UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS

Final Report

PROJECT SPR 827

Oregon Department of Transportation

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by

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16. Abstract

Many cities in Oregon are requesting a comprehensive review of speed zoning guidelines and existing procedures for streets with high volumes of active travelers. The main goal of this research is to develop recommendations for alternate criteria for setting speed zones on roadways with a high percentage of active travelers. Literature pertaining to factors affecting operating speed, speed and safety, speed management, and current speed zone practices is reviewed. The selection of the site and performance criteria is discussed. Qualities and characteristics of the speed data utilized are given. Distinctions between neighborhood and non-neighborhood greenways are noted. A before and after analysis of speeds and hypothesis testing are performed. Factors affecting operating speeds are identified by linear correlation and regression analysis. The study finds a high degree of variability in the outcomes of Posted Speed limit (PSL) changes. However, PSL reductions are more likely to reduce speeds on neighborhood greenways, and motorized traffic volume and presence of a bike lane are key variables for predicting mean speeds.

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	Meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	Meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	millimeters squared	mm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	Hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	Liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
~NOTE: Volumes greater than 1000 L shall be shown in m^3.									
		MASS					**MASS**		
oz	ounces	28.35	Grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

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1.0 INTRODUCTION

Many cities in Oregon are requesting a comprehensive review of speed zoning guidelines and existing procedures for streets with high volumes of active travelers. Cities are proposing alternative speed zoning guidelines that are starkly different from existing guidelines based on the 85th percentile speed distribution. Existing methods must be reevaluated as well as the pros and cons of alternative procedures and criteria. Speed zoning guidelines should be balanced, reasonable, and provide safe speed zones for all users.

This report describes the research study efforts and presents the final results of the data analysis and recommendations pertaining to data collection efforts, analysis methods, and factors to consider when setting speed zones in urban areas with a high level of active travelers.

1.1 SPEED DEFINITIONS

This report includes many international references. Most of the research papers and references, even many from the US, do not distinguish among statutory speed limits, speed zoning, and posted speed limits. These terms are used loosely and interchangeably in most studies to indicate the speed limit that can be enforced at a given roadway or location.

1.1.1 Organization of the Report

This report is organized into seven chapters. Chapter two presents a summary of the literature review findings, focusing on factors influencing operating speed, current speed zone guidelines, the relationship between speed and safety, and speed management practices. Chapter three details the study site selection criteria and the data collection efforts. The data used within the study is summarized and performance measures are discussed. Chapter four presents an initial analysis of the data in which two distinct speed patterns are revealed for neighborhood greenway and non-neighborhood greenway streets. Chapter five covers a robust before and after analysis of the speed data, comparing performance metric averages and employing a series of hypothesis tests. A subset of the data is also evaluated under free-flow conditions only. Chapter six presents an analysis of factors affecting operating speed. Variable correlations and simple linear regression results are discussed. Chapter seven provides a summary and final recommendations.

2.0 LITERATURE REVIEW HIGHLIGHTS

This section presents a summary of the literature review. For a detailed review, the reader is referred to the literature review report (*Figliozzi et al., 2020*).

2.1 FACTORS INFLUENECING OPERATING SPEEDS

Many factors can potentially affect driver selection of operating speed. To facilitate the presentation of the research results, this chapter tries to divide them into distinct subsections. However, many factors are confounded, and the reader should note that some overlap among explanatory variable types in the following subsections is unavoidable.

2.1.1 Posted Speed Limit

Fitzpatrick et al. (2001) investigated the relationship between geometric, roadside, and traffic control variables and operating speed on four-lane suburban arterials with speed limits ranging from 30 to 45 mph in Texas. A total of 19 sites located on horizontal curves and 36 sites located on straight sections were selected for the study. Vehicle operating speeds at the 55 sites were collected using laser guns connected to laptop computers. The analysis of speeds at sites located on horizontal curves indicated that posted speed limit, deflection angle, and access density significantly affected operating speeds. For the straight sections, only posted speed limit was found to affect operating speed significantly.

Because posted speed limits are frequently based on the observed 85th percentile operating speed, there is some concern with using it as a variable in this type of analysis. To further study the relationship between the posted speed limit and operating speed, *Fitzpatrick et al. (2001)* analyzed the data without including the posted speed limit variable and it was found that the presence of medians and roadside development became significant variables for the horizontal curve sites. Lane width was the significant variable for the straight section sites. One additional meter (3.3 foot) in lane width is expected to increase the average operational speed by 15 km/h (9.4 mph). In all cases, stronger relationships were found by including the posted speed limit in the analysis.

Himes et al. (2013) also explored the impact of including and removing the posted speed limit as an independent variable to predict operating speeds. Vehicle operating speeds were collected on both urban and rural two-lane highways with mean posted speed limits and operational speeds between 65 and 70 mph in Pennsylvania and Virginia. Speed data was collected using on-pavement sensors at 79 locations. Posted speed limit explained eighty-two percent of the variation in operating speed. The authors of the research suggested that the posted speed limit should be included as an exogenous variable to reduce the bias of variables related to roadway geometry.

Islam et al. (2014) analyzed a case study in Edmonton, Canada where the posted speed limit was reduced from 50 km/h (30 mph) to 40 km/h (25 mph) in six urban, residential communities to study the effects of reducing the posted speed limit on vehicle speeds. A before and after method was chosen with the 'before' period as one month prior to the reduction and the 'after' period consisting of the following six months. Three communities with similar traffic and environmental conditions were chosen as control sites. Seven months of speed data were collected on a 24 hour-a-day and seven day-a-week basis using Vaisala Nu-Metrics Portable Traffic Analyzers, model NC200. Only vehicles in free-flow speed were used in the analysis. Free flow was defined as a headway of more than two seconds as Edmonton advises drivers to follow a two second headway rule under normal driving conditions. Weather data was matched to the speed data, and records during adverse weather were removed from the analysis. The overall result indicated lowering the posted speed limit was effective at reducing mean vehicle speeds (3.86 km/h [2.4 mph] and 4.88 km/h [3.03 mph] three- and six-months post-treatment, respectively). Mean speeds at untreated comparison sites showed a consistent increasing trend. Speed variance was also reduced for all combinations of time of day, day of the week, road classification, and vehicle type except for heavy vehicles. In terms of road class, speed limit reduction was found to be more effective in reducing vehicle speed on local roads than on collector roads. The posted speed limit reduction was accompanied by a variety of educational and enforcement measures such as media campaigns (TV, print, online, etc.), speed display boards, community speed programs. The results suggest that speed limit reductions plus integrated educational and enforcement activities are expected to reduce overall average speed and speed variability.

A before and after study conducted on vehicle speeds in Boston indicated the proportion of vehicles exceeding 25, 30, and 35 mph slightly decreased after the default speed limit was lowered from 30 mph to 25 mph beginning January 2017, although there were no significant changes in mean and 85th percentile speeds *(Hu & Cicchino, 2019)*. At comparison sites in Providence, where the speed limit did not change, proportions of vehicles exceeding 30 and 35 mph slightly increased during the study period. Posted speed limit signage was absent at all data collection sites, but the reduction in Boston had been publicized by a press release on several news outlets and various forms of advertisements during the first year.

Gargoum et al. (2016) used data collected over a five-year period from nearly 600 urban arterial and collector road segments with speed limits ranging from 20 to 50 mph in Edmonton to identify factors that affect operating speed and compliance with speed limits. Compliance was divided into five categories to help the model differentiate between vehicles violating speed limits by different margins since the City of Edmonton typically specifies a threshold of 10 or 15 km/h (6 or 9 mph) over the posted speed limit before issuing a citation. The categories ranged from fully compliant speeds to exceeding the posted speed limit by 20 km/h (12 mph) or more. Geographic and design features were recorded as well as posted speed limits. The results of the analysis showed a positive correlation between the posted speed limit and compliance levels. The presence of medians, significant on arterials only, increase the probability of a speed limit violation. Other factors such as the number of lanes and on-street parking were significant but had different signs for arterials and collectors. It should be noted that variables associated with educational efforts and enforcement activity were not considered in the analysis because the necessary datasets were not available.

A review of speed limit studies is presented by a meta-analysis of the relationship between changes in speed limit and changes in mean traffic speed *(Elvik 2012)*. From Figure 1 it is clear that a 10 km/h speed limit increase or decrease will not result, on average, in an average 10 km/h mean traffic speed increase or decrease respectively; on average the mean speed will be reduced approximately by 3 km/h and the mean speed will be increased approximately by 2 km/h respectively. There is a lot of variability around the fitted trend line.

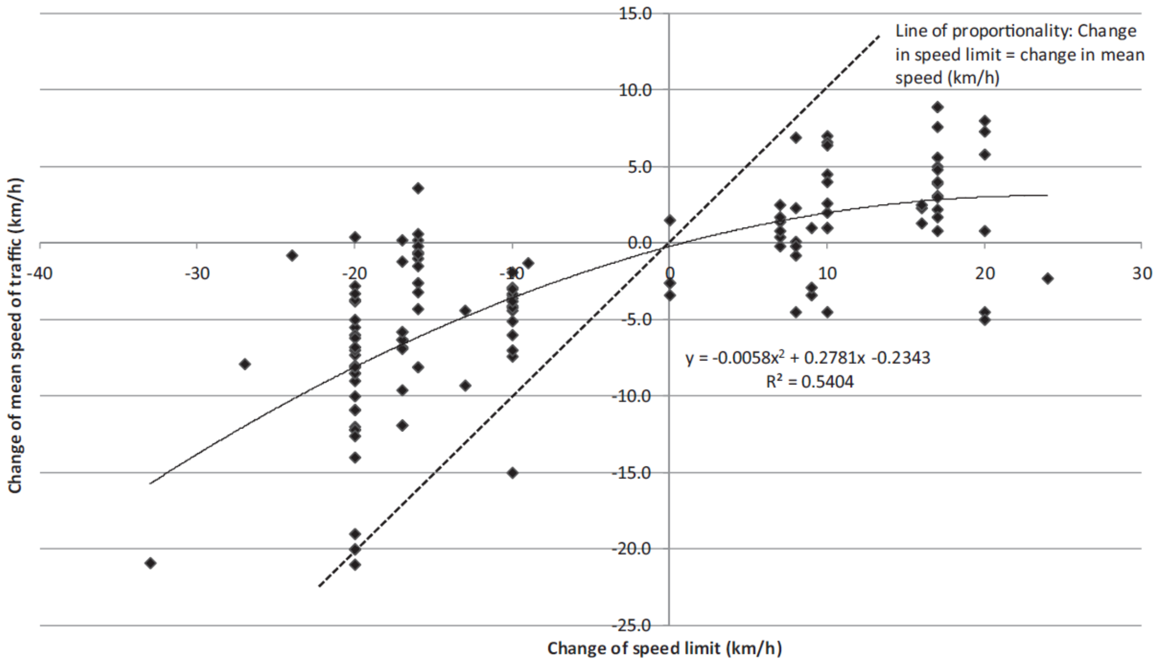

Figure 2.1: Effects of changes in the speed limit on the mean traffic speed (reproduced from *Elvik, 2012*)

2.1.2 Geometry and Roadside Characteristics

Controlling for speed limit allows the influence of street characteristics on driving speeds to be explored in more depth. *Dinh & Kubota (2013)* observed operating speeds on tangent sections of urban residential streets in Japan with a 30 km/h (20 mph) speed limit to develop models to predict 85th percentile and mean operating speeds. Using continuous speed data from STALKER ATS radar guns, 5359 individual speed profiles for 85 street sections were analyzed in relation to street alignment, cross-section variables, access density, roadside object density, and land use development. The length of the street section between two intersections and carriageway width were both found to positively correlate with mean and 85th percentile speeds. Roadside object density was found to be negatively correlated with speeds. Other significant variables with positive signs were the number of lanes and the presence of sidewalks.

Thiessen et al. (2017) attempted to explore relationships of road features and operating speeds for urban tangential road segments in Edmonton, Canada. A total of 249 arterial and collector road segments with speed limits of 40 to 100 km/h (25 to 62 mph) were analyzed. A Vaisala Nu-Metrics Portable Traffic Analyzer was used for the data collection, which occurred between 2009 and 2013. Only vehicles with a headway of 2 seconds or more were used for analysis. There was an average of 80,752.4 observations per site. The researchers found the effects of certain road elements differed between road classifications, and the two variables that stood out were median width and bus stops (positively correlated with arterials and negatively correlated with collectors). The posted speed limit was significantly positively associated with operating speed for both the arterial only model and the combined arterial and collector model. Roadside treatment (as a localized proxy for land use) was found statistically significant in the collector only model with low density areas experiencing the highest operating speeds. Sidewalks that were farther away from the road were associated with higher operating speeds. Segments with monolithic sidewalks on both sides of the road were associated with lower operating speeds. Pedestrian crossings were associated with lower operating speeds, and the presence of bike lanes correlated to higher operating speeds in the combined model. Operating speeds also seemed to decrease as access density increased while longer segments were associated with higher operating speeds.

In addition to the posted speed limit, *Gargoum et al. (2016)* also tested the effects of land usage; vertical and horizontal alignment; the presence of medians, shoulders, bus stops, and bike lanes; how many sides of the road had parking; and the number of lanes on speed limit compliance. Increased number of lanes and parking were found to positively correlate with speed limit compliance on arterial roads and negatively correlate with compliance levels on collector roads. The presence of vertical alignments, medians, and shoulders were negatively associated with compliance for both road classifications. Land use was also found to affect compliance with industrial areas seeing lower levels than residential for collector roads. For arterial roads, commercial and agricultural areas had lower levels of compliance than direct control areas.

Speed dispersion is also an important consideration when setting reasonable and safe speed limits. *Bassani et al. (2014)* sought to explore the relationships between geometric variables, mean speed, and speed dispersion on urban arterial and collector roads with speed limits of 30 to 70 km/h (20-45 mph) in northern Italy. Data was collected using a laser speed gun and high-speed digital video from each lane of 16 different road sections. Of the variables considered, lane position and number of traveled ways influenced mean speed the most. Speed dispersion was increased by the presence and width of shoulders, the presence of bus and taxi lanes, traffic calming devices, and parking lanes. The presence of sidewalks and pedestrian crossings made a significant contribution to a reduction in speed dispersion.

While most research conducted has focused on predicting mean or 85th percentile speeds, a more holistic picture can be seen by disaggregating the data and examining the distribution of speeds throughout specified speed categories. *Eluru et al. (2013)* estimated models for speed distribution profiles of urban local and arterial roads where speed limits ranged from 40 to 50 km/h (25 to 30 mph) in Montreal. Speed and volume hourly data were collected using traffic sensors for the 49 local roads and 71 arterials analyzed. Results indicated the number of lanes increased the proportion of vehicles in higher speed categories for both local roads and arterials. Speed distributions on local roads were negatively correlated with the presence of parking and positively correlated with both the number of sidewalks present and the presence of bicycle routes.

Table 2.1, at the end of this chapter, summarizes the factors found to influence operating speeds. The direction of the arrow indicates the direction of correlation. Variables indicated with * were found to be significant only when excluding the posted speed limit from the model. Also, of note, *Bassani et al. (2014)* studied how the selected variables affected speed dispersion instead of their direct effects on speed, and *Gargoum et al. (2016)* examined the selected variables' effects on speed limit compliance.

2.1.3 Environmental Variables

Along with geometric features and road characteristics, road safety and operating speed can be influenced by lighting conditions. *Bassani et al. (2016)* modeled speed distributions according to sunny, cloudy, and night-time lighting conditions of urban arterial roadways where speed limits ranged from 50 to 70 km/h (30 to 45 mph) in northern Italy. Vehicle speeds were measured using laser speed guns and video cameras. Vehicle-mounted photometers measured luminance from a driver's perspective, and a lux meter was utilized to measure the illuminance of the road surface. An increase in illuminance was found to increase the average value of speed distribution and deviation from mean speed in all lighting conditions. Deviations of mean speed were greatest during night-time conditions.

Sadia et al. (2018) used Structural Equations Modeling (SEM) to relate environmental, driver, and situational characteristics to driving speed. Data was collected through a combination of stated-preference surveys and driving simulations by 111 drivers. Four different situational risk/benefit scenarios were presented to each driver before they drove the simulator on four randomly selected road scenes, of which there were eight in total. The scenarios included an ordinary daily trip, a trip on a road with a high risk of enforcement, a trip on a road with known high crash risk, and a trip in which the driver was running late for an important meeting. Driver characteristics were collected via the survey after the drivers completed their four simulated trips. Three models were estimated as follows:

- The driver-level analysis measured the effects of gender, age, and driving frequency on the latent variables of technical aversion (how drivers perceive technical tasks related to vehicle operation and maintenance), risk awareness, law awareness, and skills-safety gap (the gap between a driver's self-assessment of driving skills and their self-proclaimed driving habits). Female gender affected all latent variables such that they reduced the average and/or standard deviation of driving speed. Age over 40 reduced average speed through the risk awareness variable. High driving frequency increased average driving speed directly and increased both average driving speed and standard deviation through the skills-safety gap variable.

- The trip-level analysis added risk/benefit, design speed (which was set to either 80 or 100 km/h [50 to 60 mph]), and interaction variables (between gender, age, and the number of trials completed by the driver) to those variables in the driver-level model. The risk/benefit scenarios were combined into a single latent category called Lower Speed Incentives. The crash risk and enforcement scenarios lowered the average and standard deviation of speed through the risk/benefit variable while the time-saving scenario had the opposite effect. A lower design speed reduced both average speed and its standard deviation. Being a female over 40 years of age reduced average driving speed, but this effect was reduced with progressive trials.

- The segment-level analysis added an environmental speed perception (ESP) variable to the trip-level model. Horizontal curves and increased longitudinal slopes were associated with a reduction in the value of the ESP variable. Presence of a 90 km/h (56 mph) speed limit sign decreased the ESP value, but not by a substantial amount. Driving speed of either 90 or 110 km/h (56 or 68 mph) by the surrounding simulated traffic increased the ESP value. Higher ESP values increased the average driving speed but reduced the standard deviation.

The goodness-of-fit comparison of models showed the driver-level model was within acceptable standards, but the trip and segment level goodness-of-fit indicators were below expectations.

2.2 CURRENT SPEED ZONE GUIDELINES

Current US speed zone guidelines are predominantly based on statutory guidelines or by conducting an engineering study utilizing the 85th percentile of vehicles operating speeds and sometimes other factors. Current procedures are well established and widely used. Reviews of guidelines set forth by the FHWA and the states of California, Massachusetts, and New York reveal adjustments as much as ten mph below the 85th percentile speed may be allowed. Adjustments are usually granted for areas with higher than average crash rates attributed to speeding, geometric constraints, high driveway or access density, or a high potential for encountering an active traveler. Unlike guidelines from other jurisdictions, Oregon guidelines indicate that other factors such as pedestrian and bicycle movements, type and density of adjacent land use, enforcement, crash history, public testimony, traffic volumes, number of accesses will be considered in the engineering study.

When conducting an engineering study, the general consensus among states is to use spot speed data to calculate prevailing speed parameters. Laser and radar guns, pneumatic tubes, and on-road sensors are the most commonly used tools to collect speed data. Continuous speed data collection methods include radar guns connected to laptop computers and vehicle-based devices such as mobile phones and GPS units. Data collection guidelines predominantly recommend a minimum of 100 observations taken in ideal weather conditions during off-peak hours while avoiding times during weekends, holidays, or special events. Geometric, road, and roadside characteristics are often recorded by conducting site visits.

Setting the speed limit near the 85th percentile can improve compliance and reduce the burden of enforcement, but the literature review indicates that there can also be unintended consequences. These unintended consequences can be summarized as follows:

a) Operating speeds may spiral up, e.g., increasing speed limits can increase operating speeds which in turn results in an increment of the 85th percentile of operating speeds,

b) Increases in speed limits can result in increases in crash frequency and crash severity along the modified speed zone, and

c) The 85th percentile of the operating speed does not directly account for the presence of active users, and some jurisdictions do not mandate the analysis of additional factors.

It is important to highlight that ODOT has recently published in May 2020 a new speed zone manual where the emphasis is on safety and indicates that in urban areas, the 50th percentile speed may be more appropriate. In addition, the new ODOT speed zone manual takes into account the functional class and context (roadside development) of the section in urban areas to better balance drivers and community perceptions of reasonable and safe operating speeds (*ODOT, 2020*).

2.3 SAFETY AND SPEED

The factors that affect operating speeds are usually confounded, which hinders the estimation of individual impacts. Furthermore, the relationship between urban traffic and crashes is more complex in urban areas than in rural highways *(Cameron and Elvik, 2010)*. However, it is widely accepted that there is a positive relationship, albeit a complex one, between speed and crash frequency; higher speed is positively correlated with higher crash frequency at a segment level. At a network or area-wide level, the relationship between speed and crash frequency is likely to be more complicated due to potential traffic diversion and speed spillover effects.

Regarding active users, there is evidence of a positively correlated relationship between speed and injury severity, although the magnitude and shape of such a relationship may differ across studies. Unfortunately, crash datasets do not report the actual speeds of motorized vehicles and active users at the time of a crash. However, based on the laws of physics and the changes in kinetic energy when a crash between a motorized vehicle and a vulnerable user takes place, this relationship can be safely assumed to be a causal relationship.

There are many studies reporting crash changes in relation to changes in posted speed limits, but the vast majority of the studies analyze motorized vehicle crashes. Extensive literature pertaining to the effects of speed limit changes on crashes involving active users in urban areas is lacking. More research is needed to better understand the impacts of traffic speed management in relation to pedestrian safety and the effectiveness of new comprehensive safety programs like Vision Zero *(Sanders et al., 2019)*.

2.4 SPEED MANAGEMENT

In recent years there is a consensus in many countries towards thinking about speed limits not at a segment level or in isolation but rather as one component of a holistic speed management system. A speed management system should encompass not only posted speed limits at the network or area level but also related aspects of the engineering design, traffic safety, enforcement, education, and emergency services. Speed management should be considered an ongoing and continuous endeavor that also requires interagency coordination *(OECD, 2006)*.

Roadway design can be utilized to affect operating speeds. The number of lanes as well as posted speed limit were commonly positively correlated with increased operating speeds. At the same time, the presence of parking or sidewalks produced mixed results within the studies examined. Other characteristics examined in the reviewed research included lighting conditions; adjacent land use; the presence of medians, shoulders, or crosswalks; roadside object density; and segment length. Speed management tools also include traffic calming treatments, which are typically applied to local or collector streets. Vertical treatments such as speed humps or raised crosswalks have been found effective at reducing motorized vehicle speeds and volumes. Lane width reductions, road diets, gateway treatments, and roundabouts or traffic circles are also common countermeasures.

The perceived credibility of speed limits, social influence, and personal biases were found to affect levels of support and speed limit compliance. Targeted social campaigns may help increase support and compliance when posted speed limits are reduced. Enforcement, including automated speed or red signal cameras, is another effective and common countermeasure.

Successful speed limit reductions often require simultaneous engineering design changes, educational campaigns, and increased enforcement. Successful interventions can be measured by the convergence of operational speeds towards design speed and speed limits. The convergence of operational speeds requires changes in both mean traffic speeds and speed variability. While speed limits are the most common method for managing speeds *(NHTSA, 2014)*, the literature review indicates that speed limits alone are usually not sufficient to effectively control operating speeds *(NTSB, 2017; AAA, 2018; Kallberg et al., 1999)*.

2.5 DATA-DRIVEN APPROACHES

Some crash studies do not take into account exposure. Many studies adjust crash data or crash severity utilizing vehicle volumes or vehicle miles traveled. Bicycle and pedestrian volumes are usually not included and therefore crash rates typically do not reflect the level of active user exposure.

Although it appears to be seldom utilized *(Fitzpatrick et al., 2019)*, the knowledge-based expert system USLIMITS2 (*FHWA, 2017*) can be used to select appropriate speed limits. A number of site-specific characteristics, speed and crash rate metrics, bicycle/pedestrian activity, AADT, and current statutory limits are required inputs. Three years of crash data are recommended. However, USLIMITS2 was not designed specifically for urban environments with a high percentage of active users. Outside the US, tools like SaCredSpeed (*Aarts et al., 2009*) are used to set credible speed limits by comparing roadway design and factors that affect speed limit credibility.

Better multimodal data and well-designed performance measures can provide an adequate framework to continuously monitor and improve roadway conditions for all users in a balanced manner.

2.6 SUMMARY

There are many factors that can potentially affect drivers' selection of operating speeds. Table 2.1 provides a summary of the effects on speed by some of the more commonly studied geometric and roadside variables. The literature review indicates that raising the posted speed limit tends to increase operating speeds and lowering the speed limit tends to decrease operating speeds; however, there is a lot of variability around the mean observed effects. It is estimated that, on average, a 1 mph speed limit decrease is likely to result in a 0.25 mph decrease in the mean traffic speed *(OECD, 2006; Elvik 2012)*.

Factors such as geometry, roadside characteristics, and environmental factors also impact operating speeds. In many cases, these factors are confounded which complicates the estimation of individual impacts and may lead to contradictory findings. In some cases, there are methodological issues. For example, some studies lack appropriate falsification tests when controlling for observations taken before and after speed limit changes.

Most studies are also conducted on rural or suburban roadways. In most studies, roadways have no or scant active users and/or there are no variables that measure and take into account the number or even the presence of active users.

Speed limit compliance is not always easily achieved. A survey of drivers conducted by AAA Foundation for Traffic Safety found that nearly half of respondents (47.6%) reported driving ten mph over the speed limit on a residential street at least once in the past 30 days with 12.9% indicating they engaged in the behavior fairly often or regularly *(AAA Foundation for Traffic Safety, 2018)*.

Table 2.1: Summary of Some Geometric and Roadside Factors Affecting Operating Speeds.

FACTOR	AUTHOR: *Bassani et al. (2014)***	*Dinh & Kubota (2013)*	*Eluru et al. (2013)* Arterial	*Eluru et al. (2013)* Local	*Fitzpatrick et al. (2001)* Curve	*Fitzpatrick et al. (2001)* Tangent	*Gargoum et al. (2016)**** Arterial	*Gargoum et al. (2016)**** Collector	*Thiessen et al. (2017)* Arterial	*Thiessen et al. (2017)* Collector	*Thiessen et al. (2017)* Combined
Access density					↓				↓	↓	↓
Auxiliary lanes (bike, bus)	↑			↑					↑ (bus stop)	↓ (bus stop)	↑ (bike)
Land use					*		↓	↓	↑	↓	↑
Lane or road width		↑				↑*			↓	↑	
Medians					↑*		↓	↓	↑ (width)	↓ (width)	↑ (width)
Number of lanes		↑	↑	↑			↑	↓			
Parking	↑			↓			↑	↓			
Pedestrian Crossings	↓									↓	
Posted speed limit		controlled	↑		↑	↑	↑	↑	↑	↓	↑
Roadside object density		↓							↓ (pole) ↓ (tree)	↑ (pole) ↑ (tree)	↓ (tree)
Segment length		↑							↑	↑	↑
Shoulders	↑						↓	↓			
Sidewalks	↓	↑		↑					↑ (width)	↑ (width)	

* indicates variable was only significant after excluding posted speed limit from the model
** indicates change in speed dispersion
*** indicates correlation to speed limit compliance

3.0 SITE SELECTION AND DATA DESCRIPTION

This section describes the selection criteria to be used in identifying potential study locations with and without a significant number of active travelers. Additionally, a list of proposed locations selected according to the given criteria is presented.

