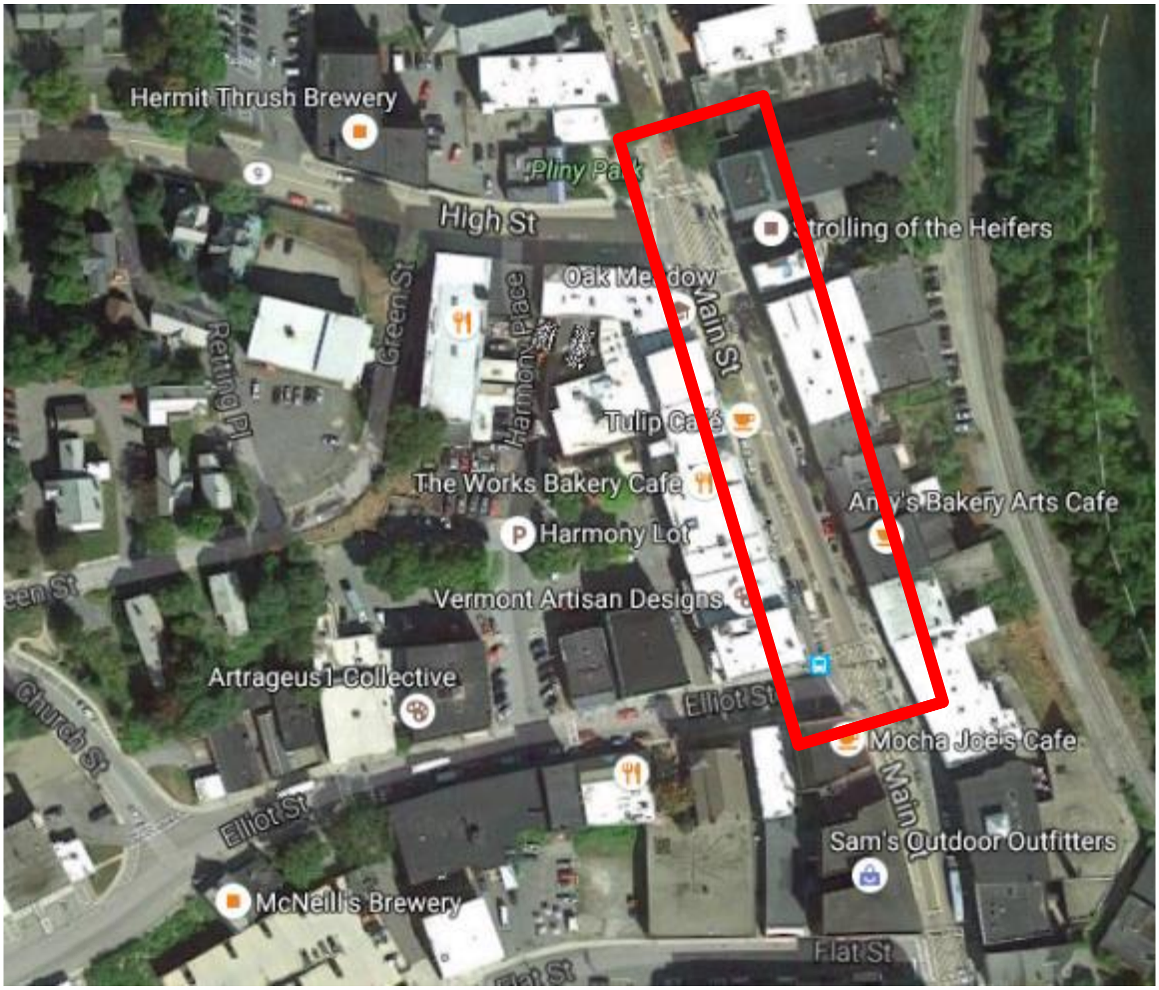


TABLE 7: OC.1 - MAIN STREET, BRATTLEBORO LOCATION CHARACTERISTICS

OC.1 - Main Street, Brattleboro	
Total crashes	4
Total Dif. Bicycling Location Votes	0
Average Use Score	13.4
Posted Speed (mph)	25
Typical Speed (mph)	40
AADT (vehicles/day)	8,000
Land Use	Mixed Use, Urban
Vehicle Lane Width (ft)	10-12
Bicycle Lane Present	No
Shoulder Width (feet)	0

The crash narratives described the following:

- Four crashes were reported, but one crash may have involved a pedestrian not a bicycle - the narrative was unclear

- The three bicycle crashes involved dooring by a parked pickup truck/SUV or a collision while the car was parking.