3.1 SIGNIFICANT NUMBER OF ACTIVE TRAVELERS

This project focuses on roadways with a significant number of active travelers. Feedback provided by the TAC helped define the concept of a significant number of active travelers.

When counts are available, the presence of a significant number of active travelers can be defined by a threshold or a percentage. Both thresholds and percentages can be useful to provide guidelines based on facility type and size of the urban area. Given the high seasonality of active trips and the lastingness of posted speed limits, it may be more appropriate to utilize data for months with high bicycle and/or pedestrian activity.

When active user counts are not available, it is necessary to utilize proxy measures for bicycle or pedestrian activity. Street functional classification and characteristics, bike/pedestrian network connectivity, transit activity, and land use (densities) can be utilized to identify streets or corridor segments that are likely to have a high percentage of active users.

3.2 SITE CRITERIA

To gather a representative sample of sites, several considerations were taken into account. These considerations included road geometry, current speed limits, traffic composition, traffic characteristics, and the level of expected active traveler presence.

Topological maps were referenced to choose segments such that significant grades are not present. The segments chosen are straight or relatively straight in alignment. Selected segments have current speed limits that range between 20 mph and 30 mph *(Portland Bureau of Transportation, 2016)*. Where available, bicycle counts obtained from PBOT *(Portland Bureau of Transportation, 2019b)* were used. The type of bicycling facility available and its designation or lack thereof as a recommended route *(Metro, 2014)* were used in conjunction with the bicycle counts to estimate expected bicycle volume. TriMet regular and frequent service bus routes were noted *(TriMet, 2019)*, and the most recently available data for passenger boardings and alightings were used to estimate areas with high pedestrian activity.

The final selection of locations was approved by the project technical advisory committee (TAC).

3.3 DATA SOURCES

Many data sources have been utilized throughout the projects. These sources are listed below:

- PBOT traffic survey data files to provide traffic volume information, including bicycle volumes as well as individual vehicle speeds (main data source).
- Satellite imagery or GIS data, for example, to estimate distances including segment length and signal spacing, or the distance to pedestrian crossings and traffic calming devices.
- Google Maps and Google Street View to obtain many attributes related to road geometry and bicycle/pedestrian facilities.
- Maps provided by the USGS to estimate the grade or presence of vertical alignment.
- Transit activity and stop locations were obtained from TriMet data.
- Segment boundary conditions were observed using Google Street View or by conducting a site visit.
- Posted speed limits were obtained from PBOT.
- On-site traffic survey and data collection to obtain other attributes that could not be obtained from the previously listed data sources.

3.4 DATA COLLECTION SITES

Speed surveys were collected by the Portland Bureau of Transportation (PBOT) from 2011 to 2019. Datasets were collected from 44 total sites for a minimum of two survey periods, with 13 of those sites having more than two survey periods. The data collection produced 106 unidirectional datasets constituting 87 pairs of surveys that were repeated at the same locations. Changes to the posted speed limit (PSL) occurred between subsequent surveys in 47 of the pairs. In this report, dataset pairs in which PSLs were reduced are referred to as treatment pairs. No changes were made to the PSL between repeat surveys in the remaining 40 dataset pairs, which are henceforth referred to as control pairs. The data collection sites consisted of roadways with a variety of speed limits and bicycle facilities but were predominantly comprised of lower functionally classed roads with PSLs in the 20-25 mph range.

PSL changes were determined from the original speed data files and verified by PBOT and by utilizing signage visible on Google Street View. Table 3.1 provides the dates of the data collections and the dates of the PSL changes. PSL change dates marked by an asterisk (*) indicate the date the change was sent to the mapping department to be updated in the records, as opposed to the date the new signage was installed. This date may not be fully reflective of the date the PSL change took effect as there may have been a time lag, for example, at Clinton west of 14th. At Lincoln east of 50th and Lincoln west of 57th, the PSL change dates do not align with the date and PSL given in the original data files. Further inspection via Google imagery revealed

20-mph advisory signs near both locations, and it is suspected this was recorded as the PSL at the time of data collection.

Table 3.1: Data Collection and PSL Change Dates.

Location	Direction	Survey Dates Before Change	PSL Change Date	Survey Dates After Change
Alberta E of 14th	EB		9/7/2017	7/11/2019; 11/18/2019
	WB		9/7/2017	7/11/2019; 11/18/2019
Alberta E of 28th	EB	10/20/2016	9/7/2017	7/18/2019
	WB	9/13/2016; 9/14/2016; 10/20/2016	9/7/2017	7/18/2019
Clinton W of 13th	EB	7/22/2015; 5/24/2016	7/3/2018*	
	WB	7/22/2015; 5/24/2016	10/3/2018*	
Clinton W of 14th	EB	8/19/2014	7/3/2018*	3/20/2018; 5/1/2018; 9/9/2019
	WB	8/19/2014	10/3/2018*	3/20/2018; 5/1/2018; 9/9/2019
Clinton E of 17th	EB	8/19/2014; 7/16/2015	7/3/2018*	
	WB	8/19/2014; 7/16/2015	7/3/2018*	
Clinton E of 23rd	EB	7/13/2015; 5/18/2016	7/3/2018*	
	WB	7/13/2015; 5/18/2016	7/3/2018*	
Clinton W of 25th	EB	3/31/2014; 6/9/2015	7/3/2018*	
	WB	3/31/2014; 6/9/2015	7/3/2018*	
Clinton E of 29th	EB	5/18/2016	12/19/2016*	7/31/2019
	WB	5/18/2016	12/19/2016*	7/31/2019
Clinton W of 30th	EB	8/19/2014; 6/9/2015	12/19/2016*	
	WB	8/19/2014; 6/9/2015	12/19/2016*	
Division E of 33rd	EB		NA	7/13/2015; 7/29/2019
	WB		NA	7/13/2015; 7/29/2019
Division E of 116th	EB	2/21/2017	3/3/2017	12/2/2019
	WB	2/21/2017; 2/22/2017	NA	4/23/2018; 10/1/2019
Fremont E of 46th	EB		NA	2/6/2018; 9/11/2019
	WB		NA	2/6/2018; 9/11/2019
Fremont E of 48th	WB		NA	12/8/2014; 7/23/2019
Harrison E of 25th	EB	2/22/2017	7/9/2018*	4/2/2019
Holgate E of 111th	EB	2/27/2017	8/9/2017*	6/6/2019
	WB	2/27/2017	8/9/2017*	6/6/2019

Location	Direction	Survey Dates Before Change	PSL Change Date	Survey Dates After Change
Lincoln E of 30th	WB		NA	2/19/2019; 4/4/2019
Lincoln W of 41st	WB	11/27/2012	5/28/2013*	1/5/2017
Lincoln E of 45th	EB	11/27/2012	5/28/2013*	7/15/2019
	WB	11/27/2012	5/28/2013*	7/15/2019
Lincoln E of 48th	EB	10/2/2012	5/28/2013*	1/3/2017
	WB	10/2/2012	5/28/2013*	1/3/2017
Lincoln E of 50th	EB		5/7/2018*	3/21/2017; 5/9/2019
	WB	4/12/2011; 2/14/2012	5/7/2018*	3/21/2017; 5/9/2019
Lincoln W of 57th	EB	2/14/2012	5/7/2018*	1/31/2017
	WB	2/14/2012	5/7/2018*	1/31/2017
Willamette E of Chase	EB	6/22/2015	9/18/2017	7/16/2019
Williams N of Going	NB	1/13/2015	8/28/2015	7/16/2019
Williams N of Hancock	NB	2/26/2015	8/28/2015	9/23/2019

* Indicates the date the change was sent to the mapping department

3.4.1 Data Cleaning

An initial data cleaning process was performed by removing observations recorded with: speeds of zero miles per hour, speeds that were higher than the posted speed limit plus 25 mph, gap times of zero seconds, or an undefined vehicle class. Less than 10% of the data was removed on average, mostly due to zero speed records. The data cleaning process and outliers found were discussed with experienced staff dealing with speed and count surveys at PBOT. After data cleaning, observations of class two vehicles or passenger cars (*FHWA, 2016*) were extracted for further analysis.

Speed histograms were inspected to determine if data followed an approximately normal distribution. Figures 3.1 and 3.2 provide representative examples of class two normal speed distributions for eastbound Fremont east of 46^{th} in February 2018 and eastbound Lincoln east of 50^{th} in March 2019. Of the 106 initial datasets, five were found to have non-normal distributions due to an insufficient number of class two observations and were excluded from the analysis. In addition, one dataset was excluded after Google Street View imagery suggested building construction activities may have interfered with the data collection efforts (*Google, 2019*). Two additional datasets containing a sufficient number of observations (> 5,000) showed non-normal speed distributions consisting of overlapping bell curves. These two datasets were retained for analysis as assumptions of normality are not a prerequisite for comparing before and after changes in speeds (discussed later in Section 5). Additionally, when datasets contain hundreds of observations, the distribution of the data can be ignored for most statistical analyses, based on the central limit theorem, which states that the means of random samples from any distribution will themselves be normally distributed (*Altman & Bland, 1995*). In total, 100 datasets were utilized. These datasets were combined into 45 treatment pairs and 37 control pairs to analyze.

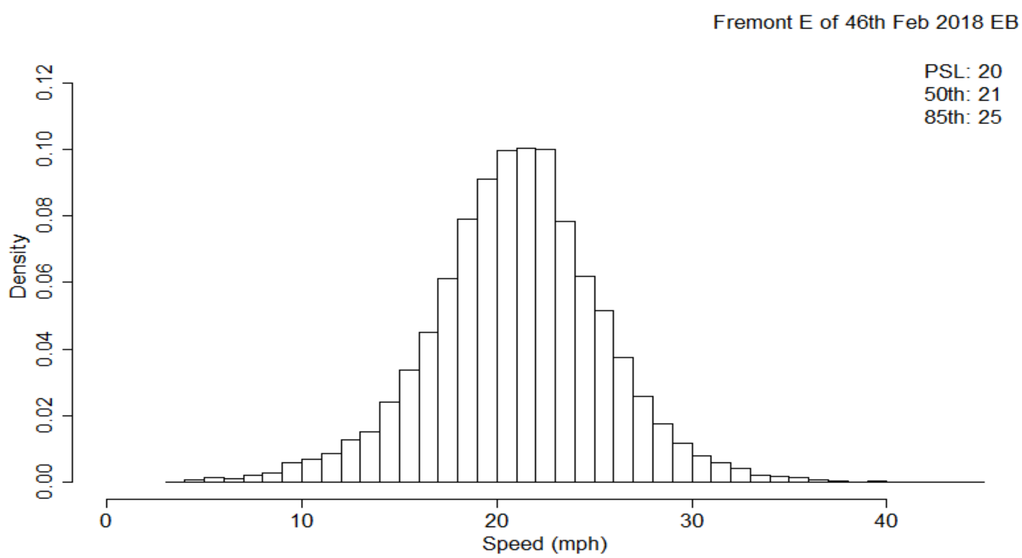

Figure 3.1: Class two speed distribution for Fremont east of 46th eastbound in February 2018.

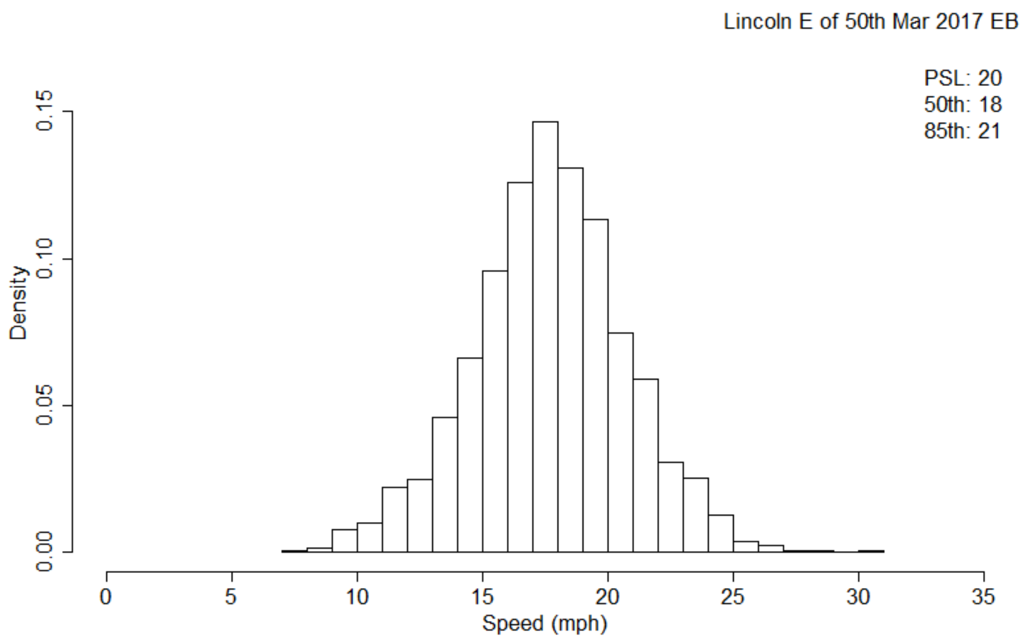

Figure 3.2: Class two speed distribution for Lincoln east of 50th eastbound in March 2017.

3.4.2 Data Classification

The data were collected from roads with a variety of functional classes or traffic classes (*Portland Bureau of Transportation, 2020*), speed limits, and bicycle facilities. Table 3.2 summarizes these basic classification characteristics for the 45 treatment and 37 control data pairs. The speed limit shown for treatment pairs is the speed limit posted during data collection of the subsequent, 'after' survey. For treatment pairs, the initial, 'before' speed limit was posted five miles per hour higher than during the 'after' survey at all sites.

Traffic classes used by PBOT are similar to FHWA functional classes in that they describe the intended service provided by the road. The majority of trips on the road should conform to the given traffic classification. A district collector is intended to connect town centers, neighborhoods, and main streets to nearby regional centers or other major destinations. A neighborhood collector is intended to distribute traffic from district collectors or other major streets to local streets and connect neighborhoods to nearby centers, communities, or destinations. Local service streets are intended to provide access to local residences and may function as through routes for bicyclists and pedestrians (*Portland Bureau of Transportation, 2020*).

Table 3.2 shows that most of the data pairs analyzed were from locations along lower-classed roadways with lower speed limits in the range of 20-25 mph. Almost two-thirds of the data pairs were from shared road facilities, which typically have high volumes of active travel. All of the shared road facilities studied within this report (63 total datasets) correspond to local service streets and are designated as neighborhood greenways – residential streets with low motorized traffic volumes and speeds where priority is given to active travelers. Traffic calming measures such as speed humps, circles, and/or diverters are used to manage motorized traffic on neighborhood greenways (*Portland Bureau of Transportation, 2015*).

Table 3.2: Summary of Basic Roadway Characteristics for All Datasets and Pairs Analyzed.

	Treatment Pairs	Control Pairs	Total Pairs	Total Datasets
Functional Class				
Local	20	10	30	37
Urban Collector	18	24	42	54
Minor Arterial	1	0	1	2
Principal Arterial	6	3	9	7
PBOT Traffic Class				
Local Service	30	24	54	63
Neighborhood Collector	9	10	19	30
District Collector	6	3	9	7
Bike Facilities				
Shared	30	24	54	63
No Facility	4	10	14	20
Bike Lane*	11	3	14	17
PSL:**				
35	0	1	1	6
30	9	2	11	8
25	2	20	22	50
20	34	14	48	36

*Bike lanes at Willamette E of Chase, Holgate E of 111th, Williams N of Going, and Williams N of Hancock have an increased spatial separation (buffer) from traffic.
**For treatment pairs, the PSL of the 'after' dataset is given.

The posted speed limit (PSL), estimated class two ADT, standard deviation (SD), mean, and the 5th, 15th 50th, 85th, and 95th percentile speeds for class two vehicles were computed for each dataset. Class two traffic volumes along neighborhood greenway sites are the lowest and tend to be less than 1,000 vehicles per day (vpd). Non-neighborhood greenway sites without bicycle facilities serve somewhat higher class two traffic volumes, ranging from 1,800 to 4,600 vpd. The highest class two traffic volumes are found along the non-neighborhood greenway sites with bicycle lanes, ranging from 4,100 to more than 10,000 vpd.

Speed limits at the neighborhood greenway sites and the non-greenway sites without bicycle facilities range from 20-25 mph. Mean speeds between 17 mph and 23 mph were seen at greenway sites and comparable mean speeds of 19-23 mph were observed at non-neighborhood greenway sites without bicycle facilities. However, the 85th percentile speeds at greenway sites (20-27 mph) appear to be slightly lower than 85th percentile speeds at non-greenway sites without bicycle facilities (23-28 mph). At non-neighborhood greenway sites with bicycle lanes, higher speed limits and higher mean and 85th percentile speeds were typically observed.

Overall, the mean and median of each dataset are very similar, differing by less than one mile per hour in all instances. A histogram of the differences (mean – median) is shown in Figure 3.3. Since the granularity of the speed data collected was limited to 1-mph integer increments and all datasets contained a large number of observations, the means were used to test hypotheses regarding central tendency.

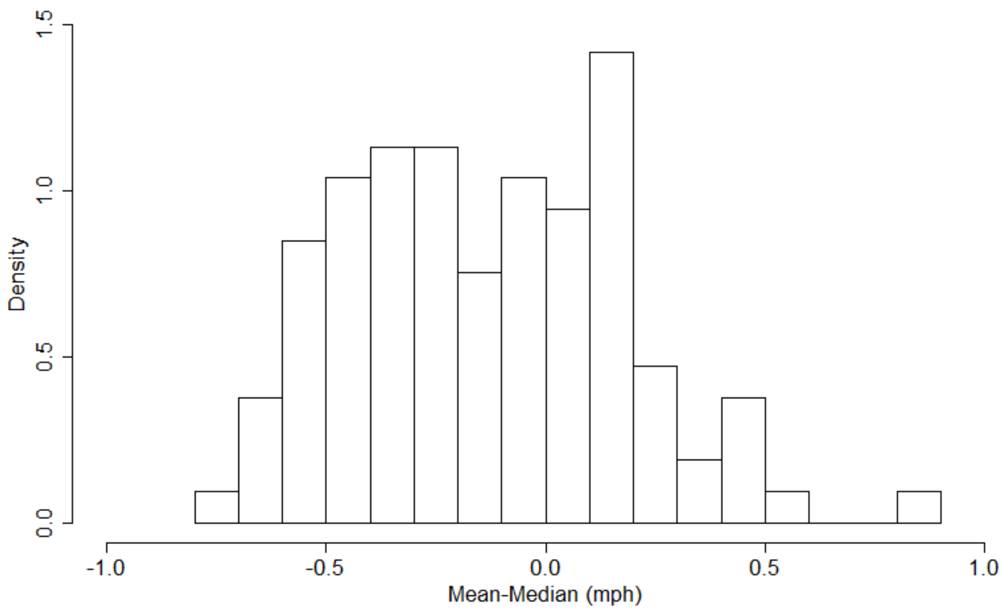

Figure 3.3: Histogram of the differences between the mean and median of each dataset.

3.5 ACTIVE TRAVEL

This research is primarily interested in locations that have high percentages of active travelers. However, as discussed with the TAC, some sites with low active travel activity were included to compare trends and findings. Levels of cycling activity were assessed by the percent of class one vehicles in the speed data. Class one vehicles correspond to bicycles and motorcycles (*FHWA, 2016*). It should be noted that most of the data collection after 2014 was performed using equipment specifically intended to record bicycles as well as motor vehicles. There appear to be significant increases in class one traffic volumes at some locations between surveys that are likely mostly due to the equipment used and, to a lesser extent, an actual increase in traffic. For example, at the neighborhood greenway location of westbound Clinton east of 17^{th}, the class one ADT was 51 vpd (4.5% of traffic) according to the August 2014 traffic survey and increased to 452 vpd (35% of traffic) in the following survey in July 2015, an increase of almost 900%. Manual bike counts conducted across the city since 2006 have shown that the number of bicycle trips is increasing but at a lower rate. Compared to the 2007-2009 three-year average, the number of bikes counted in the 2015-2017 three-year average at the same locations increased by just 27% (*Portland Bureau of Transportation 2019a*).

Studies in the U.S. have estimated typical average bicyclist speeds to range from 12-15 mph, and 85th percentile speeds in Sweden have been reported as 10-17 mph (*Hummer et al., 2006*). The class one speed distributions for datasets located on neighborhood greenways tend to be unimodal and appear to be predominantly non-motorized vehicles (bicycles). Figure 3.4 shows a typical example of a class one speed distribution for a neighborhood greenway street, at eastbound Clinton east of 29th from the May 2016 survey. The 50th and 85th percentile speeds are consistent with typical cycling speeds. Bimodal class one distributions were found at some locations along the higher classed roadways, suggesting that a larger share of the class one vehicles was motorized. Figure 3.5 shows an example of a bimodal class one distribution indicating the presence of both motorized and non-motorized vehicles for westbound Fremont east of 48th from the July 2019 survey. Lastly, at some locations, the majority of class one vehicles appeared to be motorized, based on the shape of the distribution and speed statistics. Figure 3.6 shows one such distribution, from westbound Division east of 116th in February 2017. Speeds at this location are clearly much higher than is typically achievable by a pedal cyclist.

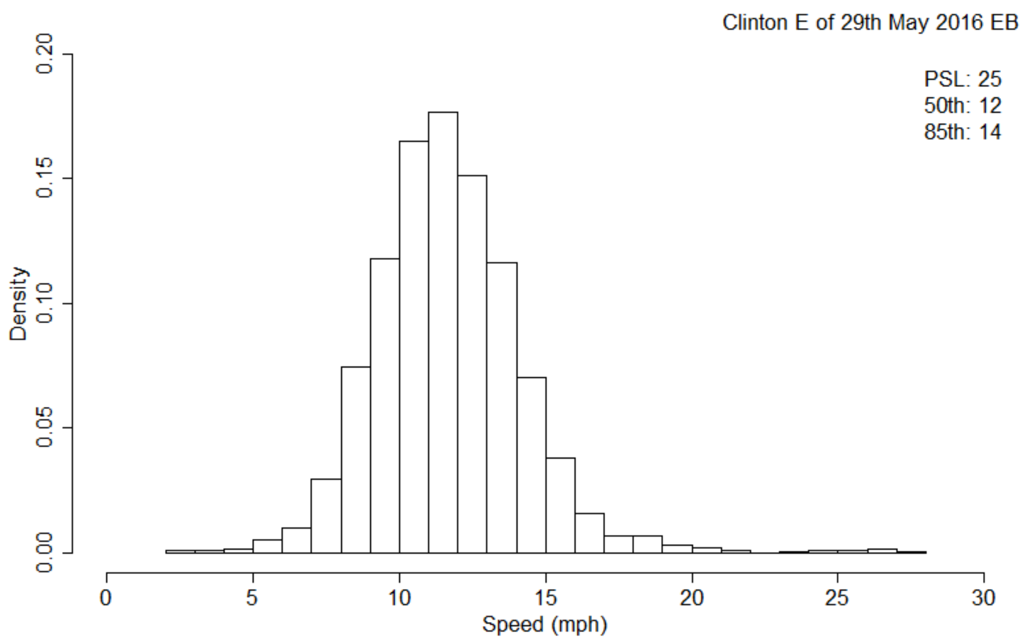

Figure 3.4: Typical class one speed distribution for a neighborhood greenway street where the majority of the class one vehicles appear to be non-motorized.

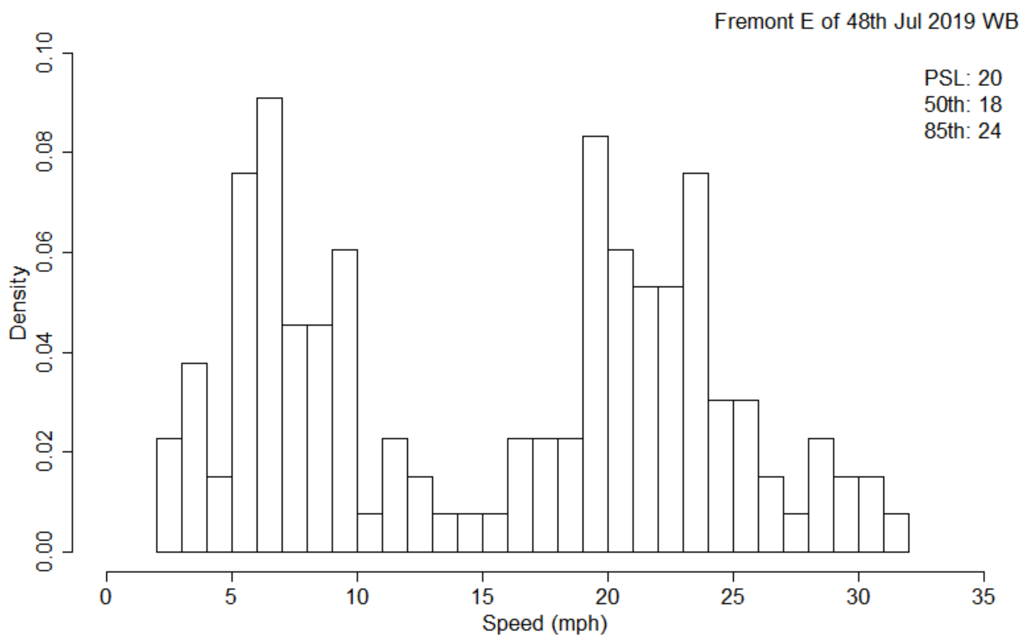

Figure 3.5: Bimodal class one speed distribution with motorized and non-motorized vehicles along a neighborhood collector street.

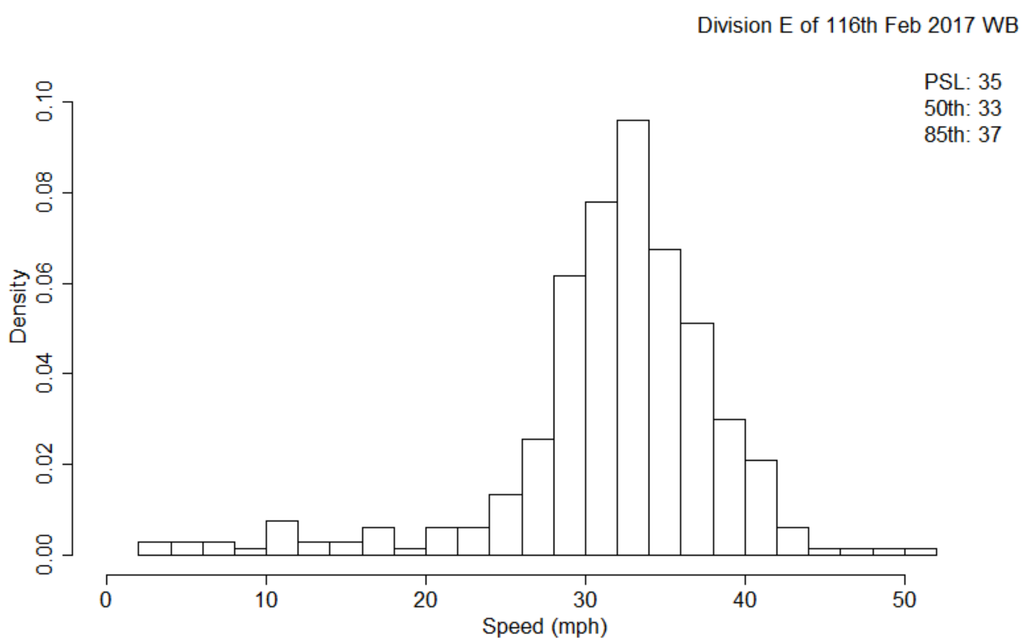

Figure 3.6: Class one speed distribution along a district collector street where the class one vehicles appear to be predominantly motorized.

To gauge the level of pedestrian activity, the presence of bus routes and locations of pedestrian districts (*Portland Bureau of Transportation, 2020*) were used as proxies in the absence of survey data. Population density estimates of the areas immediately surrounding each survey location were also consulted (*"Interactive map: Portland-area density", 2020*). Based on the interactive map, the population densities appear to be higher for locations along the neighborhood greenways and lower for locations where bicycle lanes are present.

3.6 SELECTION OF COMPLIANCE MEASURES

This section discusses speed and speed compliance performance measures.

3.6.1 Definition of Speeding

One of the key questions to answer when it comes to speed studies is to define speed limit compliance: what constitutes speeding? How can speeding be measured? And what amount of speeding is considered excessive?

Speeding can be defined as exceeding the speed limit or as driving too fast for the given conditions *(NHTSA, 2014)*. In this report, the term "speeding" will be defined as operating at a speed above the posted speed limit.

The definition of excessive speeding is not as clear. The *Global Road Safety Partnership (2008)* defines "low-level speeding" as driving a few km/h over the speed limit. On the other hand, "excessive speeding" or "high-range speeding" have been used to describe speeds typically in excess of 40 km/h (25 mph) over the posted speed limit (*Gargoum, 2015)*.

3.6.2 Measures of Compliance

Ponnaluri & Groce (2005) evaluated the effectiveness of 12-foot speed humps to calm traffic on a two-lane residential road with a 25-mph speed limit by calculating mean, median, and 85th percentile speeds before and after the speed humps were installed. Additional before and after speed parameters measured were the 10 mph pace (defined as the 10 mph window in which the highest number of vehicles travel), the percent of vehicles within the pace, and the percent of vehicles exceeding the posted speed limit.

Islam et al. (2014) used mean free-flow speed, the 85th percentile speed, the standard deviation of speed, speed percentile plots, and the percentage of vehicles exceeding 50 km/h and 65 km/h in their research regarding a reduction in the posted speed limit from 50 km/h to 40 km/h in six urban residential neighborhoods with local and collector roads in Edmonton, Canada.

Gargoum et al. (2016) collected speed data from urban arterial and collector roads in Edmonton, Canada, with posted speed limits ranging from 30 km/h to 80 km/h. Compliance with the speed limits was calculated as the difference between the speed limit and the vehicle's recorded speed and was divided into five categories for analysis within the study to further assess the various margins of speeding. The categories were:

- Fully compliant

- Exceeding the speed limit by no more than 5 km/h
- Exceeding the speed limit by more than 5 km/h but no more than 10 km/h
- Exceeding the speed limit by more than 10 km/h but no more than 20 km/h
- Exceeding the speed limit by 20 km/h or more.

A before and after evaluation of the effectiveness of an automated speed enforcement program on residential streets with speed limits of 25 to 35 mph in Montgomery County, Maryland used mean speed and the percentage of vehicles exceeding the speed limit by 10 mph or more as performance metrics *(Hu & McCartt, 2016)*.

A study by *Hu & Cicchino (2019)* investigated changes in vehicle speeds on relatively flat, straight segments that included arterial, collector, and local roads following a default speed limit reduction from 30 mph to 25 mph in Boston, MA. The raw percentages as well as estimated odds (accounting for trends at unchanged comparison site) of vehicles exceeding 25, 30, and 35 mph and mean speed were used as speed performance measures.

The *NHTSA (2008)* cites multiple studies regarding the effects of automated speed enforcement (ASE) programs. One study found that the percentage of vehicles traveling 10 mph or more over the speed limit during a four-month period post camera installation at five problematic sites in Beaverton and Portland, OR declined from 18% to 13% and the proportion of vehicles traveling 5 mph or more over the speed limit decreased from 19% to 13% in Beaverton as compared to pre-camera installation. Meanwhile, the proportions of vehicles exceeding the speed limit by 5 or 10 mph increased slightly at control sites *(Cities of Beaverton and Portland, 1997, as cited in NHTSA, 2008)*. An evaluation of the ASE program in Washington DC in 2003 found an 82% decrease in the proportion of vehicles traveling more than 10 mph over the speed limit and a 14% decrease in mean speed during enforcement hours compared to control sites *(Retting & Farmer, 2003, as cited in NHTSA, 2008)*. Lastly, the percentage of vehicles exceeding the speed limit by more than 10 mph was reduced on average by 55% at ASE treatment sites in Charlotte, NC compared to control sites. Median and 85th percentile speeds decreased by 0.88 mph and 0.99 mph, respectively, compared to the control sites *(Cunningham et al., 2005, as cited in NHTSA, 2008)*.

The Manual on Uniform Traffic Control Devices, MUTCD (Federal Highway Administration [FHWA], 2009) as well as several state (California Department of Transportation, 2018; Massachusetts Department of Transportation, 2017; New York Department of Transportation, 2017; and Oregon Department of Transportation, 2014) and other guidelines (Forbes et al., 2012) suggest using the 85th percentile speed as a basis for setting speed limits based on the idea that most drivers select appropriate speeds for the given conditions. By changing the direction of its application, the 85th percentile operating speed (and its difference from the speed limit) can be used to gauge the level of speed limit compliance.

3.6.3 Performance Measures

Following TAC recommendations and the new ODOT speed zone manual (*ODOT, 2020*), the following performance measures are analyzed in later chapters.

- The mean speed
- The standard deviation of speed
- The pace
- The 50th speed percentile and the 85th speed percentile.
- The total percentage of vehicles exceeding the posted speed limit
- The percentage of vehicles exceeding the posted speed limit by 5 and 10 miles per hour.

The data collection sites approved for this study have a very low crash rate. In addition, the before/after period of analysis is relatively short. Crash or safety performance measures are not included or discussed in future chapters.

4.0 INITIAL DATA ANALYSIS

4.1 IDENTIFICATION OF SPEED PATTERNS

This section studies the relationships between mean speed and mean gap time or vehicle count for different roadway contexts. Speed data were aggregated into 15-minute intervals. In this section, mean speed and mean gap time are defined as the averages of the observations within each 15-minute bin. The count of vehicles is defined as the number of observations within each bin. Scatterplots were constructed to show the mean speed versus the mean gap time or mean speed versus the vehicle count. A difference between streets designated as neighborhood greenways and those without the designation was found.

4.2 NEIGHBORHOOD GREENWAYS

Neighborhood greenways, streets with increased traffic calming, did not show clear relationships between the mean speed and mean gap or vehicle count for nearly all datasets. Figure 4.1 shows a typical scatterplot of mean speed vs. mean gap for a neighborhood greenway, eastbound Clinton west of 25^{th} from a March 2014 survey. The dashed line shows the overall mean gap time for that survey.

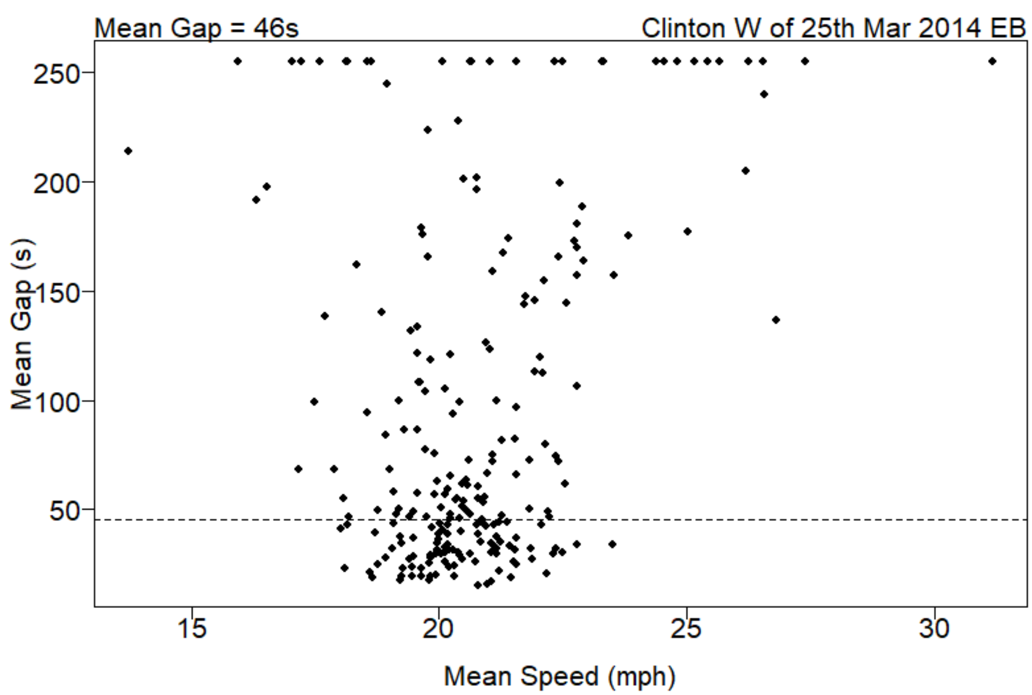

Figure 4.1: Typical example of a neighborhood greenway mean speed vs. mean gap scatterplot for the March 2014 eastbound Clinton west of 25^{th} dataset.

Similarly, Figure 4.2 shows the scatterplot of the mean speed vs. vehicle count for the March 2014 eastbound Clinton west of 25th dataset as a typical example along neighborhood greenways.

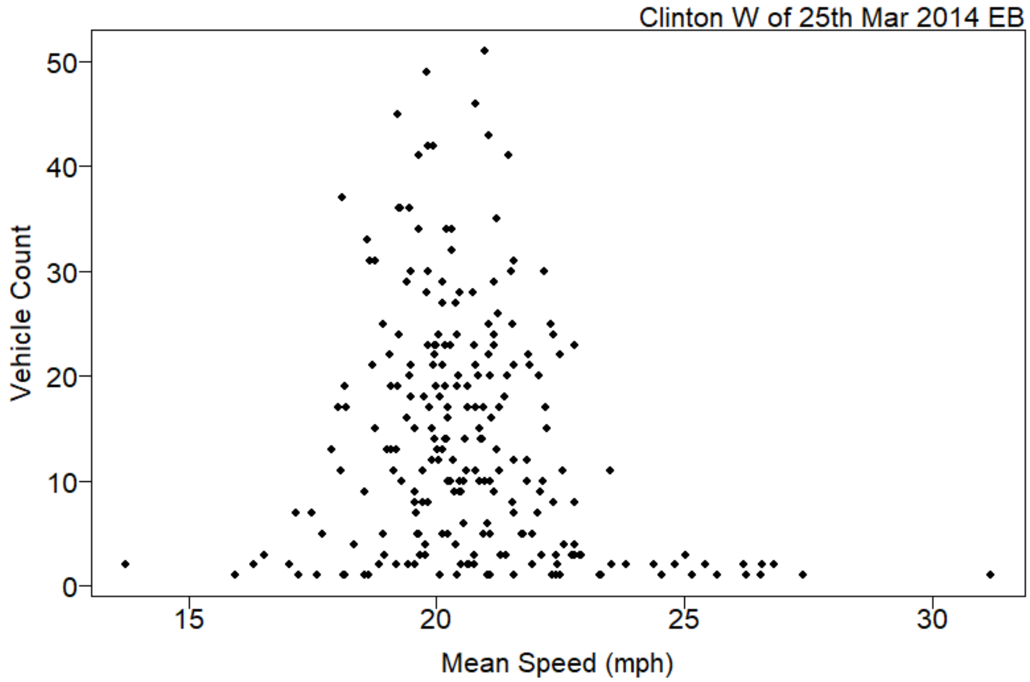

Figure 4.2: Typical example of a neighborhood greenway mean speed vs. vehicle count scatterplot for the March 2014 eastbound Clinton west of 25th dataset.

Only two out of 63 neighborhood greenway datasets deviated from the general pattern of non-correlation between mean speed and mean gap or vehicle counts when data were aggregated into the 15-minute bins. Both datasets were from the same site, westbound Lincoln east of 50th, for surveys performed in April and June of 2011. These datasets displayed patterns similar to the non-neighborhood greenway streets, where trends can be observed. Data from subsequent surveys at this site matched those from other neighborhood greenway datasets, however.

4.3 NON-NEIGHBORHOOD GREENWAY STREETS

For streets not designated as neighborhood greenways, the scatterplots did indicate speeds may be affected by gap time or traffic volume at most sites when observations were aggregated into the 15-minute bins as previously described. A positive relationship between mean speed and mean gap time was typically seen for datasets along such streets. In contrast, a negative relationship was generally found between mean speed and the 15-minute bin vehicle count. Figure 4.3 shows the scatterplot of mean speed vs. mean gap time and overall class two average gap time for the December 2014 survey of westbound Fremont east of 48th as a typical example for non-neighborhood greenway streets. Figure 4.4 shows the scatterplot for the mean speed vs. vehicle count for the same dataset.

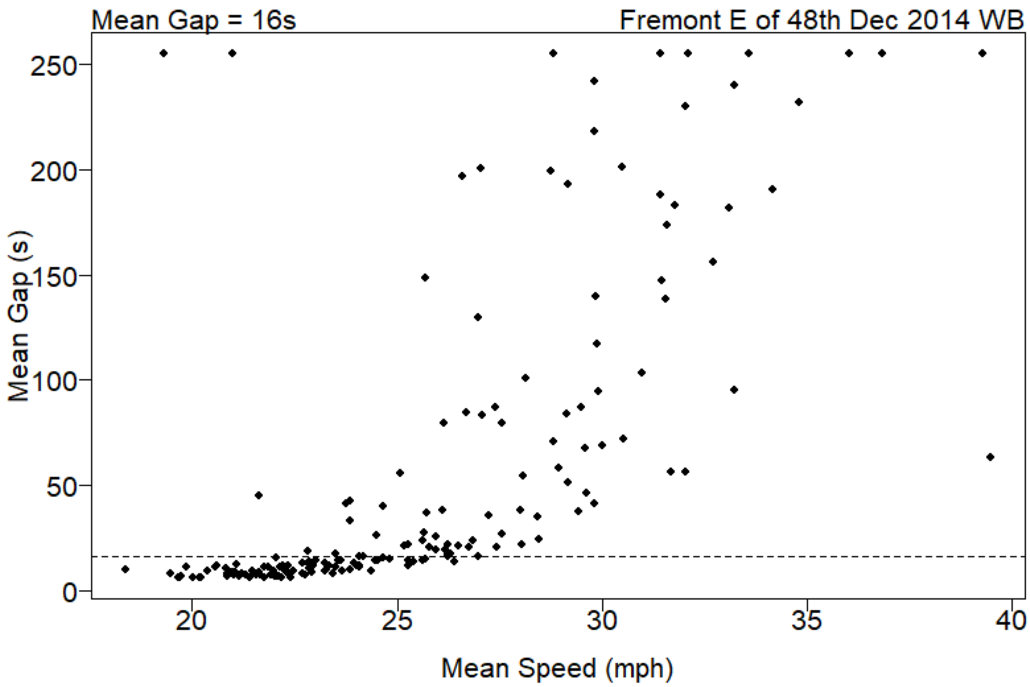

Figure 4.3: Typical example for a non-neighborhood greenway mean speed vs. mean gap scatterplot for the December 2014 westbound Fremont east of 48th dataset.

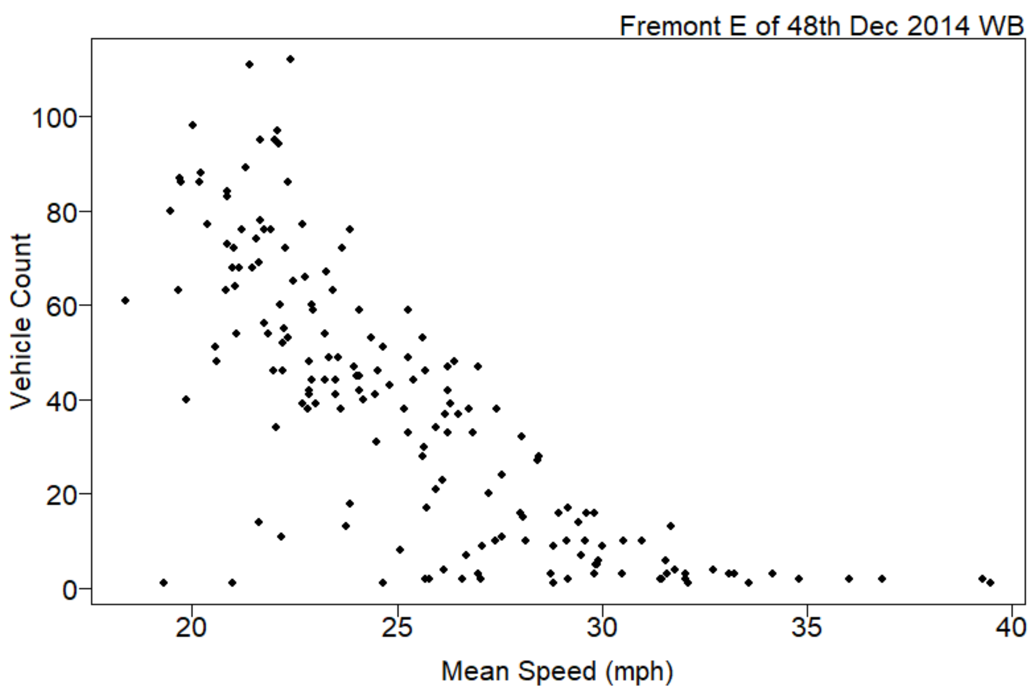

Figure 4.4: Typical example for a non-neighborhood greenway mean speed vs. vehicle count scatterplot for the December 2014 westbound Fremont east of 48th dataset.

These patterns observed in the non-neighborhood greenway datasets also held when observations during peak hours (7 a.m. – 10 a.m. and 3 p.m. – 7 p.m.) or with gap times less than five seconds (used as a threshold for free-flow conditions) were excluded.

Exceptions to the relationship pattern between mean speed and mean gap time or vehicle counts occurred in two of the 37 non-neighborhood greenway datasets in which the scatterplots looked more like those from the non-correlated neighborhood greenway sites. These exception datasets include both the eastbound and westbound directions at Holgate east of 111th for the June 2019 survey. The absence of the relationships between vehicle volume or mean gap time and mean speed is caused by the proximity to the traffic control device to the east at 112th (less than 250 feet away) and a high volume of turning traffic at 112th which inhibits the speeds and affects the behavior of traffic at Holgate east of 111th.

4.4 SUMMARY OF PATTERN IDENTIFICATION

Local service streets with shared road bicycle facilities, designated as neighborhood greenways, did not display a clear relationship between mean speed and mean gap time or vehicle count in 61 of 63 datasets (97%).

Higher classed streets, which are not designated as neighborhood greenways, showed a positive relationship between mean speed and mean gap time and a negative relationship between mean speed and the 15-minute bin vehicle count for 35 of 37 datasets (95%). These relations held true when observations during peak hours or with gap times less than a free-flow threshold of five seconds were excluded. Based on this finding, it was determined that separate analyses should be performed for all datasets containing all observations and those datasets displaying correlations between speed and gap or vehicle counts when observations are limited to free-flow conditions.

5.0 BEFORE AND AFTER SPEED COMPARISON

The repeat data pairs described in Chapter 3 enabled a before and after comparison of speeds for treatment pairs (where the posted speed limit changed) and control pairs (where the speed limit did not change). Multiple comparison methods were used. In one method, performance measures were averaged across groups defined by the posted speed limit (PSL) and neighborhood greenway designation before differences were calculated. Differences between individual dataset pairs were also calculated and displayed graphically. Finally, a series of hypothesis tests were performed. For pairs that consisted of datasets displaying correlations between mean speed and gap time, as discussed in Chapter 4, the analyses were repeated when those datasets were limited to observations with gap times greater than their mean gap time to remove observations where speeds were potentially inhibited by congestion.

This chapter provides a summary of the comparison results.

5.1 COMBINED DATASETS

In the first comparison method, performance metrics were averaged within groups of datasets defined by the PSL and neighborhood greenway status. Then, differences between the 'before' and 'after' performance measures were calculated. As previously discussed in Chapter 4, the sites located on designated neighborhood greenways displayed a more random and uncorrelated pattern with respect to speed, gap time, and traffic volume. For this reason, neighborhood greenway sites were segregated within the PSL groups.

Performance measures investigated included the mean and 85th percentile speeds, the standard deviation, the percent of observations exceeding three speed thresholds, the 10-mph pace minimum, and the percent of vehicles in the pace limits. The speed thresholds were defined as (i) the PSL in the 'after' condition, (ii) the PSL in the 'after' condition plus five miles per hour, and (iii) the PSL in the 'after' condition plus ten miles per hour.

Within the treatment datasets, the percent of vehicles within the pace limits increased for each speed group. Neighborhood greenway sites showed consistent decreases in all other performance measure categories (this group had the highest number of datasets to analyze, which were spread across 16 different sites). In other words, operating speeds and the percent of vehicles exceeding the speed thresholds were reduced in the 'after' period. Similar trends were observed for the remaining, non-neighborhood treatment groups, although a broad conclusion could not be drawn for these groups due to a low number of datasets within them.

Overall, compared to the control groups, the magnitude of differences from 'before' to 'after' were larger in the treatment groups, particularly when considering the percentages exceeding the speed thresholds. This finding suggests that the reductions seen with the treatment datasets are more likely to be caused by the reduced speed limits rather than by chance or the evolution of driver attitudes toward the speed limits.

These conclusions were further supported by the results for the analysis repeated with only the datasets from the non-neighborhood greenway sites limited to free-flow conditions.

5.2 INDIVIDUAL DATASETS

The second analysis method involved calculating the differences in the performance metrics outlined in the previous section between individual dataset pairs. Changes in ADT were also investigated. All statistics comparing 'before' and 'after observations were obtained by subtracting the 'before' value from the 'after' value. For example, if the mean speed of the 'after' condition was 20 mph and the mean speed of the 'before' condition was 21 mph, the difference is -1 mph. Negative differences represent a decrease in the speed statistic, and positive differences represent an increase in the speed statistic. All comparisons between individual dataset pairs can be seen in Appendix A.

Histograms of the differences in mean speeds are displayed in Figure 5.1 for the treatment dataset pairs and Figure 5.2 for the control dataset pairs. The histograms show the magnitude of difference in mean speeds for the treatment sites is centered near -2 mph and for the control sites, the magnitude of the difference is centered near zero. Thus, it can be concluded that overall, speeds decreased more at treatment sites than at control sites. No significant deviations to this conclusion were found when only the free-flow datasets were analyzed.

Changes in the mean and standard deviation of speed with respect to the length of time between subsequent surveys were evaluated. For both treatment and control pairs, there appeared to be a slight negative correlation between the change in mean speed and the time elapsed between surveys, indicating that speeds may be decreasing slightly over time, regardless of a change in the PSL. This may be due in part to educational safety campaigns such as Vision Zero, which were implemented during the data collection period.

An analysis of changes in ADT revealed further insights regarding the differing characteristics of neighborhood greenway and non-neighborhood greenway datasets. Significant decreases in ADT up to 60% to 80% were observed at several neighborhood greenway sites. On average, decreases were greater at neighborhood greenway treatment sites than control sites. Non-neighborhood greenway sites experienced small increases in ADT, on average, for both treatment and control groups. These increases were comparable to regional increases in VMT for arterial roads and state highways.

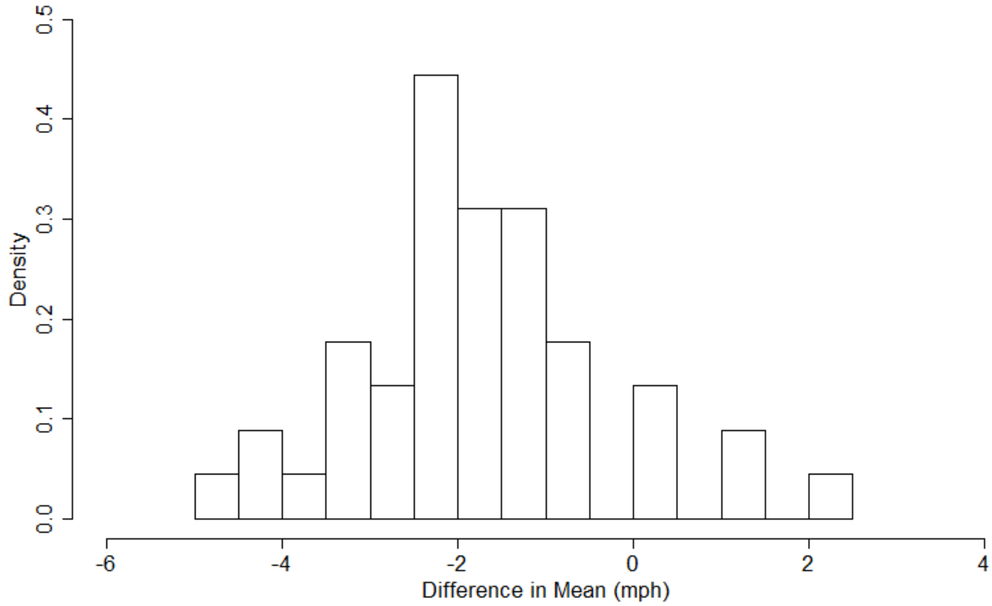

Figure 5.1: Histogram of differences in mean speed from before to after for treatment dataset pairs.