No comments were recorded for this segment.

Summary

The crashes reported here involve bicyclists conflicting with parked or parking vehicles. Because of the relatively narrow roadway width on Main Street, the only way to provide dedicated space for bicycle lanes would be the removal of parking along one side of the street or remove the dedicated turn lanes. Both will need to be studied very carefully in order to more-fully understand the impact to traffic circulation and access to businesses. A less intrusive solution would be to add shared lane markings outside of the door zone, but that may be unsatisfactory to many bicyclists.

OC.2 - State Street, Rutland

Hot spot OC.2 is located on State Street in Rutland. The section runs east-west from Pine Street to the east to Baxter Street to the west (Figure 7). The road is one lane of vehicular travel in each direction. On-street parking is present in both directions. Table 8 summarizes the location characteristics.

FIGURE 7: OC.2 LOCATION - STATE STREET, RUTLAND

TABLE 8: OC.2 - STATE STREET, RUTLAND LOCATION CHARACTERISTICS

OC.2 - State Street, Rutland	
Total crashes	3
Total Dif. Bicycling Location Votes	0
Average Use Score	10.3
Posted Speed (mph)	30
Typical Speed (mph)	45
AADT (vehicles/day)	5,400
Land Use	Mostly Residential
Vehicle Lane Width (ft)	12
Bicycle Lane Present	No
Shoulder Width (feet)	0

The crash narratives described the following:

- Three crashes involving a bicycle
- All crashes involved a bicycle on the sidewalk
- Two crashes involved a vehicle pulling out of a driveway
- Site distance past a building was a contributing factor for one crash

No comments were recorded for this segment.

Summary

All crashes involved bicycles on the sidewalk where bicycle riders may have a false perception of safety. Bicycles and cars do not expect to encounter each other in this context, so they are not looking for each other. Heightened education and enforcement may help. Providing dedicated space for bicycle riders can also address this concern.

OC.3 - North Street and Main Street, Bennington

Hot spot OC.3 is located on Main Street and North Street in Bennington. The section extends from County Street on North Street to Safford Street on Main Street (Figure 8). The roads consist of one vehicular travel lane in each direction. On-street parking is present on both sides of Main Street and is occasionally present on the southbound side of North Street. Table 9 summarizes the location characteristics.

FIGURE 8:OC.3 LOCATION - NORTH STREET AND MAIN STREET, BENNINGTON

TABLE 9: OC.3 - NORTH STREET AND MAIN STREET, BENNINGTON LOCATION CHARACTERISTICS

OC.3 - North Street & Main Street, Bennington	
Total crashes	8
Total Dif. Bicycling Location Votes	6
Average Use Score	10.6
Posted Speed (mph)	25
Typical Speed (mph)	45
AADT (vehicles/day)	9,000
Land Use	Urban, Mixed use
Vehicle Lane Width (ft)	11-14
Bicycle Lane Present	No
Shoulder Width (feet)	0-2

The crash narratives described the following:

- Eight crashes involving bicycles

- Two crashes were bicycles doored by parked cars, and one occurred as a car was parking
- Two crashes involved bicycles on the main line and drivers not seeing them as the cars crossed the main line.
- One crash involved a bicycle rider going the wrong way on one-way street Gage Street.
- One crash was at night, the bicycle had no light or working brakes, and the bicycle rider was not seen by the driver.

Summary

Crashes related to parked cars could be reduced with a buffer or a bicycle lane outside of the parking lane, or at the very least, shared lane markings to encourage bicyclists to ride outside of the door zone. There is not a clear pattern of the cause of the other five crashes, but all crash types would be addressed with dedicated space for bicycles.

OC.4 - Elm Street, Enosburg Falls

Hot spot OC.4 is located on Elm Street in Enosburg Falls. The section extends from VT 108 to Pleasant Street (Figure 9) and consists of one vehicular travel lane in each direction. Marked on-street parking is not present, but cars do park along the side of the road. Table 10 summarizes the location characteristics.

FIGURE 9: OC.4 LOCATION - ELM STREET, ENOSBURG FALLS

TABLE 10: OC.4 - ELM STREET, ENOSBURG FALLS LOCATION SUMMARY

OC.4 - Elm Street, Enosburg	
Total crashes	2
Total Dif. Bicycling Location Votes	0
Average Use Score	8.9
Posted Speed (mph)	25
Typical Speed (mph)	45
AADT (vehicles/day)	7,000
Land Use	Residential
Vehicle Lane Width (ft)	15
Bicycle Lane Present	No
Shoulder Width (feet)	0

The crash narratives described the following:

- Two crashes involving bicycles
- In one crash a bicycle rider was hit by a car departing a stop sign.
- In the other crash a child riding a bicycle was hit by a rolling tire that fell off a car.