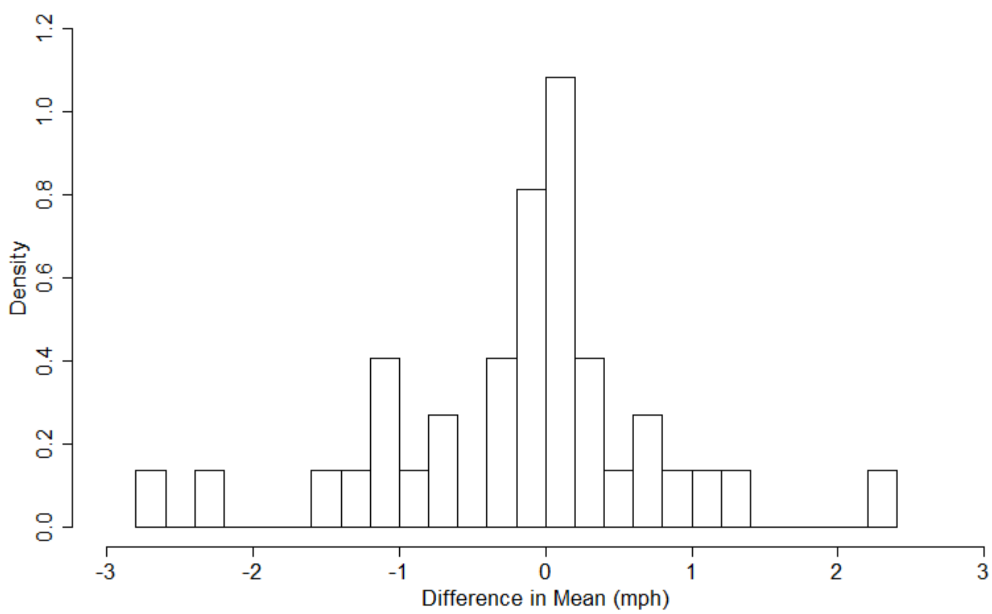

Figure 5.2: Histogram of differences in mean speed from before to after for control dataset pairs.

5.3 HYPOTHESIS TESTING (FULL DATA)

In order to ascertain the significance of any differences found among basic speed characteristics within all ‘before’ and ‘after’ dataset pairs, several hypothesis tests were employed. This section utilizes all class two observations; the following section utilizes only the free-flow data. The results are summarized in Table 5.1 and Table 5.2 at the end of this section.

First, the mean speeds were compared using one-tailed and two-tailed *t*-tests. Next, a modified version of a one-tailed and two-tailed *t*-test was used to compare the 85th percentile speeds (*Hou et al, 2012*). Differences in the variance of speed distributions were analyzed next using an F-test. Finally, the proportions of vehicles exceeding a defined speed threshold were compared using a χ^2 (chi-square) test.

An underlying assumption of the *t*-test and the F-test is that the data are normally distributed, particularly when sample sizes are small. For sample sizes in the hundreds, the distributions become much less important for *t*-tests due to the central limit theorem (*Altman & Bland, 1995*). As discussed in Section 3.4.1, nearly all of the datasets displayed approximately normal distributions. Only two datasets appeared to have normal-mixture distributions, displaying two overlapping bell curves. These datasets were collected from Holgate east of 111th during two different time periods. Both datasets contained in excess of 5,000 observations, however, thereby allowing the testing of most hypotheses without violating fundamental prerequisites. The non-normal speed distributions observed at Holgate east of 111th are likely due to the location’s proximity to a traffic signal. Further details regarding this location are discussed later in this chapter. A summary of the results of the hypothesis testing for all datasets can be found in Appendix B. Additional details for before and after speed comparisons, speed tests including all data, and speed tests including only free-flow data the reader is referred to appendices C, D, and E respectively.

5.3.1 Mean Speeds

The statistical significance of differences in mean speeds from the ‘before’ condition to the ‘after’ condition was assessed using Welch two-sample *t*-tests. Using a 95% confidence interval, if $p < 0.05$, the null hypothesis is rejected. If $p \geq 0.05$, the sample data fail to reject the null. Two hypotheses were tested for all dataset pairs in the treatment and control groups.

The first null hypothesis tested states that the mean speed in the ‘before’ condition is equal to the mean speed in the ‘after’ condition, H_0: $\mu_B - \mu_A = 0$, where the subscripts B and A symbolize the ‘before’ and ‘after’ conditions, respectively. The alternative hypothesis is that the mean speed in the ‘after’ condition is greater than the mean speed of the ‘before’ condition, H_A: $\mu_B - \mu_A < 0$. A statistically significant result, when the null is rejected, would suggest that the mean speed was higher in the ‘after’ period.

The second null hypothesis tested states that the mean speed in the ‘before’ condition is equal to 1.25 mph plus the mean speed in the ‘after’ condition, H_0: $\mu_B - \mu_A = 1.25$. The alternative hypothesis is that the mean speed of the ‘before’ condition is more than 1.25 mph greater than the mean speed of the ‘after’ condition, H_A: $\mu_B - \mu_A > 1.25$. A rejection of the null hypothesis ($p < 0.05$) would indicate that the mean speed decreased by more than 1.25 mph in the ‘after’ period. The value of 1.25 mph was chosen as the threshold for the second null hypothesis based on research by *Elvik (2012)*, which concluded that a 1:4 ratio of the change in mean operating speed to the change in posted speed limit (PSL) could be expected for a 5 mph reduction in the PSL.

5.3.1.1 Hypothesis Test for Equality of Mean Speeds

The first null hypothesis tested, stating the means of the 'before' and 'after' periods are equal, H_0: $\mu_B - \mu_A = 0$, H_A: $\mu_B - \mu_A < 0$, produced significant results for five out of the 45 treatment pairs tested (11.1%). The results indicate that mean speeds increased in the 'after' period, despite a decrease in the PSL. Increases in mean speeds ranged from 0.3 mph to 2.2 mph. All five results rejecting the null occurred at sites which are not designated as neighborhood greenways. Bike lanes were present in three of the datasets. No bicycle facilities were present in the other two datasets.

In the control group, there were 11 dataset pairs out of 37 tested (29.7%) that rejected the null hypothesis. Increases ranged from only 0.2 mph up to 2.3 mph. Nine of the 11 significant results were from locations carrying a neighborhood greenway designation.

5.3.1.2 Hypothesis Test for Decrease of Mean Speeds by 1.25 mph

Testing of the second null hypothesis, which states the mean speed of the 'before' condition is 1.25 mph greater than the mean speed of the 'after' condition, H_0: $\mu_B - \mu_A = 1.25$ (H_A: $\mu_B - \mu_A > 1.25$), yielded significant results for 28 of the 45 treatment pairs, or 62.2 %, of which 22 were located on designated neighborhood greenways. Decreases in mean speed up to approximately four and five miles per hour were detected at a few locations.

In comparison to the large number of significant results in the treatment group, only three out of 37 dataset pairs from the control group (8.1%) yielded significant results for the second null hypothesis, suggesting that mean speeds did not decrease by more than 1.25 mph at most sites.

5.3.2 85th Percentile Speeds

The 85th percentile operating speed has traditionally been used as an important input when setting speed limits. Thus, the magnitude or direction of change in the 85th percentile speed is of interest to this study. A modified *t*-test was used to determine the significance of differences in the 85th percentile speeds from the 'before' condition to the 'after' condition. Details of the test can be found in *Hou et al.* (*2012*).

As with the hypothesis tests for the mean speeds, a 95% confidence level was used, and two null hypotheses were tested. The first null hypothesis states that the 85th percentile speed in the 'before' condition is equal to the 85th percentile speed in the 'after' condition, H_0: $\zeta_{85,B} - \zeta_{85,A} = 0$. The alternative hypothesis is that the mean speed in the 'after' condition is greater than the mean speed of the 'before' condition, H_A: $\zeta_{85,B} - \zeta_{85,A} < 0$. A statistically significant result ($p < 0.05$) would imply that 85th percentile speeds were higher in the 'after' period.

The second null hypothesis tested states that the 85th percentile speed in the 'before' condition is equal to 1.25 mph greater than the 85th percentile speed in the 'after' condition, H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$. The alternative hypothesis states that the 85th percentile speed of the 'before' condition is more than 1.25 mph greater than the 85th percentile speed of the 'after' condition (H_A: $\zeta_{85,B} - \zeta_{85,A} > 1.25$). A rejection of the second null hypothesis ($p < 0.05$) would suggest that 85th percentile speeds decreased by more than 1.25 mph (one-quarter of the change in the PSL for treatment pairs) from the 'before' period to the 'after' period.

5.3.2.1 Hypothesis Test for Equality of 85th Percentile Speeds

Only two of the 45 treatment pairs (4.4%) showed statistically significant increases in the 85th percentile speeds, rejecting the null hypothesis that the 'before' and 'after' 85th percentile speeds were equal. Both dataset pairs also rejected the first null hypothesis for mean speeds, H_0: $\mu_B - \mu_A = 0$. Increases of one and five miles per hour were observed. The 5-mph increase occurred at one of the two Holgate-location datasets displaying a normal-mixture distribution.

Four of 37 control dataset pairs (10.8%) yielded significant results for the first null hypothesis for the 85th percentile speeds, three of which are designated as neighborhood greenways. All four of these control pairs also produced significant results for the first null hypothesis for mean speeds. Increases in 85th percentile speeds of one to three miles per hour were observed.

5.3.2.2 Hypothesis Test for Decrease of 85th Percentile Speeds by 1.25 mph

The second null hypothesis for 85th percentile speeds states that the 85th percentile speed 'before' is 1.25 mph higher than the 85th percentile speed 'after'. A total of 28 of the 45 treatment dataset pairs (62.2%) generated statistically significant results, rejecting the null hypothesis. These results would indicate the 85th percentile speeds in the 'after' condition were reduced by more than 1.25 mph. Most (22 out of 28) of the treatment pairs that rejected the null were located on designated neighborhood greenways. Nearly all significant dataset pairs (26 of 28) also had significant decreases in mean speed. Decreases in 85th percentile speeds for treatment pairs ranged from two to five miles per hour.

Only five of the 37 control dataset pairs (13.5%) rejected the second null hypothesis for 85th percentile speeds. Decreases in 85th percentile speeds of two to three miles per hour were observed.

5.3.3 Variance of Speed

The variance of speeds (the square of standard deviation) for the 'before' and 'after' datasets were analyzed using an F-test. The null hypothesis for variance states that the speed variance of the 'before' dataset is equal to the speed variance of the 'after' dataset, H_0: $\sigma_B^2 = \sigma_A^2$. The alternative hypothesis is that the variance in the 'after' condition is not equal to the variance in the 'before' condition, H_A: $\sigma_B^2 \neq \sigma_A^2$. For a p-value less than 0.05, the null hypothesis is rejected, which suggests that the speed variance either increased or decreased in the 'after' condition.

Only 21 of the 45 treatment dataset pairs, or 46.7%, were found to have a variance in the 'after' period that was significantly lower than in the 'before' period. Of these 21 treatment pairs, ten were collected from non-neighborhood greenways. Eight of the 45 treatment pairs (17.8%) experienced a significant *increase* in variance from the 'before' to 'after' periods.

Twelve of the 37 control dataset pairs (32.4%) resulted in a rejection of the null hypothesis in favor of a decrease in the variance during the 'after' period. Conversely, the variance significantly increased from the 'before' to 'after' periods in nine of 37 control dataset pairs (24.3%).

5.3.4 Proportions Exceeding the Speed Threshold

The proportions of vehicles exceeding a defined speed threshold were compared for all treatment and control dataset pairs using a chi-square test. In the chi-square test, the null hypothesis states that the proportion of class two vehicles exceeding the speed threshold in the 'before' condition is equal to the proportion of class two vehicles exceeding the speed threshold in the 'after' condition, H_0: $P_B - P_A = 0$. The alternative hypothesis is that the proportion of vehicles exceeding the speed threshold in the 'before' condition is not equal to the proportion exceeding the threshold in the 'after' condition, H_A: $P_B - P_A \neq 0$. A statistically significant result ($p < 0.05$) would indicate that the percent of vehicles traveling at speeds higher than the threshold either decreased or increased in the 'after' period. The posted speed limit (PSL) of the dataset from the 'after' condition was chosen as the speed threshold. Thus, for control pairs, the speed threshold is also equal to the PSL of the 'before' dataset.

For treatment data, the proportion of vehicles exceeding the speed threshold decreased significantly in 39 of the 45 (86.7%) dataset pairs. Decreases ranged from 4% up to 58%, with an average decrease of 25%. In comparison, only 12 of the 37 control datasets (32.4%) rejected the null, with decreases in the proportions exceeding the speed threshold of 2% to 12%.

Significant increases in the proportion of vehicles exceeding the speed threshold were found in 3 of the 45 treatment datasets (6.7%), all of which were collected from sites with higher PSLs. Increases ranged from 7% to 16%. For control data, significant increases of 1% to 8% were found in 7 of the 37 dataset pairs (18.9%).

5.3.5 Summary of Hypothesis Testing Full Datasets

A summary of the hypothesis testing results is given in Table 5.1. The table provides the percent of dataset pairs producing statistically significant results for each hypothesis test, for the treatment and control groups. Within each group, percentages for the neighborhood greenway and non-neighborhood greenway sites are given in addition to the total percentage. The number of dataset pairs in each category is given in the column headings.

Table 5.1: Summary of Treatment and Control Dataset Pairs Producing Statistically Significant Results for the Hypothesis Tests

	Treatment Pairs						Control Pairs					
Hypothesis Test:	**G (of 30)**		**NN (of 15)**		**Total (of 45)**		**G (of 24)**		**NN (of 13)**		**Total (of 37)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
$H_0: \mu_B - \mu_A = 0$ $H_A: \mu_B - \mu_A < 0$	0	0.0	5	33.3	5	11.1	9	37.5	2	15.4	11	29.7
$H_0: \mu_B - \mu_A = 1.25$ $H_A: \mu_B - \mu_A > 1.25$	22	73.3	6	40.0	28	62.2	2	8.3	1	7.7	3	8.1
$H_0: \zeta_{85,B} - \zeta_{85,A} = 0$ $H_A: \zeta_{85,B} - \zeta_{85,A} < 0$	0	0.0	2	13.3	2	4.4	3	12.5	1	7.7	4	10.8
$H_0: \zeta_{85,B} - \zeta_{85,A} = 1.25$ $H_A: \zeta_{85,B} - \zeta_{85,A} > 1.25$	22	73.3	6	40.0	28	62.2	3	12.5	2	15.4	5	13.5
$H_0: \sigma_B^2 = \sigma_A^2$ $H_A: \sigma_B^2 > \sigma_A^2$	11	36.7	10	66.7	21	46.7	6	25.0	6	46.2	12	32.4
$H_0: \sigma_B^2 = \sigma_A^2$ $H_A: \sigma_B^2 < \sigma_A^2$	6	20.0	2	13.3	8	17.8	8	33.3	1	7.7	9	24.3
$H_0: P_B - P_A = 0$ $H_A: P_B - P_A > 0$	30	100.0	9	60.0	39	86.7	7	29.2	5	38.5	12	32.4
$H_0: P_B - P_A = 0$ $H_A: P_B - P_A < 0$	0	0.0	3	20.0	3	6.7	5	20.8	2	15.4	7	18.9

NN = non-neighborhood greenway, G = designated neighborhood greenway

To facilitate the comparison of percentages, Table 5.2 presents the same information shown in Table 5.1 but compares treatment and control results without including the number of sites.

The results of the hypothesis tests for mean speed are generally in agreement with those for the 85th percentile speed across the treatment and control dataset pairs. More than 62% of the 45 treatment pairs showed statistically significant reductions in mean and 85th percentile speeds of more than 1.25 mph compared to only 8.1% and 13.5% of the 37 pairs in the control group for mean and 85th percentile speeds, respectively. Furthermore, the number of dataset pairs exhibiting any increase in the mean or 85th percentile speeds was lower for the treatment group than the control group.

Table 5.2: Summary of the Percent of Treatment and Control Dataset Pairs Producing Statistically Significant Results for All Hypothesis Tests

Hypothesis Test	Neighborhood Greenway (G)		Non-Neighborhood greenway (NN)		All (G+NN)	
	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.
$H_0: \mu_B - \mu_A = 0$ $H_A: \mu_B - \mu_A < 0$	37.5	0.0	15.4	33.3	29.7	11.1
$H_0: \mu_B - \mu_A = 1.25$ $H_A: \mu_B - \mu_A > 1.25$	8.3	73.3	7.7	40.0	8.1	62.2
$H_0: \zeta_{85,B} - \zeta_{85,A} = 0$ $H_A: \zeta_{85,B} - \zeta_{85,A} < 0$	12.5	0.0	7.7	13.3	10.8	4.4
$H_0: \zeta_{85,B} - \zeta_{85,A} = 1.25$ $H_A: \zeta_{85,B} - \zeta_{85,A} > 1.25$	12.5	73.3	15.4	40.0	13.5	62.2
$H_0: \sigma_B^2 = \sigma_A^2$ $H_A: \sigma_B^2 > \sigma_A^2$	25.0	36.7	46.2	66.7	32.4	46.7
$H_0: \sigma_B^2 = \sigma_A^2$ $H_A: \sigma_B^2 < \sigma_A^2$	33.3	20.0	7.7	13.3	24.3	17.8
$H_0: P_B - P_A = 0$ $H_A: P_B - P_A > 0$	29.2	100.0	38.5	60.0	32.4	86.7
$H_0: P_B - P_A = 0$ $H_A: P_B - P_A < 0$	20.8	0.0	15.4	20.0	18.9	6.7

Cont. = control group, Treat. = treatment group

Dataset pairs from neighborhood greenway sites constitute two-thirds or more of all pairs tested in both the treatment and control groups. For the treatment group, the majority of the statistically significant decreases in mean and 85th percentile speeds occurred at sites located on neighborhood greenways (22 out of 28 treatment pairs). For the control group, sites located on neighborhood greenways comprised more of the significant increases in mean and 85th percentile speeds (nine of eleven pairs for mean speed and three of four pairs for the 85th percentile).

Speed variance was significantly reduced in almost 50% more treatment pairs than control pairs (47% versus 32%). Thirteen of the 21 significant treatment pairs also experienced reduced mean speeds while four treatment pairs showed mean speeds increased in the 'after' period. About half of the significant pairs in each group (treatment and control) were from sites located on neighborhood greenways. Additionally, increases in speed variance were proportionally more prevalent in control pairs than treatment pairs at neighborhood greenway locations.

The proportion of vehicles exceeding the speed threshold, defined as the posted speed limit of the dataset in 'after' condition, decreased in almost 87% of treatment pairs by an average of 25%. In comparison, only 32% of the control pairs demonstrated decreases in the proportions of vehicles exceeding the speed thresholds. Decreases in the proportion of vehicles exceeding the speed thresholds were of smaller magnitude for control pairs than treatment pairs and ranged from 2% to 12%. Meanwhile, increases of 1% to 8% were seen in seven of the control pairs.

Overall, the mean, 85^{th} percentile, and standard deviation were reduced in more treatment pairs than control pairs. The proportion of vehicles exceeding the speed threshold was also reduced in more treatment pairs than control pairs, and by a larger amount on average.

5.4 HYPOTHESIS TESTING (FREE-FLOW DATA)

The analysis in Chapter 4 identified relationships between mean speed and mean gap time or vehicle volume for 35 of the 37 non-neighborhood greenway datasets and two of the 63 greenway datasets. Due to this discovery, a second set of hypothesis tests focusing on these treatment and control pairs were performed. Datasets were limited to observations with gap times greater than or equal to the mean gap time of the entire dataset to ensure free-flow conditions. A total of 13 treatment and 14 control pairs were tested.

As in Section 5.3, when all datasets with all class two observations were included, mean and 85^{th} percentile speeds were tested using one and two-tailed *t*-tests. Speed variance was compared using an F-test, and a chi-square test was used to compare the proportions of vehicles exceeding a speed threshold which was defined as the posted speed limit (PSL) of the dataset in the 'after' period. The confidence level was set at 95% for all hypothesis tests.

Below is the summary of the hypothesis testing free-flow datasets.

5.4.1 Summary of Hypothesis Testing Free-Flow Datasets

It is first important to note that conclusions drawn from these results should be interpreted cautiously as there are a limited number of datapoints on which to base trends. However, the results did largely agree with the insights obtained when all observations were retained for analysis in Section 5.3.

Table 5.3 provides a summary of the hypothesis testing significance results. The total number of dataset pairs in each group is given in the column headings. The percentages of significant results for each hypothesis test do not differ as much between the treatment and control groups when only the free-flow data are considered compared to when all data were considered in Section 5.3. However, if just the results for the non-neighborhood greenway pairs for the treatment and control groups from Section 5.3 are compared, it can be seen that the results of most of the hypothesis tests for free-flow datasets are largely in agreeance. A slightly higher percentage of free-flow control datasets showed increased mean and 85^{th} percentile speeds than when all observations were retained. No free-flow control datasets showed evidence of an increased proportion of vehicles exceeding the speed threshold.

Table 5.3: Summary of Free-Flow Dataset Pairs Producing Significant Results for the Hypothesis Tests

Hypothesis Test:	Treatment (of 13)		Control (of 14)	
	N	%	N	%
H_0: $\mu_B - \mu_A = 0$ H_A: $\mu_B - \mu_A < 0$	3	23.1	4	28.6
H_0: $\mu_B - \mu_A = 1.25$ H_A: $\mu_B - \mu_A > 1.25$	5	38.5	1	7.1
H_0: $\zeta_{85,B} - \zeta_{85,A} = 0$ H_A: $\zeta_{85,B} - \zeta_{85,A} < 0$	1	7.7	3	21.4
H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$ H_A: $\zeta_{85,B} - \zeta_{85,A} > 1.25$	6	46.2	2	14.3
H_0: $\sigma_B^2 = \sigma_A^2$ H_A: $\sigma_B^2 > \sigma_A^2$	10	76.9	6	42.9
H_0: $\sigma_B^2 = \sigma_A^2$ H_A: $\sigma_B^2 < \sigma_A^2$	2	15.4	2	14.3
H_0: $P_B – P_A = 0$ H_A: $P_B – P_A > 0$	7	53.8	4	28.6
H_0: $P_B – P_A = 0$ H_A: $P_B – P_A < 0$	3	23.1	0	0.0

N = number of dataset pairs, % = percent of dataset pairs

5.5 DATA COLLECTION RECOMMENDATIONS

One of the interesting discoveries made during the data analysis was that two of the datasets from the Holgate east of 111th location did not seem to follow the same patterns and trends as datasets on similarly classed roads with the same posted speed limits. As discussed in Chapter 4, neither direction of the June 2019 survey at Holgate east of 111th followed the trends observed at other non-neighborhood greenway sites where speeds seemed to be affected by gap times and vehicle volumes. Figures 5.3 and 5.4 show the mean speed versus mean gap and mean speed versus vehicle count for the eastbound direction of the June 2019 Holgate east of 111th survey. Compared to the plots provided in Chapter 4, these more closely resemble the plots from the neighborhood greenway sites.

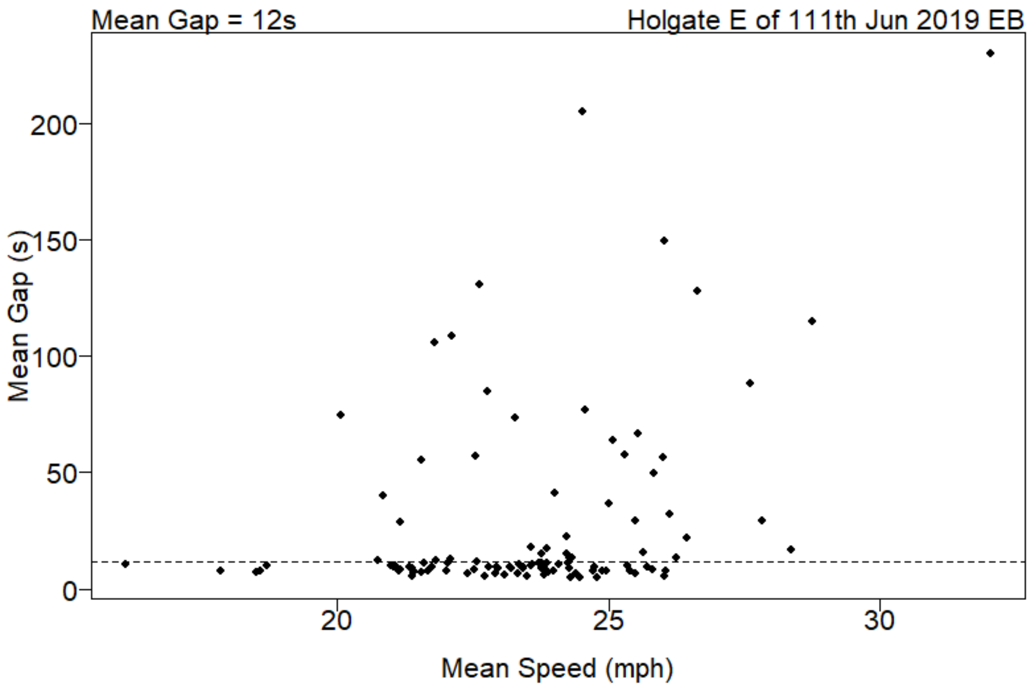

Figure 5.3: Mean speed vs. mean gap for eastbound Holgate east of 111th with data binned in 15-minute intervals.