No comments were recorded in this section.

Summary

No clear pattern emerges in the causes of these crashes.

OC.5 - VT 30, Castleton

Hot spot OC.5 is located on VT 30 in Castleton. The section extends from Taylor Road to Float Bridge Road (Figure 10) and consists of one vehicular travel lane in each direction. The shoulder is not adequate for on-street parking. Table 11 summarizes the location characteristics.

FIGURE 10: OC.5 LOCATION - VT 30, CASTLETON

TABLE 11: OC.5 - VT 30, CASTLETON LOCATION CHARACTERISTICS

OC.5 - VT 30, Castleton	
Total crashes	2
Total Dif. Bicycling Location Votes	0
Average Use Score	9.6
Posted Speed (mph)	50
Typical Speed (mph)	45
AADT (vehicles/day)	2,400
Land Use	Rural
Vehicle Lane Width (ft)	11
Bicycle Lane Present	No
Shoulder Width (feet)	2

The crash narratives described the following:

- Two crashes involving bicycles
- In one case a bicycle rider was hit by a car entering a driveway
- In the other case a bicycle rider was forced off the road by a truck and then collided with a motorcycle.

No comments were recorded in this section.

Summary

No clear pattern emerges in the causes of these crashes.

PHASE TWO

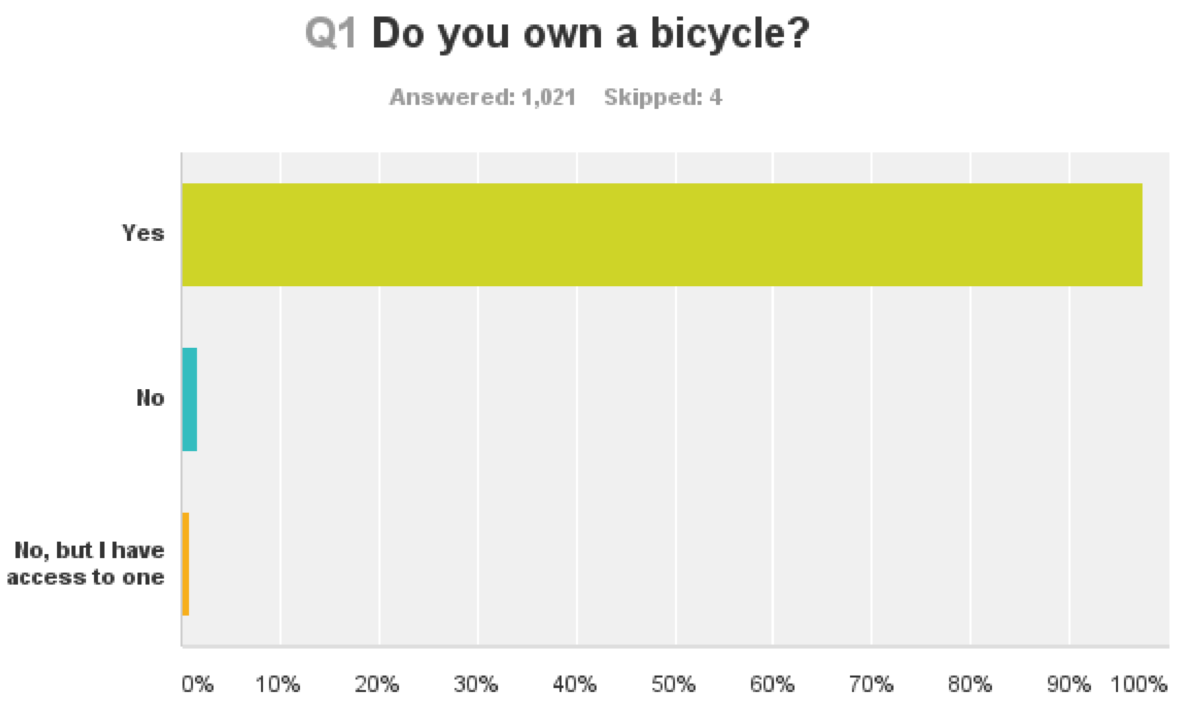
VTRANS ON-ROAD BICYCLE PLAN

APPENDIX D: SURVEY RESULTS

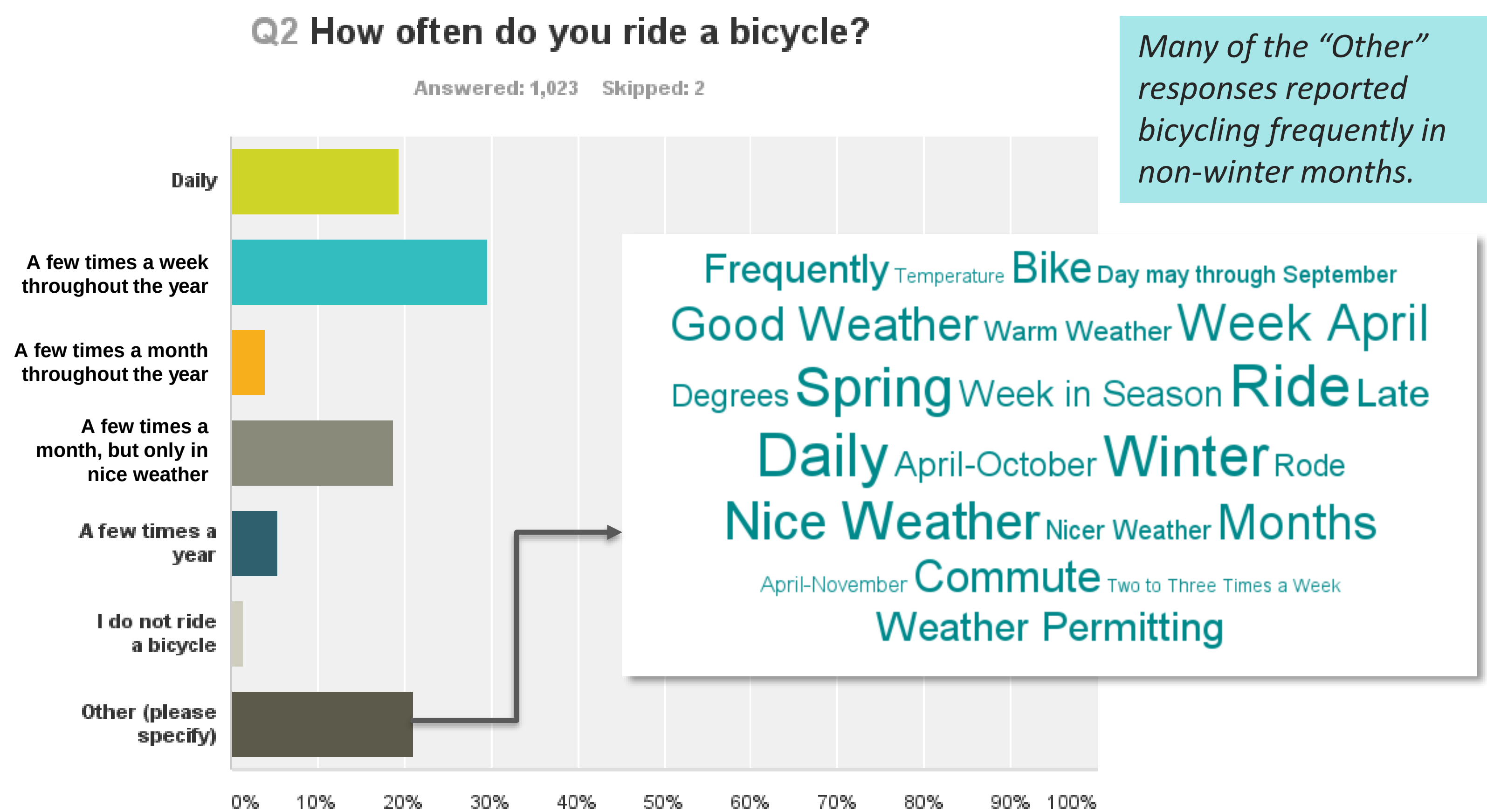
Survey Info

- Open February 9 – March 10, 2017
- 1,025 responses
- 7 questions + 2 demographic questions

Q1 Bicycle Ownership (multiple choice)

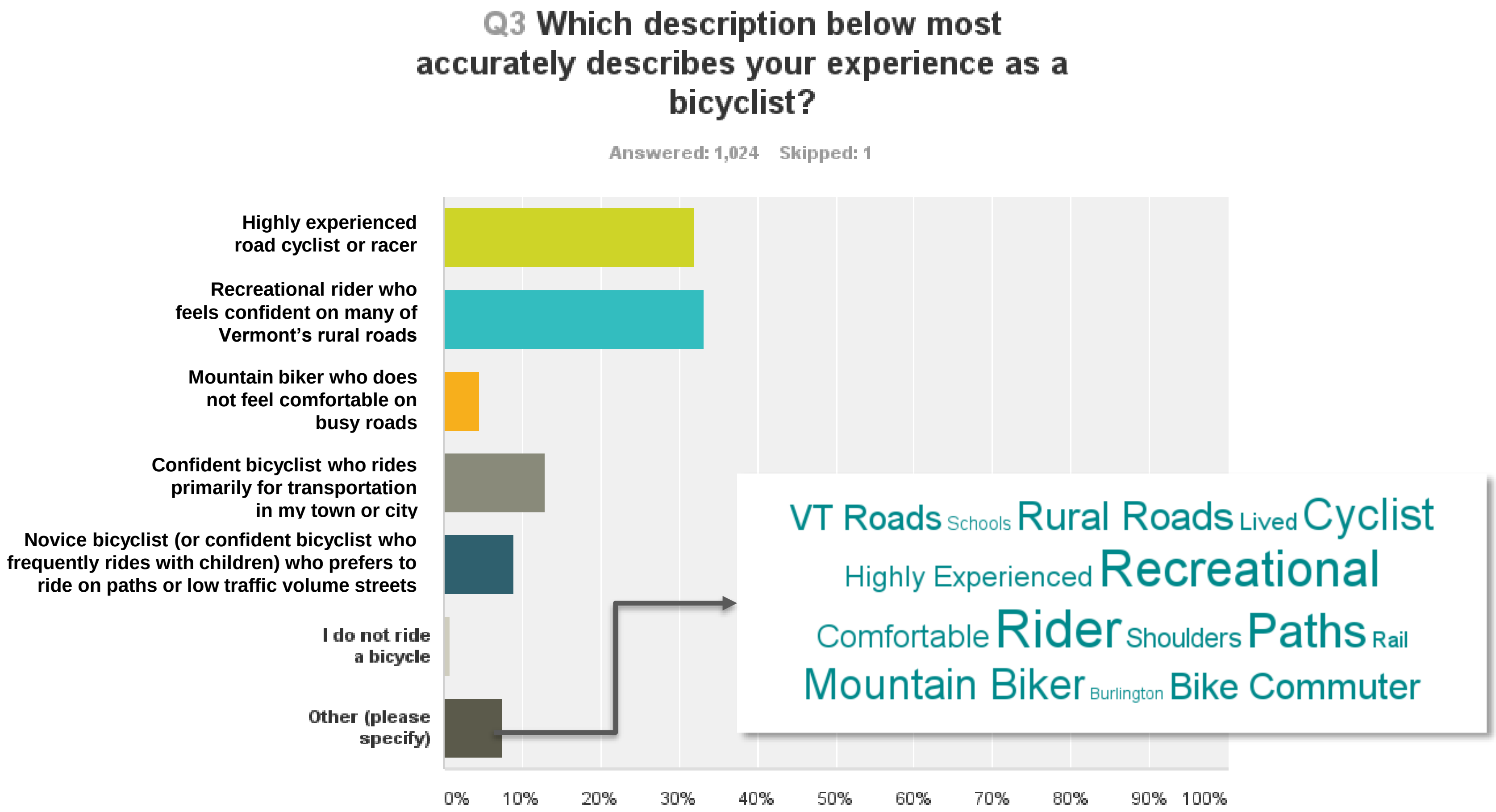


Q2 Frequency of Bicycle Riding (multiple choice)



Many of the "Other" responses reported bicycling frequently in non-winter months.