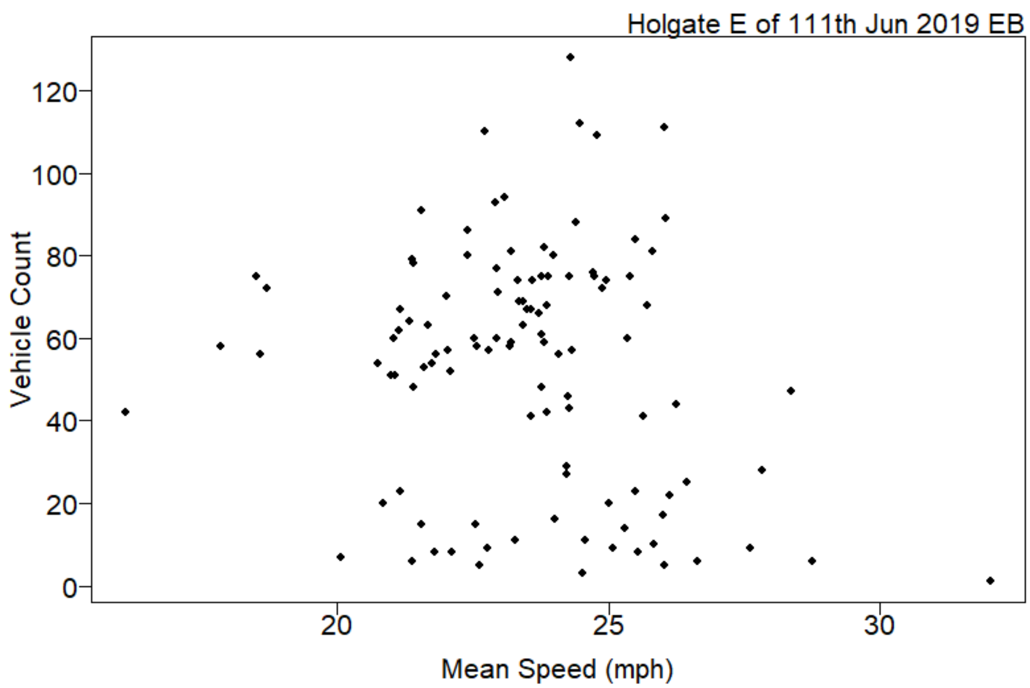

Figure 5.4: Mean speed vs. vehicle count for eastbound Holgate east of 111th with data binned in 15-minute intervals.

In addition to the deviation from the relationship patterns found at other non-neighborhood sites, two datasets from the Holgate east of 111th location – westbound from the February 2017 survey and eastbound from the June 2019 survey –displayed speed distributions which appear to be comprised of a combination of two normal distributions, having two distinct modes, as seen in Figures 5.5 and 5.6. The posted speed limit (PSL) and the 50th and 85th percentiles for the entire dataset are shown in the figures. It is evident that the 50th and 85th percentiles would be much higher for the eastbound dataset if only the group of observations on the right were considered. The 50th percentile of the right-hand group of observations in Figure 5.6 is estimated by visual inspection to be about 32 mph, significantly higher than the value of 23 mph calculated for the whole dataset.

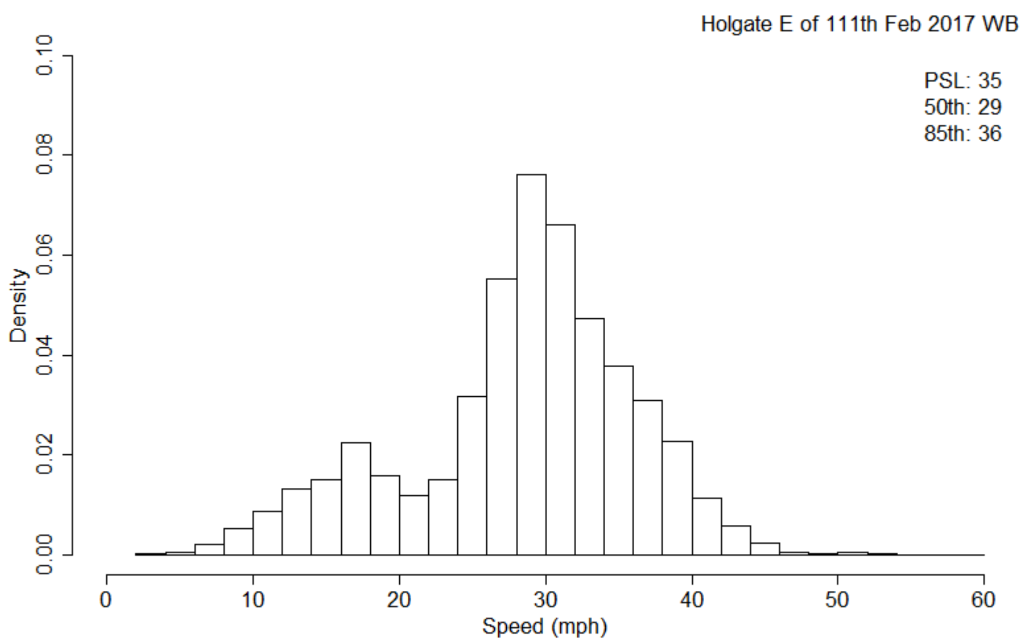

Figure 5.5: Class two speed histogram for the February 2017 westbound Holgate east of 111th dataset.

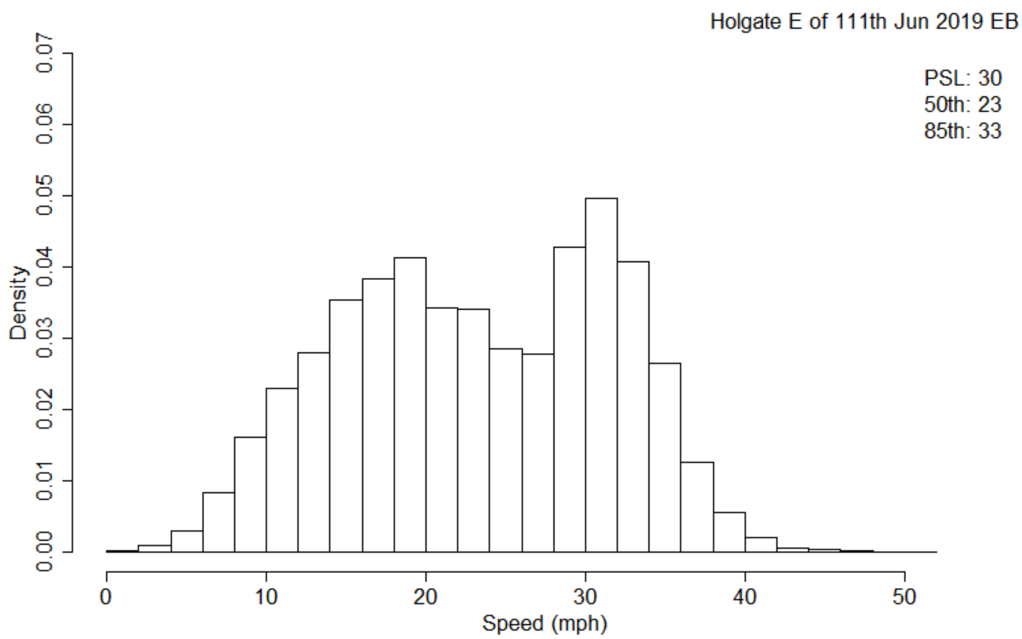

Figure 5.6: Class two speed histogram for the June 2019 eastbound Holgate east of 111th dataset.

It is suspected that the close proximity to the traffic signal at 112th (250 ft. east) and a high volume of traffic turning from 112th affects vehicle speeds at the Holgate east of 111th location. An overview of the area is provided in Figure 5.7, with a red arrow indicating the approximate location of the data collection. The smaller group on the left in the histogram of Figure 5.5 may be representing vehicles that were accelerating from the signal or had made a right turn onto Holgate from 112th but had not yet reached cruising speed by the time they crossed the data collection location. The larger group on the left of the histogram in Figure 5.6 likely captured vehicles slowing for the signal or for left turns at 112th. The groups on the right of Figures 5.5 and 5.6 are expected to be more representative of the uninhibited free-flow speeds at this location.

The speed characteristics at Holgate east of 111th may lead to incorrect conclusions about speeding along Holgate due to the significant presence of slow moving right turning vehicles (westbound) or vehicles that slow down due to a red indication (eastbound).

Figure 5.7: Location of data collection at Holgate east of 111th. (*Google Maps, 2020*)

Data collected along Holgate at nearby locations further from the traffic signal at 112th show higher mean and 85th percentile speeds than those from data collected at 111th. Mean speeds on Holgate east of 113th are approximately 33 mph, and 85th percentile speeds are 37 mph. Data from Holgate east of 116th also provide evidence of higher speeds as the distance from the traffic signal increases. Mean speeds at 116th are approximately 33 mph to 35 mph, and 85th percentile speeds are 37 mph to 39 mph. These speeds are generally much higher than mean and 85th percentile speeds for data collected east of 111th (refer to Figures 5.5 and 5.6). The effect of right-turning traffic from 112th is also apparent by looking at the ADT for westbound traffic at 111th and 113th. Data at these locations were collected concurrently in June 2019. The westbound ADT at 113th was approximately 8,000 vehicles and was about 1,000 vehicles more east of 111th.

In general, speed data collected from a location too close to a traffic control device or another condition that would inhibit free flow may not be representative of the whole segment. Several other datasets within the analysis that were collected from within 500 feet of a traffic control device were identified. When speed data from a nearby location along the segment was available from a comparable time period, differences among the mean and 85th percentile speeds and the percent of vehicles exceeding the PSL were examined. These results are shown in Table 5.4, along with the approximate distances from the nearest traffic control device. Differences in mean speed from the nearby upstream or downstream locations range from approximately one mile per hour to more than 11 mph faster than the sites within 500 ft. of a traffic control device. Increased

85th percentile speeds and the percent of vehicles exceeding the PSL are also seen at all comparable locations.

These findings highlight the importance of selecting data collection locations where vehicle speeds are not constrained by traffic control devices or large volumes of turning traffic. A distance of 500 ft. from such constraints may be sufficient for roads such as those examined in this study and is recommended as the minimum distance from a data collection location.

Table 5.4: Basic Speed Statistics for Sites Within 500 ft. of a Traffic Control Device Compared to a Nearby Location on the Segment.

Sites	PSL	Mean	85th	% Exc. PSL	Distance (ft.)
Clinton W of 13th Jul 2015 EB	25	20.17	23	3.62	260
Clinton W of 14th Aug 2014 EB	25	22.30	25	14.66	520
Difference		*2.13*	*2*	*11.04*	
Clinton W of 13th Jul 2015 WB	25	17.68	21	16.67	260
Clinton W of 14th Aug 2014 WB	25	22.00	25	70.38	520
Difference		*4.32*	*4*	*53.71*	
Harrison E of 25th Feb 2017 EB	25	18.00	21	18.91	210
Harrison W of 23rd Jun 2016 EB	25	21.93	25	67.85	670
Difference		*3.93*	*4*	*48.94*	
Harrison E of 25th Feb 2017 WB	25	17.84	21	1.42	210
Harrison W of 23rd Jun 2016 WB	25	22.60	27	22.59	670
Difference		*4.76*	*6*	*21.17*	
Holgate E of 111th Jun 2019 EB	30	18.52	22	1.87	250
Holgate E of 116th Sep 2019 EB	30	22.97	27	26.25	1160
Difference		*4.45*	*5*	*24.38*	
Holgate E of 111th Jun 2019 WB	30	20.73	24	5.80	250
Holgate E of 116th Sep 2019 WB	30	21.83	27	21.79	1160
Difference		*1.10*	*3*	*15.99*	
Lincoln E of 50th Mar 2017 EB	20	19.12	23	1.64	100
Lincoln E of 52nd Feb 2017 EB	20	24.65	29	42.71	640
Difference		*5.53*	*6*	*41.07*	
Lincoln E of 50th Mar 2017 WB	20	23.29	33	25.66	100
Lincoln E of 52nd Feb 2017 WB	20	34.61	39	86.68	640
Difference		*11.32*	*6*	*61.02*	
Lincoln E of 50th Feb 2012 WB	25	26.90	32	23.90	100
Lincoln W of 53rd Feb 2012 WB	25	33.18	37	77.55	800
Difference		*6.28*	*5*	*53.65*	

Distance = distance to the nearest traffic control device

5.6 SUMMARY AND DISCUSSION

This section compared speed trends and characteristics on sites with PSL changes (treatment sites) and sites with no PSL change (control sites). Some clear trends were observed, which are summarized in this section. A discussion of insights related to data collection and analysis methods, the impact of facility type, and speed monitoring procedures are also included.

5.6.1 Summary

A high percentage of cyclists, more than 20% of traffic, are typically present on shared-use roadways that are also neighborhood greenways. Overall, the results of the data analyses suggest there are distinct differences between neighborhood greenway sites and non-neighborhood greenway sites, and between treatment pairs and control pairs. Class two traffic volumes and 85th percentile speeds were generally lower at neighborhood greenway sites than non-neighborhood greenway sites with comparable speed limits. Also, class one volumes (including bicycles) were highest at neighborhood greenway sites, on average.

Neighborhood greenway and non-neighborhood greenway sites displayed different relationship patterns between speed and gap time or vehicle counts when data were aggregated into and averaged over 15-minute intervals. Positive relationships between mean speed and mean gap time and negative relationships between mean speed and vehicle counts were revealed in most non-neighborhood greenway datasets, suggesting that speeds at these sites were affected by non-free-flow conditions. These patterns were absent in nearly all of the neighborhood greenway datasets. This discovery guided the decision to perform separate analyses on datasets displaying the relationship patterns when the observations were limited to free-flow conditions.

The results of a before and after study indicate that treatment sites experienced larger decreases in mean, 85th percentile, and 10-mph pace speeds than control sites when all observations are included. However, plots of the change in mean speed versus the length of time between repeated surveys suggest speeds may be declining over time regardless of a change in the posted speed limit. This may be due in part to an ongoing educational traffic safety campaign. When specific datasets identified in Chapter 4 were limited to free-flow observations, the changes across the performance measure categories were largely in agreement with the analysis that included all datasets with all observations.

Differences between neighborhood greenway and non-neighborhood greenway sites were observed when class two traffic volumes were compared in the before and after analysis. The estimated ADT decreased significantly on average for both the treatment and control neighborhood greenway dataset pairs. In contrast, a minor increase, on par with regional VMT changes throughout the data collection period, was observed for non-neighborhood greenway dataset pairs. Treatment pairs did show a larger average decrease for neighborhood greenways and a smaller average increase for non-neighborhood greenways than control pairs. Changes in the mean speed and changes in class two ADT are correlated at neighborhood greenway sites with larger decreases in mean speed coinciding with larger reductions in ADT. This correlation was not observed at non-neighborhood greenway sites.

Hypothesis tests, including all observations of all datasets, also revealed differences between treatment and control groups, and neighborhood greenway and non-neighborhood greenway sites. Mean and 85th percentile speeds and the standard deviation significantly decreased in a larger share of the treatment pairs than control pairs. The proportion of vehicles exceeding defined speed thresholds also decreased in a higher percentage of treatment pairs, and by a larger amount on average than control pairs. Within the treatment pairs, the percent of neighborhood greenway pairs resulting in significant reductions in mean and 85th percentile speeds and the proportion of vehicles exceeding speed thresholds was higher compared to the percent of non-neighborhood greenway pairs. Meanwhile, significant increases in the mean and 85th percentile speeds and proportion of vehicles exceeding the speed thresholds were found in a higher percentage of control pairs than treatment pairs.

Limiting the hypothesis testing to free-flow datasets, a similar conclusion was reached as to when all datasets with all observations were included – treatment pairs were more likely to result in significant decreases in mean and 85th percentile speeds and the proportion of vehicles exceeding speed thresholds than control pairs. The difference between the two groups was less prominent than when all datasets were retained, possibly due to the absence of neighborhood greenway pairs in the free-flow analysis, which were previously found to have an increased likelihood of producing significant decreases.

5.6.2 Discussion

In terms of data collection, it is recommended that data collected to analyze speed characteristics are not obtained from locations near traffic control devices. It is recommended that data collection is performed more than 500 ft. from a traffic control device, intersection with a high volume of turning traffic, or major traffic calming installations to avoid non-free-flowing traffic conditions.

It is recommended that speed distributions are always plotted and analyzed to determine whether traffic control devices or other factors are affecting the speed measurements. Otherwise, the speed data collected will not be representative of free-flowing traffic and likely underestimate speed characteristics along a roadway segment. It is also recommended that speed distributions are analyzed to observe significant departures from normal distribution shapes that may signal the presence of non-free flowing traffic conditions.

Based on the results observed, it recommended that speed-gap and speed-volume scatter plots are utilized to discern the type of operation of a location and if the type of traffic observed matches what is expected from the functional classification.

The statistical tests indicate that a PSL reduction is more likely to reduce speed characteristics on neighborhood greenways than on non-neighborhood greenways. More than 73% of the treatment sites located on neighborhood greenways experienced a reduction in mean and 85th speed distributions of at least 1.25 mph. For non-neighborhood greenway treatment sites, only 40% of the treatment sites experienced a decrease in mean and 85th speed distributions of at least 1.25 mph. These percentages are noticeably higher than the approximately 10% of control sites with a reduction in mean and 85th speed distributions of at least 1.25 mph.

PSL reductions of 5 mph are likely to reduce speed characteristics such as mean or 85th percentile by 1.25 mph. However, it is important to highlight that there is a high degree of variability in the outcomes and that a priori, it is not possible to ascertain whether a PSL will reduce speed characteristics. For example, nearly 33% of the treatment non-neighborhood greenways experienced an increase in mean speed even though the PSL was reduced by 5 mph. Nearly 13% of the treatment non-neighborhood greenways experienced an increase in the 85th speed percentile even though the PSL was reduced by 5 mph. Approximately 18% of the treatment sites experienced an increase in speed variance. Hence, it is always recommended to monitor speed characteristics before and after PSL changes and take additional measures to address situations where speed characteristics such as mean, 85th percentile, and speed variance increase after a PSL reduction.

It is also recommended to monitor traffic volumes before and after PSL changes at the site and alternative travel paths for motorized vehicles. Despite increases in VMT figures in the region, a trend towards a reduction in motorized volumes was observed. There is a high degree of variability across sites, though. In some roadways, it is likely that changes in motorized volumes are also linked to reductions in speed characteristics such as the mean or 85th percentile. It is also possible that motorized traffic is diverting to other roadways without PSL changes, or that more general changes related to mode choice or origin-destination matrices are taking place.

6.0 ANALYSIS OF FACTORS THAT AFFECT AVERAGE OPERATING SPEED

Many traffic, roadway, and contextual variables were collected for analysis in conjunction with the speed data provided by PBOT. This section provides the names and descriptions of the variables deemed to be most important based on findings in the literature review and guidance from the TAC. The focus is on variables that can be measured or observed on the field.

High correlations within these variables and between the natural logarithm of mean speed and these variables are discussed. Also, the results of simple linear regression models using two variables – the posted speed limit (PSL) plus each of the additional variables added one at a time – are summarized. The logarithmic transformation is utilized to facilitate comparisons because it is prevalent in similar studies, e.g. Hu and Cicchino *(2020)*, and because the transformed model better meets the least square regression assumptions. It is also important to note that the median or 50^{th} percentile and the mean are very similar as discussed in a previous section. However, for regression analysis it is advantageous to utilize the mean instead of the median. The analyses discussed in this chapter were performed using all observations (as opposed to free-flow only).

The names and descriptions of the variables used in the correlation and regression analyses are listed in Table 6.1. In this table, the following classical definitions are utilized to define the type of variable: Nominal or categorical to identify different type or classifications, ordinal when there is a natural order, interval when there is a fixed size of interval between data points (e.g. grade) and ratio when the variable has true "absolute" zero point (e.g. traffic volume).

6.1 LINEAR CORRELATION ANALYSIS

Throughout the study, it was observed that many of the independent variables collected were correlated with each other and with the dependent variable, the natural logarithm of mean speed (LogAvg). Table 6.2 provides a correlation matrix for all variables listed in Table 6.1. Most of the high correlations (highlighted) are rather intuitive but it is important to recognize there are several high correlations among independent variables and with the dependent variable. Henceforward, "correlation values" or simply "*r"* are used to denote linear correlation values.

This section discusses the relationships between LogAvg and each independent variable. Independent variables that were highly positively ($r \geq 0.5$) or highly negatively ($r \leq -0.5$) correlated with each other are also reviewed. The posted speed limit (PSL) was noted throughout the literature review as a significant factor affecting operating speed. As expected, the data analyzed within this research produced a high, positive correlation for LogAvg and PSL, with $r = 0.72$. High positive correlations between LogAvg and ADT ($r = 0.80$), Counts ($r = 0.79$), RoadWidth ($r = 0.72$), and BikeLane ($r = 0.83$) were also observed.

Table 6.1: Data Dictionary for Correlation and Regression Analyses

Dependent Variable		
Name	**Type**	**Definition**
LogAvg	Ratio	Natural logarithm of mean speed in mph.
Independent Variables		
Name	**Type**	**Definition**
PSL	Ratio	Posted speed limit in mph.
Counts	Ratio	Number of class two vehicles observed per hour between the hours of 10am and 3pm, divided by 10.
ADT	Ratio	Average daily traffic for class two vehicles in the direction of travel, divided by 100.
VolChg	Interval	Percent change in class two volume from the 'before' to 'after' period. All 'before' periods are therefore equal to zero.
C1Per	Ratio	Class one vehicles as percent of the total traffic volume.
RoadWidth	Ratio	Width of the entire roadway in feet. Sourced from PortlandMaps Open Data Pavement Management dataset.
SegLength	Ratio	Approximate length in miles between the centers of the intersections of the nearest traffic control devices that encompass the data collection location. Includes on-demand pedestrian signals and yield signs.
AccessDens	Ratio	Number of access points/driveways on both sides of the street within one block in either direction of the data collection location, divided by the length in miles of the two blocks.
Grade	Interval	Estimated road grade, in percent, in the direction of travel. Measured as the change in elevation divided by the distance between the adjacent contour lines that encompass the data collection location. Contour data sourced from USGS.
BikeShared	Categ.	TRUE = Observation was from a shared road/ neighborhood greenway.
BikeLane	Categ.	TRUE = Observation was from a road with a bike or buffered bike lane.
Bus	Categ.	TRUE = Observation was from a location along a TriMet bus route.
DotYel	Categ.	TRUE = Observation was from a location with a dotted yellow centerline.
LandUseCom	Categ.	TRUE = data collection site was located wholly within an "area of interest" on Google Maps (*Li, 2016*); used as a proxy to indicate commercial land use.
TrafCalmUp	Categ.	TRUE = speed hump of mini traffic circle was present within the segment and upstream of the data collection location.
TrafCalmDn	Categ.	TRUE = speed hump of mini traffic circle was present within the segment and downstream of the data collection location.

Table 6.2: Variable Correlation Matrix

	Log-Avg	ADT	Counts	Road-Width	PSL	Seg-Length	Vol-Chg	Grade	Access-Dens	C1-Per	Bike-Lane	Bus	Dot-Yel	Land-Use-Com	Traf-Calm-Dn	Traf-Calm-Up	Bike-Shared
LogAvg	1.00																
ADT	0.80	1.00															
Counts	0.79	0.98	1.00														
RoadWidth	0.72	0.82	0.82	1.00													
PSL	0.72	0.65	0.61	0.70	1.00												
SegLength	0.24	0.21	0.18	-0.14	0.08	1.00											
VolChg	0.23	0.27	0.24	0.20	0.16	0.16	1.00										
Grade	0.02	0.03	0.02	0.00	0.02	0.01	-0.13	1.00									
AccessDens	-0.24	-0.41	-0.42	-0.12	-0.02	-0.37	0.00	-0.06	1.00								
C1Per	-0.38	-0.47	-0.45	-0.26	-0.24	-0.33	-0.23	0.03	0.23	1.00							
BikeLane	0.83	0.83	0.79	0.80	0.77	0.10	0.19	0.08	-0.16	-0.29	1.00						
Bus	0.45	0.64	0.61	0.38	0.35	0.24	0.36	0.05	-0.32	-0.43	0.44	1.00					
DotYel	-0.11	0.13	0.13	-0.13	-0.33	0.43	0.29	0.01	-0.50	-0.33	-0.21	0.44	1.00				
LandUseCom	-0.18	0.19	0.19	-0.16	-0.28	0.40	0.24	0.00	-0.54	-0.38	-0.24	0.50	0.87	1.00			
TrafCalmDn	-0.33	-0.66	-0.63	-0.40	-0.26	-0.29	-0.31	-0.01	0.39	0.53	-0.46	-0.61	-0.46	-0.53	1.00		
TrafCalmUp	-0.36	-0.68	-0.65	-0.42	-0.25	-0.29	-0.27	-0.20	0.43	0.49	-0.48	-0.66	-0.48	-0.55	0.78	1.00	
BikeShared	-0.49	-0.81	-0.77	-0.49	-0.36	-0.42	-0.35	-0.06	0.58	0.54	-0.57	-0.77	-0.57	-0.66	0.80	0.84	1.00

Highlighted cells indicate highly correlated variables ($r \leq -0.5$ or $r \geq 0.5$).

From Table 6.2, it can also be seen that all of these variables are highly correlated with each other and with PSL, producing correlation values between 0.61 and 0.98. These relationships can be summarized as follows:

- Higher speed traffic is typically found on roads with higher PSLs,
- Wider roads tend to carry more vehicles and have higher operating speeds,
- Roads with more traffic tend to be of higher functional class with higher PSLs, and
- Bike lanes are more likely to be present on roads with higher speeds and higher volumes.

Figure 6.1 provides visual representations of these relationships. Each plot displays LogAvg vs. PSL, with the points shaded according to the values of the studied independent variable.