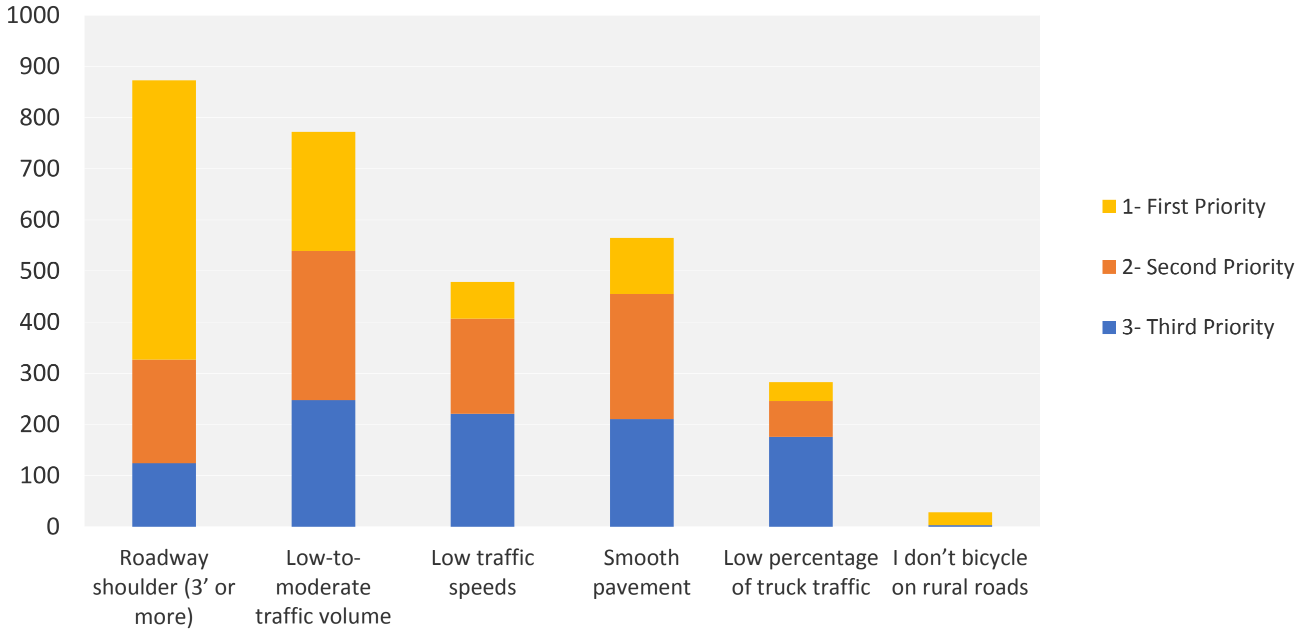
Q3 Bicyclist Experience (multiple choice)



Q4 Rural Roadway Safety Characteristics (priority)

Q4 When bicycling on rural roadways, please identify the top 3 road characteristics that make you feel comfortable riding (in order of priority).

Answered: 1,022 Skipped: 3



Q5 Rural Roadway Safety Characteristics (open response)

Q5 Are there other important rural road characteristics not listed above that impact your comfort level while bicycling? If so, please include them here:

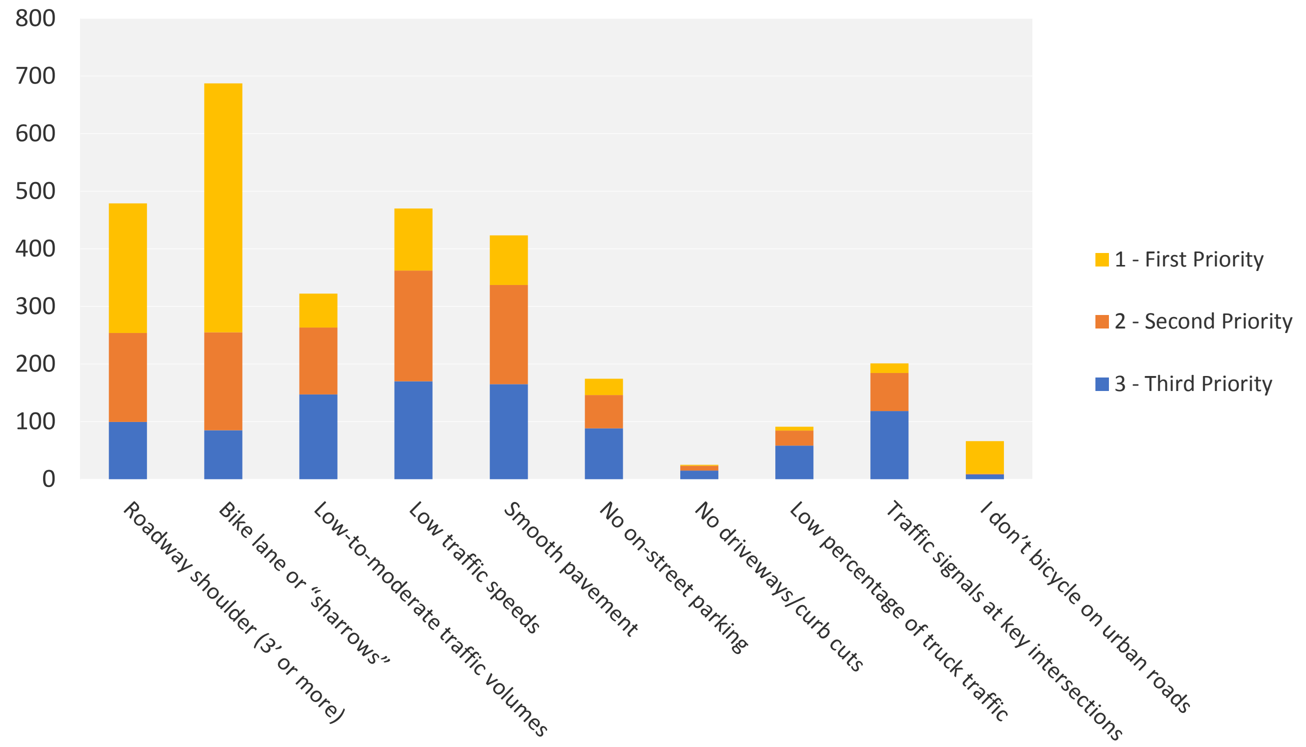
Answered: 447 Skipped: 578

Blind Corners Pull Rural Roads Turns Motorists
Road Surface Pot Holes Motor Vehicles Visibility
Sight Distances Lines Cycling Bike
Pavement Condition Shoulder Driveways
Drivers Intersections Speed Rough Route
Trees Share the Road Dogs Dirt Roads
Swept Free of Debris Bicycle

Q6 Downtown Roadway Safety Characteristics (priority)

Q6 When bicycling in downtowns, village centers and other populated areas, please identify the top 3 road characteristics that make you feel comfortable riding (in order of priority).