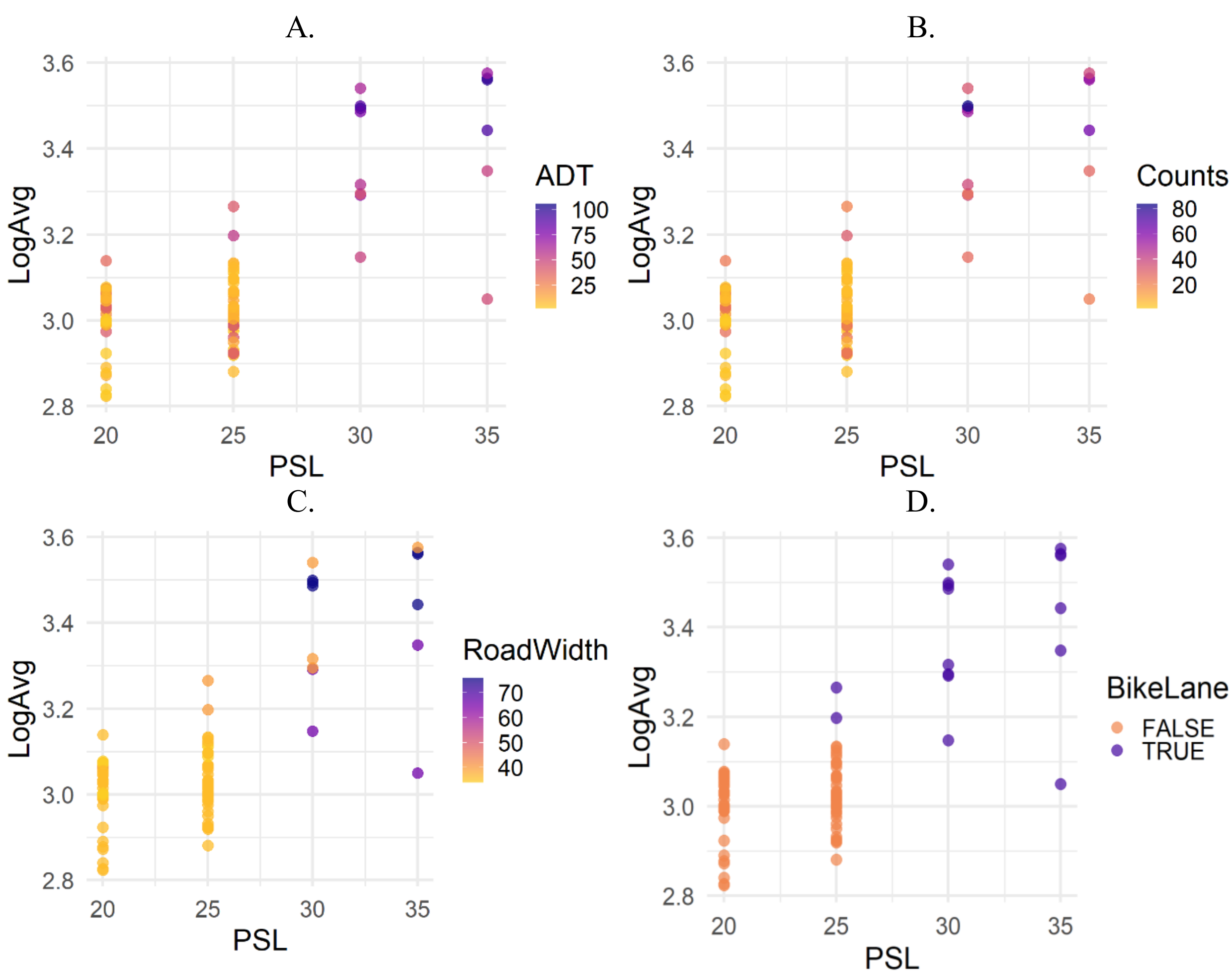

Figure 6.1: Scatterplots for independent variables highly positively correlated with LogAvg with respect to PSL.

Moderate negative correlations were observed between LogAvg and C1Per, BikeShared, and both variables representing the presence of traffic calming (TrafCalmUp and TrafCalmDn). These relationships are displayed visually in Figure 6.2 with respect to the PSL, similar to the plots in Figure 6.1. From Figure 6.2, it can be seen that shared bike facilities and traffic calming measures are only present at locations with lower PSLs, and that the class one volume (bicycles) is highest at such locations. Thus, it follows that these four variables are moderately to highly correlated with each other with correlation values in the range of 0.49 to 0.84.

In general, locations in this study with traffic calming, shared bikeway facilities, and high class one volumes represent neighborhood greenways. Since the purpose of this roadway type is to prioritize active travelers by reducing motorized vehicle speeds and volumes, it is not surprising that moderate to strong negative correlations were observed between variables representing neighborhood greenways and ADT, Counts, RoadWidth, or BikeLane.

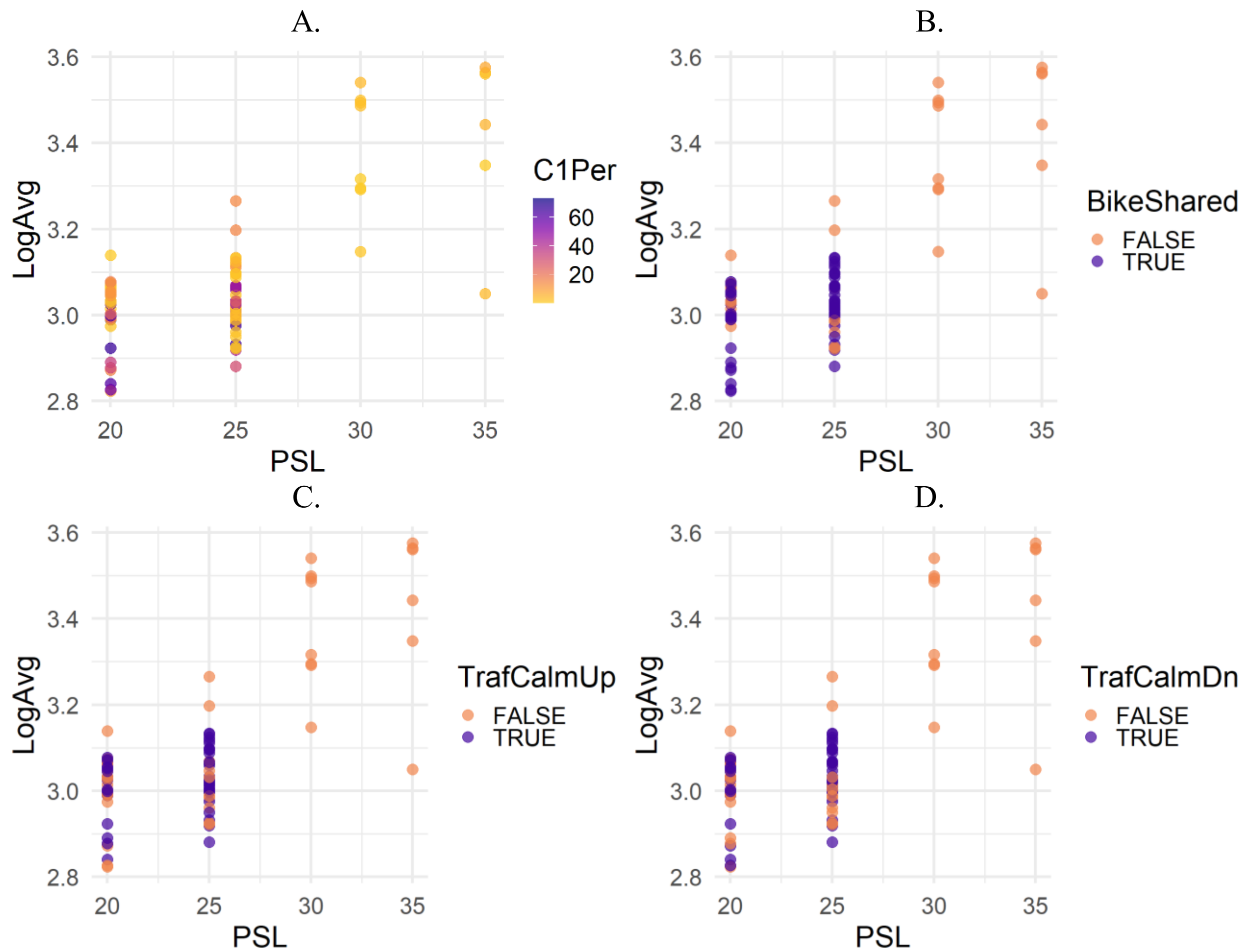

Figure 6.2: Scatterplots for independent variables moderately negatively correlated with LogAvg with respect to PSL.

The variables of Bus, DotYel, LandUseCom, and AccessDens did not display strong correlations with LogAvg, visualized in Figure 6.3, but they did show moderate to strong relationships with most of the variables representing neighborhood greenways. In addition, Bus was positively correlated with LandUseCom ($r = 0.5$), Counts ($r = 0.61$), and ADT ($r = 0.64$), and LandUseCom was highly positively correlated with DotYel ($r = 0.87$) and negatively correlated with AccessDens ($r = -0.54$). These correlations essentially indicate that dotted yellow centerlines are often present in areas of commercial land use, and bus routes tend to serve higher volumes streets and areas of commercial activity.

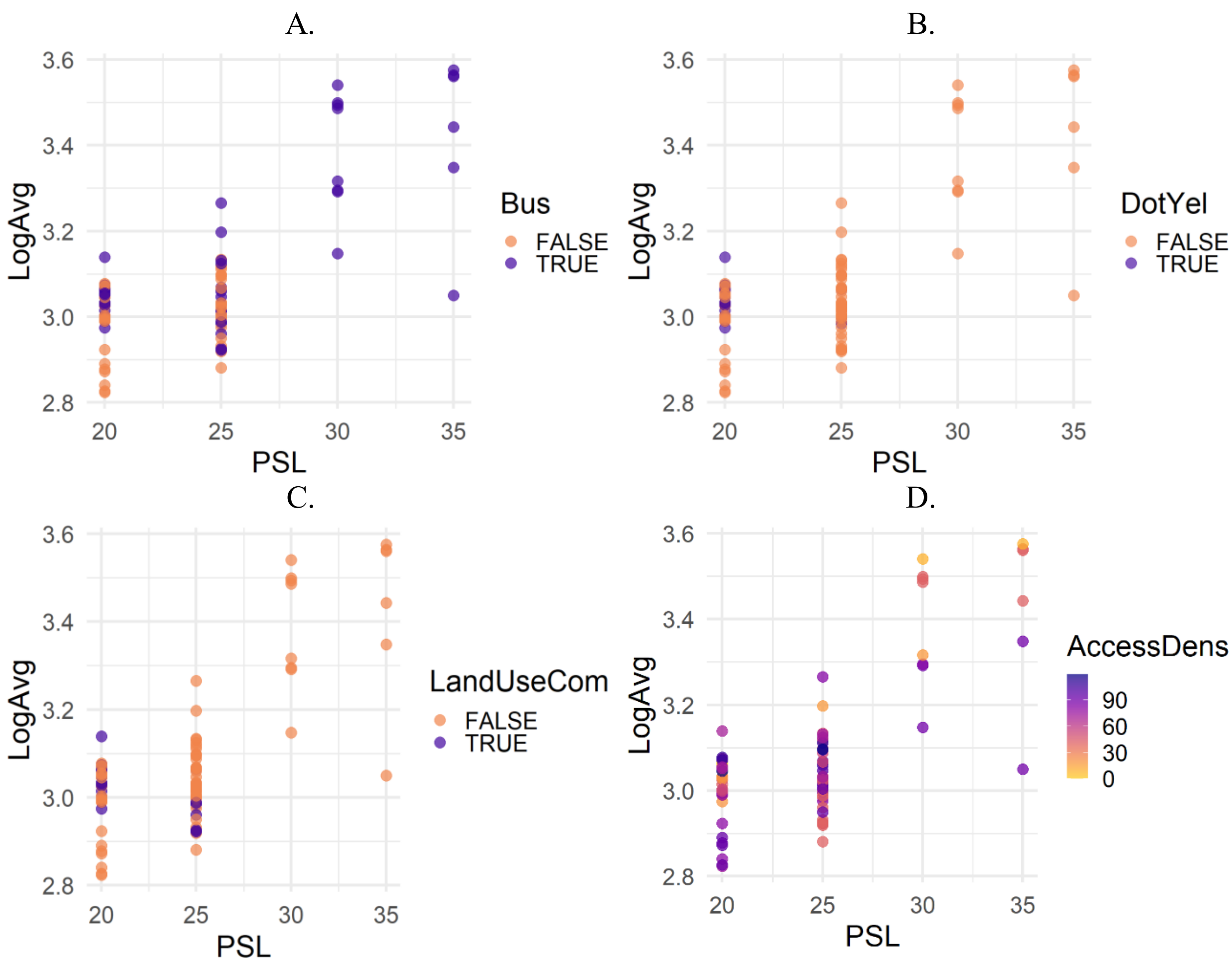

Figure 6.3: Scatterplots showing relationships of LogAvg to Bus, DotYel, LandUseCom, and AccessDens.

A few of the collected variables did not appear to have significant relationships to any other variables used in this analysis. Plots of SegLength, VolChg, and Grade versus LogAvg with respect to PSL are shown in Figure 6.4.

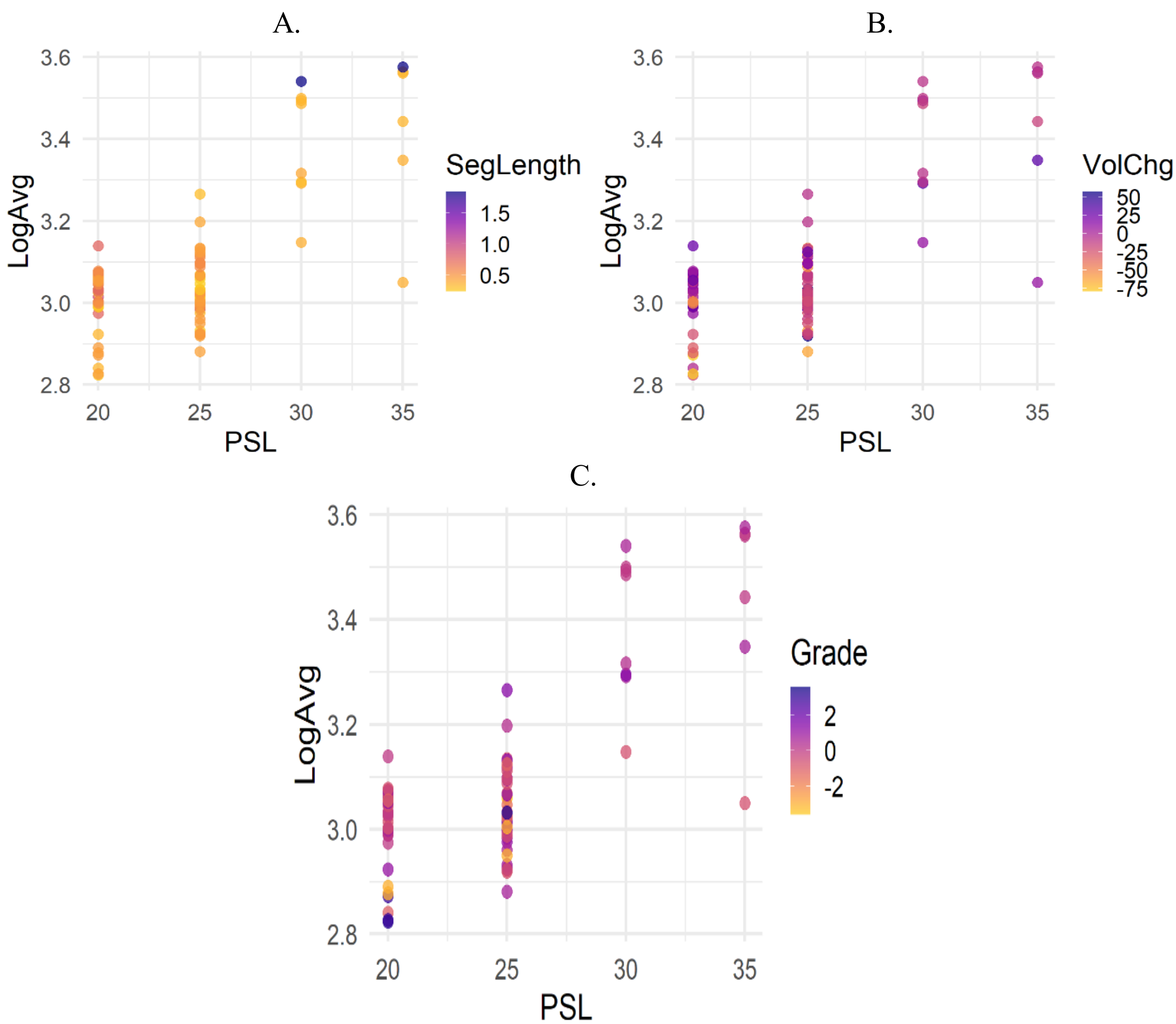

Figure 6.4: Scatterplots of uncorrelated variables.

6.2 VARIABLE SIGN AND CONTRIBUTION

To better understand the impact the independent variables described in Table 6.1 might have on the mean speed of a roadway, linear regression models were constructed using the natural logarithm of mean speed (LogAvg) as the dependent variable. Each model included the variable of PSL (base model) plus one of the additional independent variables. For each additional variable, the sign of the coefficient and the resulting change in the adjusted R^2 value from the base model, including only PSL, were recorded.

This section discusses the effects each additional variable has on the predictive power of the base model and how each variable affects the predicted mean speed. Ratio and interval type variables are discussed first, followed by the categorical variables. A summary of these results is provided in Table 6.3.

Table 6.3: Summary of Linear Regression Results for Each Independent Variable

Additional Variable Name	Type	Sign of Coefficient	Change in Adj. R^2
Base (PSL)	Ratio	+	NA
ADT	Ratio	+	0.192
Counts	Ratio	+	0.189
BikeLane	Categ.	+	0.187
RoadWidth	Ratio	+	0.090
BikeShared	Categ.	-	0.057
AccessDens	Ratio	-	0.045
C1Vol	Ratio	-	0.040
Bus	Categ.	+	0.039
SegLength	Ratio	+	0.027
TrafCalmUp	Categ.	-	0.027
TrafCalmDn	Categ.	-	0.015
DotYel	Categ.	+	0.012
VolChg	Interval	+	0.009
LandUseCom	Categ.	*	-0.005
Grade	Interval	*	-0.006

* not significant and negative contribution to adjusted R^2

6.2.1 Ratio and Interval Variables

On its own, the posted speed limit (PSL) explains about 51% of the variation in LogAvg. Table 6.3 shows that the variables of ADT and Counts add the biggest improvements to the fit of the base model. These two variables were very highly positively correlated with each other (r = 0.98), so it is not surprising that they explain nearly the same amount of variation in the models. The positive signs of the coefficients imply higher mean speeds are predicted at locations with higher traffic volumes, after accounting for PSL.

The addition of RoadWidth to the base model seems to provide a small improvement in the fit. The sign of the coefficient is positive, predicting higher mean speeds occur on wider roadways, after accounting for PSL.

Access or driveway density (AccessDens) also slightly improves the fit of the linear model. A negative coefficient implies slower mean speeds are predicted as access density increases, after accounting for PSL.

The class one percentage (C1Per) appears to have a small effect on the model fit. The negative sign of the coefficient indicates that lower mean speeds are predicted at sites where bicycles (class one vehicles) comprise a higher percentage of the total traffic, after accounting for PSL. Such conditions are typically found along neighborhood greenway streets.

Segment length (SegLength) offers a minor improvement in the model fit. A positive coefficient signifies that faster mean speeds are predicted at locations where vehicles can travel longer distances without encountering a traffic control device, after accounting for PSL.

The variable VolChg, a measure of the difference in traffic volume from the 'before' period to the 'after' period at the repeated survey sites, does not appear to have much effect on the prediction of mean speed. The positive sign for the coefficient suggests that sites that have higher volumes in the 'after' period might have slightly higher mean speeds, after accounting for PSL.

The grade of a roadway does not appear to affect the predictive power of the model in a significant way after accounting for PSL. In fact, when accounting for model parsimoniousness, the contribution is negative, as reflected by the negative change in adjusted R^2 square values.

6.2.2 Categorical Variables

Of the seven categorical variables examined, the addition of BikeLane to the base model with PSL showed the biggest improvement to the overall model adjusted R^2, after accounting for PSL. It provided the third largest improvement to the model overall. A positive coefficient means higher mean speeds would be predicted at locations where a bike lane was present, after accounting for PSL.

The BikeShared variable did not have nearly the same effect on model fit as the BikeLane variable appeared to have, with only a small improvement shown over the base model with only PSL. The negative coefficient signifies lower mean speeds are predicted (after accounting for PSL) at locations with shared road bike facilities, such as along neighborhood greenways.

Adding the Bus variable to the base model only brings a minor improvement in the predictive power. A positive coefficient suggests higher mean speeds are predicted at locations along a bus route, after accounting for PSL.

The presence of traffic calming, both upstream and downstream (TrafCalmUp and TrafCalmDn) seems to have very little effect on the fit of the models. Negative coefficients for both variables would imply lower mean speeds at locations where traffic calming was present, after accounting for PSL.

The categorical variable indicating the presence of a dotted yellow centerline (DotYel) has almost no effect on the model fit, but the positive coefficient would indicate higher mean speeds are predicted at locations with such centerline present, after accounting for PSL.

The presence of commercial land use also has essentially no contribution to the regression model, after accounting for PSL (similar to grade).

6.3 SUMMARY

The plots, correlation, sign, and variable contribution analysis supports the findings detailed in Section 4 regarding the different traffic behaviors of neighborhood greenway and non-neighborhood greenway streets. Neighborhood greenways are located on residential streets and employ traffic calming measures to keep traffic volumes and speeds low. These streets prioritize active travelers, and bicycles tend to comprise a significantly larger than average portion of the total traffic. Non-neighborhood greenway streets carry higher traffic volumes and fewer cyclists. There is more variety within non-neighborhood streets regarding PSL and traffic speeds. Bus routes, commercial areas, and bike lanes are all associated with non-neighborhood greenway streets.

The results of the variable sign and variable contribution analysis suggest that traffic volumes and the presence of a bike lane are important variables for predicting mean speeds after accounting for PSL. Small improvements to the model fit (after accounting for PSL) were observed with the addition of variables related to roadway width, class one (bicycle) volume, access density, or the presence of a shared bikeway or bus route. Since there is a high degree of correlation among some of the analyzed variables, caution should be used when discussing or applying these findings.

7.0 FINAL SUMMARY AND RECOMMENDATIONS

The goal of this research project is to provide recommendations pertaining to data collection efforts, analysis methods, and factors to consider when setting speed zones in urban areas with a high level of active travelers. Utilizing data from multiple locations in Portland with different characteristics and PSL levels, comparisons and statistical hypothesis testing were conducted between sites with PSL changes (treatment sites) and sites with no PSL change (control sites). Main findings and recommendations are summarized in this final chapter.

7.1 MAIN FINDINGS

A few clear trends and findings were observed throughout this study. They have been separated into four categories.

7.1.1 Characteristics of Sites with a High Percentage of Active Travelers

A high percentage of cyclists, more than 20% of traffic, is typically present on shared-use roadways that are also neighborhood greenways. Class two traffic volumes and 85th percentile speeds are generally lower at neighborhood greenway sites than non-neighborhood greenway sites with comparable speed limits. Also, class one volumes (including bicycles) are highest at neighborhood greenway sites, on average.

Differences are also seen when analyzing speed-volume-gap relationships. When data were aggregated into and averaged over 15-minute intervals, positive relationships between mean speed and mean gap time and negative relationships between mean speed and vehicle counts were revealed in most non-neighborhood greenway datasets, suggesting that speeds at these sites were affected by non-free-flow conditions. These patterns were absent in nearly all of the neighborhood greenway datasets.

7.1.2 Expected Changes After PSL Reductions

The statistical tests indicate that a PSL reduction is more likely to reduce speed characteristics on neighborhood greenways than on non-neighborhood greenways. More than 73% of the treatment sites located on neighborhood greenways experienced a reduction in mean and 85th speed distributions of at least 1.25 mph. For non-neighborhood greenway treatment sites, only 40% of the treatment sites experienced a decrease in mean and 85th speed distributions of at least 1.25 mph. These percentages are noticeably higher than the approximately 10% of control sites with a reduction in mean and 85th speed distributions of at least 1.25 mph. The different performance of neighborhood greenways may be linked to factors such as motorized ADT values, roadway width, presence of a bike lane, and percentage of cyclists, as analyzed in Chapter 6.

PSL reductions of 5 mph are likely to reduce speed characteristics such as mean or 85th percentile by 1.25 mph. However, it is important to highlight that there is a high degree of variability in the outcomes and that a priori, it is not possible to ascertain whether a PSL will reduce speed characteristics. For example, nearly 33% of the treatment non-neighborhood greenways experienced an increase in mean speed, even though the PSL was reduced by 5 mph. Nearly 13% of the treatment non-neighborhood greenways experienced an increase in the 85^{th} speed percentile despite a 5-mph PSL reduction. Additionally, approximately 18% of the treatment sites experienced an increase in speed variance.

7.1.3 Traffic Volume Changes

Class two traffic volumes were compared throughout the data collection period, and ADT decreased significantly on average for both the treatment and control neighborhood greenway dataset pairs. In contrast, a minor increase, on par with regional VMT changes throughout the data collection period, was observed for non-neighborhood greenway dataset pairs. Treatment pairs did show a larger average decrease for neighborhood greenways and a smaller average increase for non-neighborhood greenways than control pairs.

7.1.4 Impact of Different Roadway and Traffic Variables

The results of the variable sign and variable contribution analysis utilizing linear regression suggest that motorized traffic volumes and the presence of a bike lane are key variables for predicting mean speeds. Small improvements to the model fit (after accounting for PSL) were observed with the addition of variables related to roadway width, access density, class one (bicycle) volumes, and the presence of a shared bikeway or bus route.

Motorized traffic volumes, the presence of a bike lane, roadway with, and the presence of a bus route are positively correlated to mean speeds, after accounting for posted speed limits. Access density, bicycle volumes, shared roadways, and traffic calming are negatively correlated to mean speeds, after accounting for posted speed limits.

Due to the high degree of correlation among many of the roadway and traffic variables, prudence should be exercised when discussing or applying these findings.

7.2 RECOMMENDATIONS

Setting reasonable and adequate speed limits requires a careful study of the roadway context and facility operation before and after PSL changes.

7.2.1 Data Collection

It is strongly recommended that data collected to analyze speed characteristics are not obtained from locations near traffic control devices. If viable, the data collection should be performed more than 500 ft. from a traffic control device, intersection with a high volume of turning traffic, or major traffic calming installations to avoid non-free-flowing traffic conditions. It is recommended that speed distributions are always plotted and analyzed to determine whether traffic control devices or other factors are affecting the speed measurements. Otherwise, the speed data collected will not be representative of free-flowing traffic and will likely underestimate speed characteristics along a roadway segment.

7.2.2 Data Analysis

Changes in the mean speed and changes in class two ADT are correlated at neighborhood greenway sites, with larger decreases in mean speed coinciding with larger reductions in ADT. This correlation was not observed at non-neighborhood greenway sites.

It is recommended that speed-gap and speed-volume scatter plots are utilized to discern the type of operation of a location, and if the type of traffic observed matches what is expected from the functional classification. It is also recommended that speed distributions are analyzed to observe significant departures from normal distribution shapes that may signal the presence of non-free flowing traffic conditions.

7.2.3 Traffic Volume Monitoring

It is recommended that motorized traffic volumes at the site and on alternative travel paths are monitored before and after PSL changes. Despite increases in VMT figures in the region, a trend towards a reduction in motorized volumes was observed mainly at neighborhood greenways. There is a high degree of variability across sites, though. On some roadways, it is likely that changes in motorized volumes are also linked to reductions in speed characteristics. It is also possible that motorized traffic is diverting to other roadways without PSL changes, or that more general changes related to mode choice or origin-destination matrices are taking place.

7.2.4 Traffic Speed Monitoring

The analysis of control and treatment sites indicated that there is a high degree of variability in the outcomes of PSL changes and that a priori, it is not possible to ascertain whether a PSL will reduce speed characteristics.