Answered: 1,022 Skipped: 3

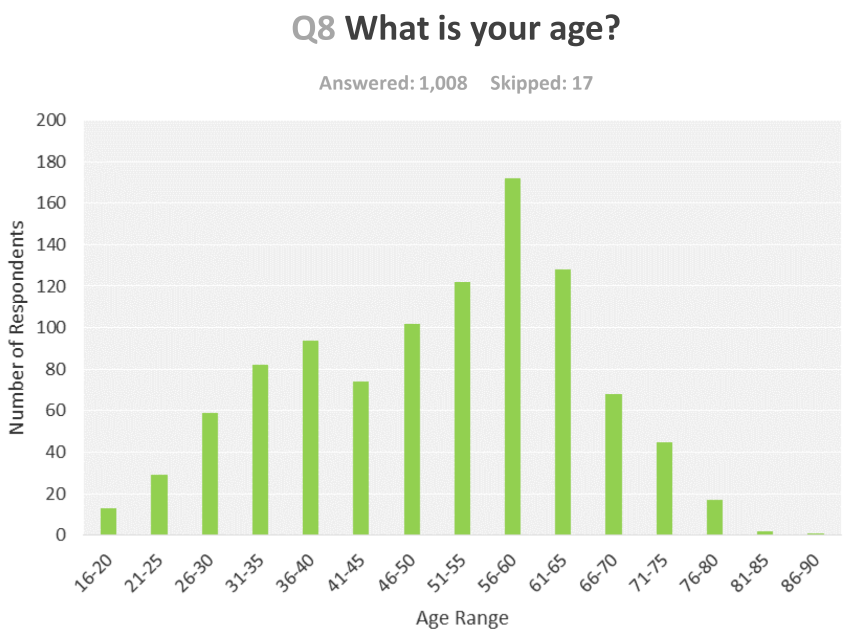


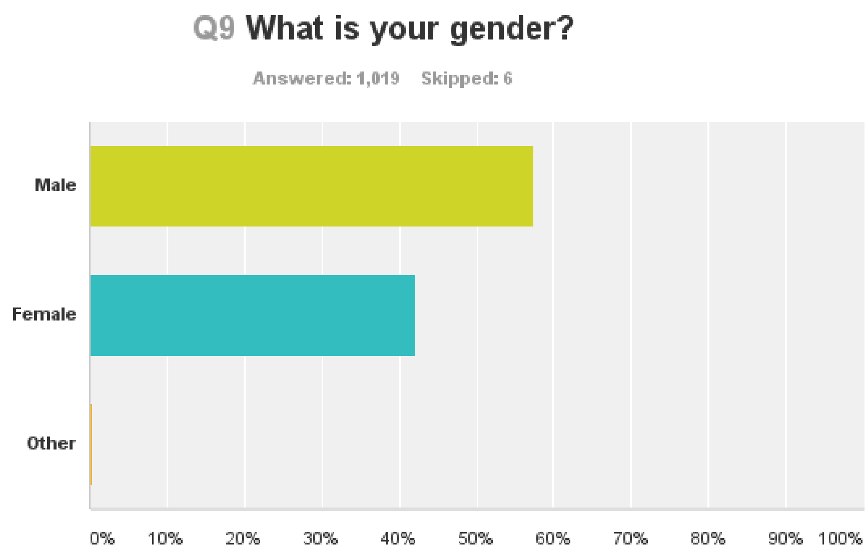
Q7 Downtown Roadway Safety Characteristics (open response)

Q7 Are there other important downtown and village center road characteristics that improve your comfort level while bicycling? If so, please include them here:

Answered: 384 Skipped: 641

Q8 Respondent Demographics





PHASE TWO

VTRANS ON-ROAD BICYCLE PLAN

APPENDIX E: CALIBRATING BLTS FOR VT

alta PLANNING + DESIGN

RSG

MEMO

TO: Sommer Bucossi
FROM: Erica Wygonik, PhD/PE; Isaac Old; Fletcher Passow
DATE: September 5, 2017
SUBJECT: Appendix E: Review of Rural BLTS Results using CDOT Method

1.0 INTRODUCTION

RSG conducted a review of the results from the Bicycle Level of Traffic Stress (BLTS) rural model to determine if the results match rider experience and to identify any factors that might benefit from adjustment.

2.0 METHODOLOGY

This assessment involved having staff who bicycle frequently in Vermont evaluate the roadways, and included two steps. First, the BLTS scores created from the CDOT Methodology for frequently ridden state roads were identified and compared to the experiences of the staff evaluators. The evaluators considered how less confident riders would feel riding along these segments as well.

Secondly, a more data-driven review of the state-wide BLTS scores was conducted. Road segments with various criteria were identified in GIS, and their scores examined. For example, all rural roads with daily traffic volumes of 1500 were identified and reviewed, then roads with daily traffic volumes of 1600, etc. Shoulder width and speed were similarly considered. The VTrans Crash Analysis results were evaluated as well to determine if roadway variables over-represented in crashes should influence the scoring table.

3.0 FINDINGS

Several roads (i.e. VT 73, VT 12 north of Woodstock, VT 116 between Middlebury and Bristol) are consider uncomfortable by even confident riders despite low traffic volumes. Reviewers found these roadways to be more stressful than the BLTS scores indicated. These roads have relatively narrow shoulders along with higher speed limits.

All reviewers identified speed as a factor that influences comfort levels in all roadway contexts. For example, the reviewers deemed VT 73 uncomfortable to ride, due exclusively to the speed limit which is as high as 50 mph in places. The reviewers determined that, in general, posted speeds of 40 mph seem to be the threshold for comfort. Even with low traffic volumes (>1,500 vpd), the perception of the reviewers is they are at higher exposure to risk when vehicles are driving at speeds greater than 40 mph.

The reviewers also evaluated the shoulder width categories included in the Rural BLTS scoring table. The reviewers found that the categories should be adjusted to better align with rider experience. The perception of the usefulness of shoulders surrounded their adequacy as a travel lane for bicyclists, or if they allowed adequate space to avoid encroaching vehicles. Reviewers suggested shoulders 0 – 3 feet wide would be generally unusable as a travel lane or space to avoid vehicles, shoulders 3 - 5 feet wide would be usable as a space to avoid vehicles, and 6+ feet would be usable as a travel lane and space to avoid vehicles. As roads with no shoulder are over-represented in the crash data, including a category for no shoulder usable is also recommended.

4.0 RECOMMENDATIONS

Based on the review of BLTS scores and associated input data, RSG suggests the following modifications be considered.

1) Speed should also be a factor for the rural BLTS model.
2) Paved shoulder width categories should be adjusted to 0-2', 2-3', 3-5', and 6' or greater.
3) The AADT categories that align with the reviewer experiences are 0-500, 500-1500, 1500-5000, and greater than 5000. Roads with over 5,000 vehicles per day are overrepresented in the crash data.
4) Traffic volumes above 7000 AADT should always be a "BLTS 4", except along roadways with wide shoulders (6ft or wider).