Traffic speed monitoring is strongly recommended in all cases after a PSL change and especially in locations with high values of motorized traffic volumes, road width, and where bike lanes are present. Since there is a high degree of correlation among traffic volumes, roadway widths, and functional classification, it is also necessary to evaluate whether the road classification matches the characteristics of the traffic volumes and operation. Speed-gap and speed-volume scatter plots are recommended to monitor traffic characteristics and operation of the facility. Additional measures may be required to address situations where speed characteristics such as mean, 85th percentile, and speed variance do not change or even increase after a PSL reduction.

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APPENDIX A

TABLE NOTATION:
ADT = average daily traffic
SD = standard deviation
% Exc. PSL = % exceeding the posted speed limit of the 'after' period
B and A represent before and after, respectively

Table A.1: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 35-30 mph Non-neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Division E of 116th EB	Feb 2017	Apr 2018	9231	8897	31.27	32.61	6.64	5.92	37	38	62.05	69.28	25.17	29.29	4.68	7.11
Division E of 116th EB	Feb 2017	Dec 2019	9231	7737	31.27	32.68	6.64	4.78	37	37	62.05	71.49	25.17	24.56	4.68	4.76
Division E of 116th WB	Feb 2017	Apr 2018	9336	10571	35.29	32.91	5.46	4.35	41	37	84.27	73.92	49.36	24.58	15.05	4.19
Division E of 116th WB	Feb 2017	Oct 2019	9336	8915	35.29	33.07	5.46	4.67	41	37	84.27	73.68	49.36	27.34	15.05	5.23
Division E of 116th WB	Feb 2017 b	Apr 2018	9920	10571	35.18	32.91	5.40	4.35	40	37	83.17	73.92	48.47	24.58	14.10	4.19
Division E of 116th WB	Feb 2017 b	Oct 2019	9920	8915	35.18	33.07	5.40	4.67	40	37	83.17	73.68	48.47	27.34	14.10	5.23
Holgate E of 111th EB	Feb 2017	Jun 2019	4672	5122	21.11	23.29	7.10	8.41	28	33	9.78	25.66	3.08	5.31	0.71	0.47
Holgate E of 111th WB	Feb 2017	Jun 2019	5166	6903	28.44	26.90	7.74	5.14	36	32	41.03	23.90	17.08	5.93	3.42	0.68
Willamette E of Chase EB	Jun 2015	Jul 2019	6760	6201	35.73	34.49	3.98	4.30	39	38	92.07	86.67	54.19	39.96	9.21	6.27

Table A.2: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 30-25 mph Non-neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Williams N of Going NB	Jan 2015	Jul 2019	4408	4093	26.99	26.20	4.20	4.14	31	30	64.56	55.91	18.12	13.32	2.43	1.90
Williams N of Hancock NB	Feb 2015	Sep 2019	5880	5456	27.56	24.47	5.10	4.48	32	29	68.25	40.12	27.79	8.19	4.81	0.95

Table A.3: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 25-20 mph Non-neighborhood Greenway Treatment Pairs.

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Alberta E of 28th EB	Oct 2016	Jul 2019	2213	2309	21.42	20.38	4.91	4.79	26	25	57.53	49.71	19.27	12.56	3.18	2.16
Alberta E of 28th WB	Oct 2016	Jul 2019	2256	2030	20.03	20.14	4.56	4.52	25	24	44.51	46.41	12.05	11.39	1.48	1.65
Alberta E of 28th WB	Sep 2016	Jul 2019	1765	2030	19.76	20.14	4.92	4.52	25	24	44.88	46.41	12.92	11.39	1.72	1.65
Alberta E of 28th WB	Sep 2016 b	Jul 2019	2121	2030	19.84	20.14	5.02	4.52	25	24	44.18	46.41	12.77	11.39	1.80	1.65

Table A.4: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 25-20 mph Neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton E of 23rd EB	Jul 2015	Apr 2019	693	385	20.37	18.66	3.59	3.55	24	22	50.77	29.92	6.39	2.22	0.24	0.00
Clinton E of 23rd EB	May 2016	Apr 2019	655	385	20.70	18.66	3.80	3.55	24	22	54.50	29.92	8.05	2.22	0.47	0.00
Clinton E of 23rd WB	Jul 2015	Apr 2019	873	491	21.32	18.11	3.75	3.04	25	21	59.13	20.74	12.75	1.19	0.77	0.00
Clinton E of 23rd WB	May 2016	Apr 2019	716	491	21.44	18.11	3.89	3.04	25	21	60.97	20.74	12.79	1.19	1.22	0.00
Clinton E of 29th EB	Apr 2014	Jul 2019	1006	317	21.87	18.61	4.03	4.25	26	23	65.64	32.07	15.46	5.14	1.50	0.45
Clinton E of 29th EB	May 2016	Jul 2019	415	317	19.6	18.61	4.31	4.25	24	23	44.4	32.07	7.34	5.14	0.36	0.45
Clinton E of 29th WB	Apr 2014	Jul 2019	991	308	21.27	17.12	3.96	3.79	25	21	57.36	17.26	13.02	1.32	0.9	0.07
Clinton E of 29th WB	May 2016	Jul 2019	320	308	18.6	17.12	3.86	3.79	22	21	30.05	17.26	4.23	1.32	0.16	0.07
Clinton W of 14th EB	Aug 2014	Mar 2018	582	263	22.60	19.96	4.04	3.91	27	24	72.82	45.84	22.59	7.00	2.09	0.40
Clinton W of 14th EB	Aug 2014	May 2018	582	288	22.60	19.91	4.04	4.38	27	24	72.82	45.07	22.59	8.20	2.09	1.19
Clinton W of 14th EB	Aug 2014	Sep 2019	582	221	22.60	19.88	4.04	3.86	27	23	72.82	43.92	22.59	6.97	2.09	0.32
Clinton W of 14th WB	Aug 2014	Mar 2018	1048	578	22.97	21.64	4.13	4.26	27	26	75.1	62.05	26.25	17.89	3.06	1.75
Clinton W of 14th WB	Aug 2014	May 2018	1048	537	22.97	20.69	4.13	4.74	27	25.4	75.1	53.93	26.25	15.02	3.06	1.66

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton W of 14th WB	Aug 2014	Sep 2019	1048	428	22.97	20.61	4.13	4.72	27	25	75.10	51.93	26.25	14.09	3.06	1.93
Harrison E of 25th EB	Feb 2017	Apr 2019	792	647	20.73	16.83	3.07	3.35	24	20	50.92	11.54	5.80	0.32	0.13	0.00
Harrison E of 25th WB	*Feb 2017*	*Apr 2019*	*447*	*9*	*19.12*	*19.00*	*3.36*	*6.68*	*23*	*24.8*	*35.45*	*41.18*	*1.64*	*17.65*	*0.00*	*5.88*
Lincoln E of 45th EB	Nov 2012	Jul 2019	424	201	22.16	20.07	3.92	3.75	26	24	69.58	44.64	18.63	6.98	2.12	0.25
Lincoln E of 45th WB	Nov 2012	Jul 2019	618	289	21.94	20.15	3.71	3.34	26	23	65.86	48.09	15.37	4.86	1.62	0.52
Lincoln E of 48th EB	Oct 2012	Jan 2017	513	611	22.10	21.56	4.40	3.83	26	25	66.94	63.15	21.19	13.24	2.24	1.56
Lincoln E of 48th WB	Oct 2012	Jan 2017	532	560	22.45	21.71	4.09	3.88	26	25	71.27	63.46	21.30	14.54	1.76	1.79
Lincoln E of 50th EB	Apr 2011	Mar 2017	1108	1079	21.81	17.68	3.14	3.04	25	21	70.09	16.67	9.69	0.52	0.25	0.05
Lincoln E of 50th EB	Apr 2011	May 2019	1108	225	21.81	16.90	3.14	3.15	25	20	70.09	12.56	9.69	0.00	0.25	0.00
Lincoln E of 50th WB	Apr 2011	Mar 2017	1368	711	19.10	18.00	4.80	3.18	24	21	40.58	18.91	6.23	1.29	0.68	0.00
Lincoln E of 50th WB	Apr 2011	May 2019	1368	496	19.10	17.78	4.80	2.86	24	20	40.58	14.11	6.23	0.63	0.68	0.00
Lincoln E of 50th WB	Feb 2012	Mar 2017	1070	711	20.17	18.00	3.05	3.18	23	21	44.81	18.91	3.62	1.29	0.19	0.00
Lincoln E of 50th WB	Feb 2012	May 2019	1070	496	20.17	17.78	3.05	2.86	23	20	44.81	14.11	3.62	0.63	0.19	0.00
Lincoln E of 50th WB	Jun 2011	Mar 2017	1093	711	19.50	18.00	4.07	3.18	23	21	42.85	18.91	5.00	1.29	0.25	0.00

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
Lincoln E of 50th WB	Jun 2011	May 2019	1093	496	19.50	17.78	4.07	2.86	23	20	42.85	14.11	5.00	0.63	0.25	0.00
Lincoln W of 41st EB	*Nov 2012*	*Jan 2017*	*13*	*16*	*17.75*	*19.38*	*5.59*	*3.67*	*24.35*	*23.25*	*25.00*	*31.25*	*8.33*	*6.25*	*0.00*	*0.00*
Lincoln W of 41st WB	Nov 2012	Jan 2017	726	809	22.13	21.02	4.15	4.15	26	25	66.47	56.31	18.71	13.61	2.59	0.74
Lincoln W of 57th EB	Feb 2012	Jan 2017	833	730	22.92	21.16	3.72	3.46	26	24	78.17	62.66	21.71	9.23	1.51	0.14
Lincoln W of 57th WB	Feb 2012	Jan 2017	748	960	22.75	21.22	3.19	3.53	26	25	78.24	59.51	17.43	10.2	1.53	1.06

Italicized rows were not included in the body of the report due to an insufficient number of observations.

Table A.5: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 35 mph Non-neighborhood Greenway Control Pair

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
Division E of 116th WB	Feb 2017	Feb 2017 b	9336	9920	35.29	35.18	5.46	5.40	41	40	49.36	48.47	15.05	14.10	2.94	2.49

Table A.6: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 30 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
Division E of 116th EB	Apr 2018	Dec 2019	8897	7737	32.61	32.68	5.92	4.78	38	37	69.28	71.49	29.29	24.56	7.11	4.76
Division E of 116th WB	Apr 2018	Oct 2019	10571	8915	32.91	33.07	4.35	4.67	37	37	73.92	73.68	24.58	27.34	4.19	5.23

Table A.7: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 25 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
Alberta E of 28th WB	Sep 2016	Sep 2016 b	1765	2121	19.76	19.84	4.92	5.02	25	25	12.92	12.77	1.72	1.80	0.00	0.24
Alberta E of 28th WB	Sep 2016	Oct 2016	1765	2256	19.76	20.03	4.92	4.56	25	25	12.92	12.05	1.72	1.48	0.00	0.04
Alberta E of 28th WB	Sep 2016 b	Oct 2016	2121	2256	19.84	20.03	5.02	4.56	25	25	12.77	12.05	1.80	1.48	0.24	0.04
Division E of 33rd EB	Jul 2015	Jul 2019 b	4127	3603	19.30	18.65	5.34	5.21	25	24	10.96	9.12	1.78	1.49	0.22	0.14
Division E of 33rd EB	*Jul 2015*	*Jul 2019*	*4127*	*3922*	*19.30*	*17.30*	*5.34*	*5.05*	*25*	*22*	*10.96*	*5.38*	*1.78*	*0.70*	*0.22*	0.09
Division E of 33rd WB	Jul 2015	Jul 2019	4620	3846	19.86	18.59	4.76	4.78	25	23	10.95	7.85	1.54	0.98	0.11	0.21
Division E of 33rd EB	*Jul 2019*	*Jul 2019 b*	*3922*	*3603*	*17.30*	*18.65*	*5.05*	*5.21*	*22*	*24*	*5.38*	*9.12*	*0.70*	*1.49*	*0.09*	0.14

Italicized rows were not included in the body of the report due to interference from construction activities.

Table A.8: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 20 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Alberta E of 14th EB	Jul 2019	Nov 2019	3287	3074	21.37	21.43	5.15	4.79	26	26	59.17	59.80	20.27	18.59	2.95	2.27
Alberta E of 14th WB	Jul 2019	Nov 2019	2959	2668	20.78	21.46	4.97	4.89	25	26	54.21	61.52	14.63	18.85	2.29	2.66
Fremont E of 46th EB	Feb 2018	Sep 2019	3773	3926	21.03	20.64	4.45	4.45	25	25	56.01	51.45	13.95	11.88	2.00	1.95
Fremont E of 46th WB	Feb 2018	Sep 2019	3654	4020	20.75	19.57	4.82	4.74	25	24	53.00	41.53	13.90	8.83	2.28	1.49
Fremont E of 48th WB	Dec 2014	Jul 2019	3503	4465	23.07	21.64	4.83	4.68	28	26	71.31	61.71	28.97	18.90	6.78	2.75

Table A.9: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 25 mph Neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton E of 17th EB	Aug 2014	Jul 2015	682	569	21.46	20.44	3.33	3.11	25	23	11.40	4.67	0.50	0.09	0.00	0.00
Clinton E of 17th WB	Aug 2014	Jul 2015	924	725	20.01	20.21	3.09	3.23	23	23	3.19	4.45	0.11	0.21	0.00	0.00
Clinton E of 23rd EB	Jul 2015	May 2016	693	655	20.37	20.70	3.59	3.80	24	24	6.39	8.05	0.24	0.47	0.00	0.00
Clinton E of 23rd WB	Jul 2015	May 2016	873	716	21.32	21.44	3.75	3.89	25	25	12.75	12.79	0.77	1.22	0.00	0.14
Clinton E of 29th EB	Apr 2014	May 2016	1006	415	21.87	19.60	4.03	4.31	26	24	15.46	7.34	1.50	0.36	0.18	0.00
Clinton E of 29th WB	Apr 2014	May 2016	991	320	21.27	18.60	3.96	3.86	25	22	13.02	4.23	0.90	0.16	0.09	0.00
Clinton W of 13th EB	Jul 2015	May 2016	764	276	17.84	18.76	3.49	3.82	21	22	1.42	3.16	0.11	0.00	0.00	0.00
Clinton W of 13th WB	Jul 2015	May 2016	369	580	18.52	20.78	3.36	4.08	22	25	1.87	10.26	0.06	0.35	0.00	0.00
Clinton W of 25th EB	Mar 2014	Jun 2015	1169	841	20.36	20.12	3.65	3.51	24	24	5.64	4.04	0.21	0.24	0.00	0.00
Clinton W of 25th WB	Mar 2014	Jun 2015	1319	1115	21.04	21.51	3.60	3.72	25	25	9.92	12.02	0.54	0.63	0.03	0.09
Clinton W of 30th EB	Aug 2014	Jun 2015	863	769	20.09	21.48	3.94	3.94	24	25	6.33	12.36	0.28	1.25	0.00	0.00
Clinton W of 30th WB	Aug 2014	Jun 2015	1067	904	20.52	20.61	3.89	3.76	24	24	9.68	9.55	0.36	0.53	0.03	0.00
Lincoln E of 50th WB	Apr 2011	Jun 2011	1368	1093	19.10	19.50	4.80	4.07	24	23	6.23	5.00	0.68	0.25	0.14	0.06

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Lincoln E of 50th WB	Apr 2011	Feb 2012	1368	1070	19.10	20.17	4.80	3.05	24	23	6.23	3.62	0.68	0.19	0.14	0.00
Lincoln E of 50th WB	Jun 2011	Feb 2012	1093	1070	19.50	20.17	4.07	3.05	23	23	5.00	3.62	0.25	0.19	0.06	0.00

Table A.10: Before and After ADT, Mean, Standard Deviation, 85th Percentile, and Percent Exceeding Speed Thresholds for 20 mph Neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		% Exc. PSL +5 mph		% Exc. PSL +10 mph	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton W of 14th EB	Mar 2018	May 2018	263	288	19.96	19.91	3.91	4.38	24	24	45.84	45.07	7.00	8.20	0.40	1.19
Clinton W of 14th EB	Mar 2018	Sep 2019	263	221	19.96	19.88	3.91	3.86	24	23	45.84	43.92	7.00	6.97	0.40	0.32
Clinton W of 14th WB	Mar 2018	May 2018	578	537	21.64	20.69	4.26	4.74	26	25.4	62.05	53.93	17.89	15.02	1.75	1.66
Clinton W of 14th WB	Mar 2018	Sep 2019	578	428	21.64	20.61	4.26	4.72	26	25	62.05	51.93	17.89	14.09	1.75	1.93
Clinton W of 14th EB	May 2018	Sep 2019	288	221	19.91	19.88	4.38	3.86	24	23	45.07	43.92	8.20	6.97	1.19	0.32
Clinton W of 14th WB	May 2018	Sep 2019	537	428	20.69	20.61	4.74	4.72	25.4	25	53.93	51.93	15.02	14.09	1.66	1.93
Lincoln E of 30th EB	*Feb 2019*	*Apr 2019*	*13*	*16*	*23.66*	*17.76*	*9.75*	*4.51*	*33.8*	*21.6*	*57.14*	*29.41*	*34.29*	*0.00*	*20.00*	*0.00*
Lincoln E of 30th WB	Feb 2019	Apr 2019	582	742	19.98	19.90	3.28	3.33	23	23	43.54	45.67	4.49	2.72	0.12	0.00
Lincoln E of 50th EB	Mar 2017	May 2019	1079	225	17.68	16.90	3.04	3.15	21	20	16.67	12.56	0.52	0.00	0.05	0.00
Lincoln E of 50th WB	Mar 2017	May 2019	711	496	18.00	17.78	3.18	2.86	21	20	18.91	14.11	1.29	0.63	0.00	0.00

Italicized rows were not included in the body of the report due to an insufficient number of observations.

Table A.11: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 35-30 mph Non-neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Division E of 116th EB	Feb 2017	Apr 2018	9231	8897	31.27	32.61	6.64	5.92	37	38	62.05	69.28	28	29	64.19	67.52
Division E of 116th EB	Feb 2017	Dec 2019	9231	7737	31.27	32.68	6.64	4.78	37	37	62.05	71.49	28	28	64.19	75.73
Division E of 116th WB	Feb 2017	Apr 2018	9336	10571	35.29	32.91	5.46	4.35	41	37	84.27	73.92	31	28	69.21	78.83
Division E of 116th WB	Feb 2017	Oct 2019	9336	8915	35.29	33.07	5.46	4.67	41	37	84.27	73.68	31	29	69.21	76.36
Division E of 116th WB	Feb 2017 b	Apr 2018	9920	10571	35.18	32.91	5.4	4.35	40	37	83.17	73.92	31	28	69.07	78.83
Division E of 116th WB	Feb 2017 b	Oct 2019	9920	8915	35.18	33.07	5.4	4.67	40	37	83.17	73.68	31	29	69.07	76.36
Holgate E of 111th EB	Feb 2017	Jun 2019	4672	5122	21.11	23.29	7.1	8.41	28	33	9.78	25.66	16	24	52.15	38.12
Holgate E of 111th WB	Feb 2017	Jun 2019	5166	6903	28.44	26.9	7.74	5.14	36	32	41.03	23.9	26	22	56.65	67.26
Willamette E of Chase EB	Jun 2015	Jul 2019	6760	6201	35.73	34.49	3.98	4.3	39	38	92.07	86.67	31	30	82.87	81.52

Table A.12: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 30-25 mph Non-neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Williams N of Going NB	Jan 2015	Jul 2019	4408	4093	26.99	26.20	4.20	4.14	31	30	64.56	55.91	22	21	79.40	80.25
Williams N of Hancock NB	Feb 2015	Sep 2019	5880	5456	27.56	24.47	5.10	4.48	32	29	68.25	40.12	24	20	69.95	75.10

Table A.13: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 25-20 mph Non-neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Alberta E of 28th EB	Oct 2016	Jul 2019	2213	2309	21.42	20.38	4.91	4.79	26	25	57.53	49.71	17	16	71.86	71.76
Alberta E of 28th WB	Oct 2016	Jul 2019	2256	2030	20.03	20.14	4.56	4.52	25	24	44.51	46.41	15	15	73.11	75.43
Alberta E of 28th WB	Sep 2016	Jul 2019	1765	2030	19.76	20.14	4.92	4.52	25	24	44.88	46.41	15	15	68.33	75.43
Alberta E of 28th WB	Sep 2016 b	Jul 2019	2121	2030	19.84	20.14	5.02	4.52	25	24	44.18	46.41	15	15	68.08	75.43

Table A.14: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 25-20 mph Neighborhood Greenway Treatment Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton E of 23rd EB	Jul 2015	Apr 2019	693	385	20.37	18.66	3.59	3.55	24	22	50.77	29.92	16	14	84.32	84.90
Clinton E of 23rd WB	Jul 2015	Apr 2019	873	491	21.32	18.11	3.75	3.04	25	21	59.13	20.74	16	14	81.42	90.55
Clinton E of 23rd EB	May 2016	Apr 2019	655	385	20.70	18.66	3.80	3.55	24	22	54.50	29.92	16	14	83.74	84.90
Clinton E of 23rd WB	May 2016	Apr 2019	716	491	21.44	18.11	3.89	3.04	25	21	60.97	20.74	17	14	82.06	90.55
Clinton E of 29th EB	Apr 2014	Jul 2019	1006	317	21.87	18.61	4.03	4.25	26	23	65.64	32.07	17	14	81.18	77.57
Clinton E of 29th WB	Apr 2014	Jul 2019	991	308	21.27	17.12	3.96	3.79	25	21	57.36	17.26	17	12	81.60	81.15
Clinton E of 29th EB	May 2016	Jul 2019	415	317	19.60	18.61	4.31	4.25	24	23	44.40	32.07	16	14	75.81	77.57
Clinton E of 29th WB	May 2016	Jul 2019	320	308	18.60	17.12	3.86	3.79	22	21	30.05	17.26	15	12	81.06	81.15
Clinton W of 14th EB	Aug 2014	Mar 2018	582	263	22.60	19.96	4.04	3.91	27	24	72.82	45.84	19	15.5	81.48	80.98
Clinton W of 14th EB	Aug 2014	May 2018	582	288	22.60	19.91	4.04	4.38	27	24	72.82	45.07	19	16	81.48	77.29
Clinton W of 14th EB	Aug 2014	Sep 2019	582	221	22.60	19.88	4.04	3.86	27	23	72.82	43.92	19	15	81.48	81.04
Clinton W of 14th WB	Aug 2014	Mar 2018	1048	578	22.97	21.64	4.13	4.26	27	26	75.10	62.05	19	17	79.26	77.17
Clinton W of 14th WB	Aug 2014	May 2018	1048	537	22.97	20.69	4.13	4.74	27	25.4	75.10	53.93	19	16	79.26	71.18
Clinton W of 14th WB	Aug 2014	Sep 2019	1048	428	22.97	20.61	4.13	4.72	27	25	75.10	51.93	19	17	79.26	71.98

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Harrison E of 25th EB	Feb 2017	Apr 2019	792	647	20.73	16.83	3.07	3.35	24	20	50.92	11.54	16	13	91.16	87.27
Harrison E of 25th WB	*Feb 2017*	*Apr 2019*	*447*	*9*	*19.12*	*19.00*	*3.36*	*6.68*	*23*	*24.8*	*35.45*	*41.18*	*15*	*14*	*89.20*	*64.71*
Lincoln E of 45th EB	Nov 2012	Jul 2019	424	201	22.16	20.07	3.92	3.75	26	24	69.58	44.64	18	16	83.49	82.54
Lincoln E of 45th WB	Nov 2012	Jul 2019	618	289	21.94	20.15	3.71	3.34	26	23	65.86	48.09	17	15	84.30	87.15
Lincoln E of 48th EB	Oct 2012	Jan 2017	513	611	22.10	21.56	4.40	3.83	26	25	66.94	63.15	18	17	76.21	83.39
Lincoln E of 48th WB	Oct 2012	Jan 2017	532	560	22.45	21.71	4.09	3.88	26	25	71.27	63.46	18	17	80.51	81.49
Lincoln E of 50th EB	Apr 2011	Mar 2017	1108	1079	21.81	17.68	3.14	3.04	25	21	70.09	16.67	18	13	90.98	88.78
Lincoln E of 50th EB	Apr 2011	May 2019	1108	225	21.81	16.90	3.14	3.15	25	20	70.09	12.56	18	13	90.98	88.37
Lincoln E of 50th WB	Apr 2011	Mar 2017	1368	711	19.10	18.00	4.80	3.18	24	21	40.58	18.91	16	13	73.98	88.50
Lincoln E of 50th WB	Apr 2011	May 2019	1368	496	19.10	17.78	4.80	2.86	24	20	40.58	14.11	16	13.5	73.98	90.95
Lincoln E of 50th WB	Feb 2012	Mar 2017	1070	711	20.17	18.00	3.05	3.18	23	21	44.81	18.91	16	13	90.82	88.50
Lincoln E of 50th WB	Feb 2012	May 2019	1070	496	20.17	17.78	3.05	2.86	23	20	44.81	14.11	16	13.5	90.82	90.95
Lincoln E of 50th WB	Jun 2011	Mar 2017	1093	711	19.50	18.00	4.07	3.18	23	21	42.85	18.91	16	13	80.87	88.50
Lincoln E of 50th WB	Jun 2011	May 2019	1093	496	19.50	17.78	4.07	2.86	23	20	42.85	14.11	16	13.5	80.87	90.95
Lincoln W of 41st EB	*Nov 2012*	*Jan 2017*	*13*	*16*	*17.75*	*19.38*	*5.59*	*3.67*	*24.35*	*23.25*	*25.00*	*31.25*	*13*	*17*	*66.67*	*87.50*

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Lincoln W of 41st WB	Nov 2012	Jan 2017	726	809	22.13	21.02	4.15	4.15	26	25	66.47	56.31	17	17	81.87	80.20
Lincoln W of 57th EB	Feb 2012	Jan 2017	833	730	22.92	21.16	3.72	3.46	26	24	78.17	62.66	18.5	16	85.19	85.73
Lincoln W of 57th WB	Feb 2012	Jan 2017	748	960	22.75	21.22	3.19	3.53	26	25	78.24	59.51	19	16	88.15	84.59

Italicized rows were not included in the body of the report due to an insufficient number of observations.

Table A.15: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 35 mph Non-neighborhood Greenway Control Pair

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Division E of 116th WB	Feb 2017	Feb 2017 b	9336	9920	35.29	35.18	5.46	5.40	41	40	49.36	48.47	31	31	69.21	69.07

Table A.16: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 30 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Division E of 116th EB	Apr 2018	Dec 2019	8897	7737	32.61	32.68	5.92	4.78	38	37	69.28	71.49	29	28	67.52	75.73
Division E of 116th WB	Apr 2018	Oct 2019	10571	8915	32.91	33.07	4.35	4.67	37	37	73.92	73.68	28	29	78.83	76.36

Table A.17: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 25 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Alberta E of 28th WB	Sep 2016	Sep 2016 b	1765	2121	19.76	19.84	4.92	5.02	25	25	12.92	12.77	15	15	68.33	68.08
Alberta E of 28th WB	Sep 2016	Oct 2016	1765	2256	19.76	20.03	4.92	4.56	25	25	12.92	12.05	15	15	68.33	73.11
Alberta E of 28th WB	Sep 2016 b	Oct 2016	2121	2256	19.84	20.03	5.02	4.56	25	25	12.77	12.05	15	15	68.08	73.11
Division E of 33rd EB	Jul 2015	Jul 2019 b	4127	3603	19.30	18.65	5.34	5.21	25	24	10.96	9.12	15	14	66.13	67.14
Division E of 33rd EB	*Jul 2015*	*Jul 2019*	*4127*	*3922*	*19.30*	*17.30*	*5.34*	*5.05*	*25*	*22*	*10.96*	*5.38*	*15*	*12*	*66.13*	*68.36*
Division E of 33rd WB	Jul 2015	Jul 2019	4620	3846	19.86	18.59	4.76	4.78	25	23	10.95	7.85	16	14	72.09	71.97
Division E of 33rd EB	*Jul 2019*	*Jul 2019 b*	*3922*	*3603*	*17.30*	*18.65*	*5.05*	*5.21*	*22*	*24*	*5.38*	*9.12*	*12*	*14*	*68.36*	*67.14*

Italicized rows were not included in the body of the report due to interference from construction activities.

Table A.18: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 20 mph Non-neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Alberta E of 14th EB	Jul 2019	Nov 2019	3287	3074	21.37	21.43	5.15	4.79	26	26	59.17	59.80	17	17	68.27	72.14
Alberta E of 14th WB	Jul 2019	Nov 2019	2959	2668	20.78	21.46	4.97	4.89	25	26	54.21	61.52	16	18	71.87	72.42
Fremont E of 46th EB	Feb 2018	Sep 2019	3773	3926	21.03	20.64	4.45	4.45	25	25	56.01	51.45	17	16	77.07	76.84
Fremont E of 46th WB	Feb 2018	Sep 2019	3654	4020	20.75	19.57	4.82	4.74	25	24	53.00	41.53	16	15	73.63	75.26
Fremont E of 48th WB	Dec 2014	Jul 2019	3503	4465	23.07	21.64	4.83	4.68	28	26	71.31	61.71	18	17	72.29	73.99

Table A.19: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 25 mph Neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton E of 17th EB	Aug 2014	Jul 2015	682	569	21.46	20.44	3.33	3.11	25	23	11.40	4.67	17	16	88.15	89.30
Clinton E of 17th WB	Aug 2014	Jul 2015	924	725	20.01	20.21	3.09	3.23	23	23	3.19	4.45	16	16	90.29	88.29
Clinton E of 23rd EB	Jul 2015	May 2016	693	655	20.37	20.70	3.59	3.80	24	24	6.39	8.05	16	16	84.32	83.74
Clinton E of 23rd WB	Jul 2015	May 2016	873	716	21.32	21.44	3.75	3.89	25	25	12.75	12.79	16	17	81.42	82.06
Clinton E of 29th EB	Apr 2014	May 2016	1006	415	21.87	19.60	4.03	4.31	26	24	15.46	7.34	17	16	81.18	75.81
Clinton E of 29th WB	Apr 2014	May 2016	991	320	21.27	18.60	3.96	3.86	25	22	13.02	4.23	17	15	81.60	81.06
Clinton W of 13th EB	Jul 2015	May 2016	764	276	17.84	18.76	3.49	3.82	21	22	1.42	3.16	13	15	85.62	84.20
Clinton W of 13th WB	Jul 2015	May 2016	369	580	18.52	20.78	3.36	4.08	22	25	1.87	10.26	14	16	87.21	79.40
Clinton W of 25th EB	Mar 2014	Jun 2015	1169	841	20.36	20.12	3.65	3.51	24	24	5.64	4.04	15.5	16	80.98	77.29
Clinton W of 25th WB	Mar 2014	Jun 2015	1319	1115	21.04	21.51	3.60	3.72	25	25	9.92	12.02	15.5	15	80.98	81.04
Clinton W of 30th EB	Aug 2014	Jun 2015	863	769	20.09	21.48	3.94	3.94	24	25	6.33	12.36	17	16	77.17	71.18
Clinton W of 30th WB	Aug 2014	Jun 2015	1067	904	20.52	20.61	3.89	3.76	24	24	9.68	9.55	17	17	77.17	71.98
Lincoln E of 50th WB	Apr 2011	Jun 2011	1368	1093	19.10	19.50	4.80	4.07	24	23	6.23	5.00	16	15	77.29	81.04
Lincoln E of 50th WB	Apr 2011	Feb 2012	1368	1070	19.10	20.17	4.80	3.05	24	23	6.23	3.62	16	17	71.18	71.98

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Lincoln E of 50th WB	Jun 2011	Feb 2012	1093	1070	19.50	20.17	4.07	3.05	23	23	5.00	3.62	16	16	84.70	85.85

Table A.20: Before and After ADT, Mean, Standard Deviation, 85th Percentile, Percent Exceeding PSL, Pace Minimum, and Percent in Pace for 20 mph Neighborhood Greenway Control Pairs

Site	Date		ADT		Mean		SD		85th Perc.		% Exc. PSL		Pace Min.		% in Pace	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Clinton W of 14th EB	Mar 2018	May 2018	263	288	19.96	19.91	3.91	4.38	24	24	45.84	45.07	17	17	85.17	84.39
Clinton W of 14th EB	Mar 2018	Sep 2019	263	221	19.96	19.88	3.91	3.86	24	23	45.84	43.92	16	16	82.39	80.40
Clinton W of 14th WB	Mar 2018	May 2018	578	537	21.64	20.69	4.26	4.74	26	25.4	62.05	53.93	16	16	80.90	82.06
Clinton W of 14th WB	Mar 2018	Sep 2019	578	428	21.64	20.61	4.26	4.72	26	25	62.05	51.93	15	13.5	54.29	76.47
Clinton W of 14th EB	May 2018	Sep 2019	288	221	19.91	19.88	4.38	3.86	24	23	45.07	43.92	15	15	87.76	86.55
Clinton W of 14th WB	May 2018	Sep 2019	537	428	20.69	20.61	4.74	4.72	25.4	25	53.93	51.93	16	16	73.98	80.87
Lincoln E of 30th EB	*Feb 2019*	*Apr 2019*	*13*	*16*	*23.66*	*17.76*	*9.75*	*4.51*	*33.8*	*21.6*	*57.14*	*29.41*	*16*	*16*	*73.98*	*90.82*
Lincoln E of 30th WB	Feb 2019	Apr 2019	582	742	19.98	19.90	3.28	3.33	23	23	43.54	45.67	16	16	80.87	90.82
Lincoln E of 50th EB	Mar 2017	May 2019	1079	225	17.68	16.90	3.04	3.15	21	20	16.67	12.56	13	13	88.78	88.37
Lincoln E of 50th WB	Mar 2017	May 2019	711	496	18.00	17.78	3.18	2.86	21	20	18.91	14.11	13	13.5	88.50	90.95

Italicized rows were not included in the body of the report due to an insufficient number of observations.

APPENDIX B

TABLE NOTATION:
μ = mean speed
ζ_{85} = 85th percentile speed
SD = standard deviation
Prop. Exc. = % exceeding the 'after' period PSL
p-val. = *p*-value
Hyp1: H_0: $\mu_B - \mu_A = 0$; H_A: $\mu_B - \mu_A < 0$
Hyp2: H_0: $\mu_B - \mu_A = 1.25$; H_A: $\mu_B - \mu_A > 1.25$
Hyp3: H_0: $\zeta_{85,B} - \zeta_{85,A} = 0$; H_A: $\zeta_{85,B} - \zeta_{85,A} < 0$
Hyp4: H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$; H_A: $\zeta_{85,B} - \zeta_{85,A} > 1.25$
Hyp5: H_0: $\sigma_B^2 = \sigma_A^2$; H_A: $\sigma_B^2 \neq \sigma_A^2$
Hyp6: H_0: $P_B - P_A = 0$; H_A: $P_B - P_A \neq 0$
Subscripts B and A represent Before and After, respectively.

Table B.1: Hypothesis Testing Results for 35-30 mph Non-neighborhood Greenway Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th EB	Feb 2017	Dec 2019	31.27	32.68	37	37	6.64	4.78	0.62	0.72	0.000	1.000	0.500	1.000	0.000	0.000
Division E of 116th EB	Feb 2017	Apr 2018	31.27	32.61	37	38	6.64	5.92	0.62	0.69	0.000	1.000	0.000	1.000	0.000	0.000
Division E of 116thWB	Feb 2017	Oct 2019	35.29	33.07	41	37	5.46	4.67	0.84	0.74	1.000	0.000	1.000	0.000	0.000	0.000
Division E of 116th WB	Feb 2017	Apr 2018	35.29	32.91	41	37	5.46	4.35	0.84	0.74	1.000	0.000	1.000	0.000	0.000	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	35.18	33.07	40	37	5.40	4.67	0.83	0.74	1.000	0.000	1.000	0.000	0.000	0.000
Division E of 116th WB	Feb 2017 b	Apr 2018	35.18	32.91	40	37	5.40	4.35	0.83	0.74	1.000	0.000	1.000	0.000	0.000	0.000
Holgate E of 111th EB	Feb 2017	Jun 2019	21.11	23.29	28	33	7.10	8.41	0.10	0.26	0.000	1.000	0.000	1.000	1.000	0.000
Holgate E of 111th WB	Feb 2017	Jun 2019	28.44	26.90	36	32	7.74	5.14	0.41	0.24	1.000	0.009	1.000	0.000	0.000	0.000
Willamette E of Chase EB	Jun 2015	Jul 2019	35.73	34.49	39	38	3.98	4.30	0.92	0.87	1.000	0.542	1.000	1.000	1.000	0.000

Table B.2: Hypothesis Test Results for 30-25 mph Non-neighborhood Greenway Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Williams N of Going NB	Jan 2015	Jul 2019	26.99	26.20	31	30	4.20	4.14	0.65	0.56	1.000	1.000	1.000	0.999	0.066	0.000
Williams N of Hancock NB	Feb 2015	Sep 2019	27.56	24.47	32	29	5.10	4.48	0.68	0.40	1.000	0.000	1.000	0.000	0.000	0.000

Table B.3: Hypothesis Test Results for 25-20 mph Non-neighborhood Greenway Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 28th EB	Oct 2016	Jul 2019	21.42	20.38	26	25	4.91	4.79	0.58	0.50	1.000	0.934	1.000	0.878	0.104	0.000
Alberta E of 28th WB	Oct 2016	Jul 2019	20.03	20.14	25	24	4.56	4.52	0.45	0.46	0.207	1.000	1.000	0.887	0.341	0.199
Alberta E of 28th WB	Sep 2016	Jul 2019	19.76	20.14	25	24	4.92	4.52	0.45	0.46	0.016	1.000	1.000	0.817	0.001	0.417
Alberta E of 28th WB	Sep 2016 b	Jul 2019	19.84	20.14	25	24	5.02	4.52	0.44	0.46	0.009	1.000	1.000	0.899	0.000	0.100

Table B.4: Hypothesis Test Results for 25-20 mph Neighborhood Greenway Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Clinton E of 23rd EB	Jul 2015	Apr 2019	20.37	18.66	24	22	3.59	3.55	0.51	0.30	1.000	0.003	1.000	0.002	0.354	0.000
Clinton E of 23rd WB	Jul 2015	Apr 2019	21.32	18.11	25	21	3.75	3.04	0.59	0.21	1.000	0.000	1.000	0.000	0.000	0.000
Clinton E of 23rd EB	May 2016	Apr 2019	20.70	18.66	24	22	3.80	3.55	0.55	0.30	1.000	0.000	1.000	0.002	0.020	0.000
Clinton E of 23rd WB	May 2016	Apr 2019	21.44	18.11	25	21	3.89	3.04	0.61	0.21	1.000	0.000	1.000	0.000	0.000	0.000
Clinton E of 29th EB	Apr 2014	Jul 2019	21.87	18.61	26	23	4.03	4.25	0.66	0.32	1.000	0.000	1.000	0.000	0.974	0.000
Clinton E of 29th WB	Apr 2014	Jul 2019	21.27	17.12	25	21	3.96	3.79	0.57	0.17	1.000	0.000	1.000	0.000	0.059	0.000
Clinton E of 29th EB	May 2016	Jul 2019	19.60	18.61	24	23	4.31	4.25	0.44	0.32	1.000	0.926	1.000	0.812	0.320	0.000
Clinton E of 29th WB	May 2016	Jul 2019	18.60	17.12	22	21	3.86	3.79	0.30	0.17	1.000	0.108	1.000	0.816	0.276	0.000
Clinton W of 14th EB	Aug 2014	Sep 2019	22.60	19.88	27	23	4.04	3.86	0.73	0.44	1.000	0.000	1.000	0.000	0.090	0.000
Clinton W of 14th EB	Aug 2014	Mar 2018	22.60	19.96	27	24	4.04	3.91	0.73	0.46	1.000	0.000	1.000	0.000	0.144	0.000
Clinton W of 14th EB	Aug 2014	May 2018	22.60	19.91	27	24	4.04	4.38	0.73	0.45	1.000	0.000	1.000	0.000	0.997	0.000
Clinton W of 14th WB	Aug 2014	Sep 2019	22.97	20.61	27	25	4.13	4.72	0.75	0.52	1.000	0.000	1.000	0.001	1.000	0.000
Clinton W of 14th WB	Aug 2014	May 2018	22.97	20.69	27	25.4	4.13	4.74	0.75	0.54	1.000	0.000	1.000	0.052	1.000	0.000
Clinton W of 14th WB	Aug 2014	Mar 2018	22.97	21.64	27	26	4.13	4.26	0.75	0.62	1.000	0.257	1.000	0.899	0.932	0.000

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Harrison E of 25th EB	Feb 2017	Apr 2019	20.73	16.83	24	20	3.07	3.35	0.51	0.12	1.000	0.000	1.000	0.000	0.997	0.000
Harrison E of 25th WB	*Feb 2017*	*Apr 2019*	*19.12*	*19.00*	*23*	*24.8*	*3.36*	*6.68*	*0.35*	*0.41*	*0.528*	*0.752*	*0.235*	*0.890*	*1.000*	*0.629*
Lincoln E of 45th EB	Nov 2012	Jul 2019	22.16	20.07	26	24	3.92	3.75	0.70	0.45	1.000	0.001	1.000	0.033	0.194	0.000
Lincoln E of 45th WB	Nov 2012	Jul 2019	21.94	20.15	26	23	3.71	3.34	0.66	0.48	1.000	0.004	1.000	0.000	0.006	0.000
Lincoln E of 48th EB	Oct 2012	Jan 2017	22.10	21.56	26	25	4.40	3.83	0.67	0.63	1.000	1.000	1.000	0.888	0.000	0.018
Lincoln E of 48th WB	Oct 2012	Jan 2017	22.45	21.71	26	25	4.09	3.88	0.71	0.64	1.000	1.000	1.000	0.884	0.018	0.000
Lincoln E of 50th EB	Apr 2011	May 2019	21.81	16.90	25	20	3.14	3.15	0.70	0.13	1.000	0.000	1.000	0.000	0.514	0.000
Lincoln E of 50th EB	Apr 2011	Mar 2017	21.81	17.68	25	21	3.14	3.04	0.70	0.17	1.000	0.000	1.000	0.000	0.101	0.000
Lincoln E of 50th WB	Apr 2011	May 2019	19.10	17.78	24	20	4.80	2.86	0.41	0.14	1.000	0.340	1.000	0.000	0.000	0.000
Lincoln E of 50th WB	Apr 2011	Mar 2017	19.10	18.00	24	21	4.80	3.18	0.41	0.19	1.000	0.831	1.000	0.000	0.000	0.000
Lincoln E of 50th WB	Feb 2012	May 2019	20.17	17.78	23	20	3.05	2.86	0.45	0.14	1.000	0.000	1.000	0.000	0.051	0.000
Lincoln E of 50thWB	Feb 2012	Mar 2017	20.17	18.00	23	21	3.05	3.18	0.45	0.19	1.000	0.000	1.000	0.000	0.936	0.000
Lincoln E of 50th WB	Jun 2011	May 2019	19.50	17.78	23	20	4.07	2.86	0.43	0.14	1.000	0.001	1.000	0.000	0.000	0.000
Lincoln E of 50th WB	Jun 2011	Mar 2017	19.50	18.00	23	21	4.07	3.18	0.43	0.19	1.000	0.007	1.000	0.000	0.000	0.000

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Lincoln W of 41st EB	*Nov 2012*	*Jan 2017*	*17.75*	*19.38*	*24.35*	*23.25*	*5.59*	*3.67*	*0.25*	*0.31*	*0.197*	*0.930*	*0.651*	*0.521*	*0.065*	*0.717*
Lincoln W of 41st WB	Nov 2012	Jan 2017	22.13	21.02	26	25	4.15	4.15	0.67	0.56	1.000	0.753	0.999	0.777	0.491	0.000
Lincoln W of 57th EB	Feb 2012	Jan 2017	22.92	21.16	26	24	3.72	3.46	0.78	0.63	1.000	0.003	1.000	0.004	0.022	0.000
Lincoln W of 57th WB	Feb 2012	Jan 2017	22.75	21.22	26	25	3.19	3.53	0.78	0.60	1.000	0.047	1.000	0.838	0.998	0.000

Italicized rows were not included in the body of the report due to an insufficient number of observations.

Table B.5: Hypothesis Test Results for 35 mph Non-neighborhood Greenway Control Pair

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th WB	Feb 2017	Feb 2017 b	35.29	35.18	41	40	5.46	5.40	0.49	0.49	0.938	1.000	1.000	0.987	0.152	0.191

Table B.6: Hypothesis Test Results for 30 mph Non-neighborhood Greenway Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th EB	Apr 2018	Dec 2019	32.61	32.68	38	37	5.92	4.78	0.69	0.72	0.091	1.000	1.000	0.999	0.000	0.000
Division E of 116th WB	Apr 2018	Oct 2019	32.91	33.07	37	37	4.35	4.67	0.74	0.74	0.002	1.000	0.500	1.000	1.000	0.648

Table B.7: Hypothesis Test Results for 25 mph Non-neighborhood Greenway Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 28th WB	Sep 2016	Sep 2016 b	19.76	19.84	25	25	4.92	5.02	0.13	0.13	0.317	1.000	0.500	1.000	0.788	0.898
Alberta E of 28th WB	Sep 2016	Oct 2016	19.76	20.03	25	25	4.92	4.56	0.13	0.12	0.059	1.000	0.500	1.000	0.002	0.474
Alberta E of 28th WB	Sep 2016 b	Oct 2016	19.84	20.03	25	25	5.02	4.56	0.13	0.12	0.057	1.000	0.500	1.000	0.000	0.403
Division E of 33rd EB	Jul 2015	Jul 2019 b	19.30	18.65	25	24	5.34	5.21	0.11	0.09	1.000	1.000	1.000	0.938	0.045	0.002
Division E of 33rd EB	*Jul 2015*	*Jul 2019*	*19.30*	*17.30*	*25*	*22*	*5.34*	*5.05*	*0.11*	*0.05*	*1.000*	*0.000*	*1.000*	*0.000*	*0.000*	*0.000*
Division E of 33rd WB	Jul 2015	Jul 2019	19.86	18.59	25	23	4.76	4.78	0.11	0.08	1.000	0.405	1.000	0.000	0.617	0.000
Division E of 33rd EB	*Jul 2019*	*Jul 2019 b*	*17.30*	*18.65*	*22*	*24*	*5.05*	*5.21*	*0.05*	*0.09*	*0.000*	*1.000*	*0.000*	*1.000*	*0.998*	*0.000*

Italicized rows were not included in the body of the report due to interference from construction activities.

Table B.8: Hypothesis Test Results for 20 mph Non-neighborhood Greenway Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 14th EB	Jul 2019	Nov 2019	21.37	21.43	26	26	5.15	4.79	0.59	0.60	0.311	1.000	0.500	1.000	0.000	0.610
Alberta E of 14th WB	Jul 2019	Nov 2019	20.78	21.46	25	26	4.97	4.89	0.54	0.62	0.000	1.000	0.000	1.000	0.180	0.000
Fremont E of 46th EB	Feb 2018	Sep 2019	21.03	20.64	25	25	4.45	4.45	0.56	0.51	1.000	1.000	0.500	1.000	0.477	0.000
Fremont E of 46th WB	Feb 2018	Sep 2019	20.75	19.57	25	24	4.82	4.74	0.53	0.42	1.000	0.845	1.000	0.990	0.055	0.000
Fremont E of 48th WB	Dec 2014	Jul 2019	23.07	21.64	28	26	4.83	4.68	0.71	0.62	1.000	0.005	1.000	0.000	0.001	0.000

Table B.9: Hypothesis Test Results for 25 mph Neighborhood Greenway Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Clinton E of 17th EB	Aug 2014	Jul 2015	21.46	20.44	25	23	3.33	3.11	0.11	0.05	1.000	0.990	1.000	0.000	0.001	0.000
Clinton E of 17th WB	Aug 2014	Jul 2015	20.01	20.21	23	23	3.09	3.23	0.03	0.04	0.010	1.000	0.500	1.000	0.992	0.015
Clinton E of 23rd EB	Jul 2015	May 2016	20.37	20.70	24	24	3.59	3.80	0.06	0.08	0.013	1.000	0.500	1.000	0.975	0.107
Clinton E of 23rd WB	Jul 2015	May 2016	21.32	21.44	25	25	3.75	3.89	0.13	0.13	0.199	1.000	0.500	1.000	0.926	0.970
Clinton E of 29th EB	Apr 2014	May 2016	21.87	19.60	26	24	4.03	4.31	0.16	0.07	1.000	0.000	1.000	0.005	0.983	0.000
Clinton E of 29th WB	Apr 2014	May 2016	21.27	18.60	25	22	3.96	3.86	0.13	0.04	1.000	0.000	1.000	0.000	0.249	0.000
Clinton W of 13th EB	Jul 2015	May 2016	17.84	18.76	21	22	3.49	3.82	0.01	0.03	0.000	1.000	0.000	1.000	0.998	0.003
Clinton W of 13th WB	Jul 2015	May 2016	18.52	20.78	22	25	3.36	4.08	0.02	0.10	0.000	1.000	0.000	1.000	1.000	0.000
Clinton W of 25th EB	Mar 2014	Jun 2015	20.36	20.12	24	24	3.65	3.51	0.06	0.04	0.960	1.000	0.500	1.000	0.079	0.065
Clinton W of 25th WB	Mar 2014	Jun 2015	21.04	21.51	25	25	3.60	3.72	0.10	0.12	0.000	1.000	0.500	1.000	0.917	0.044
Clinton W of 30th EB	Aug 2014	Jun 2015	20.09	21.48	24	25	3.94	3.94	0.06	0.12	0.000	1.000	0.000	1.000	0.510	0.000
Clinton W of 30th WB	Aug 2014	Jun 2015	20.52	20.61	24	24	3.89	3.76	0.10	0.10	0.246	1.000	0.500	1.000	0.097	0.908
Lincoln E of 50th WB	Apr 2011	Feb 2012	19.10	20.17	24	23	4.80	3.05	0.06	0.04	0.000	1.000	1.000	0.853	0.000	0.003
Lincoln E of 50th WB	Apr 2011	Jun 2011	19.10	19.50	24	23	4.80	4.07	0.06	0.05	0.002	1.000	1.000	0.884	0.000	0.061

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Lincoln E of 50th WB	Jun 2011	Feb 2012	19.50	20.17	23	23	4.07	3.05	0.05	0.04	0.000	1.000	0.500	1.000	0.000	0.052

Table B.10: Hypothesis Test Results for 20 mph Neighborhood Greenway Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Clinton W of 14th EB	Mar 2018	Sep 2019	19.96	19.88	24	23	3.91	3.86	0.46	0.44	0.654	1.000	0.999	0.781	0.377	0.477
Clinton W of 14th EB	Mar 2018	May 2018	19.96	19.91	24	24	3.91	4.38	0.46	0.45	0.592	1.000	0.500	1.000	0.999	0.757
Clinton W of 14th WB	Mar 2018	Sep 2019	21.64	20.61	26	25	4.26	4.72	0.62	0.52	1.000	0.900	1.000	0.829	1.000	0.000
Clinton W of 14th WB	Mar 2018	May 2018	21.64	20.69	26	25.4	4.26	4.74	0.62	0.54	1.000	0.972	0.993	0.996	1.000	0.000
Clinton W of 14th EB	May 2018	Sep 2019	19.91	19.88	24	23	4.38	3.86	0.45	0.44	0.565	1.000	0.999	0.775	0.000	0.664
Clinton W of 14th WB	May 2018	Sep 2019	20.69	20.61	25.4	25	4.74	4.72	0.54	0.52	0.679	1.000	0.925	0.999	0.429	0.297
Lincoln E of 30th EB	*Feb 2019*	*Apr 2019*	*23.66*	*17.76*	*33.8*	*21.6*	*9.75*	*4.51*	*0.57*	*0.29*	*0.998*	*0.012*	*1.000*	*0.000*	*0.001*	*0.060*
Lincoln E of 30th WB	Feb 2019	Apr 2019	19.98	19.90	23	23	3.28	3.33	0.44	0.46	0.720	1.000	0.500	1.000	0.682	0.328
Lincoln E of 50th EB	Mar 2017	May 2019	17.68	16.90	21	20	3.04	3.15	0.17	0.13	1.000	0.982	0.998	0.767	0.753	0.120
Lincoln E of 50th WB	Mar 2017	May 2019	18.00	17.78	21	20	3.18	2.86	0.19	0.14	0.920	1.000	1.000	0.852	0.002	0.018

Italicized rows were not included in the body of the report due to an insufficient number of observations.

Table B.11: Hypothesis Test Results for 35-30 mph Free-flow Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th EB	Feb 2017	Apr 2018	33.99	35.07	40	41	7.15	6.13	0.79	0.82	0.000	1.000	0.000	1.000	0.000	0.000
Division E of 116th EB	Feb 2017	Dec 2019	33.99	34.39	40	39	7.15	5.70	0.79	0.81	0.013	1.000	1.000	0.821	0.000	0.047
Division E of 116th WB	Feb 2017	Apr 2018	37.35	34.04	43	39	6.03	5.26	0.90	0.79	1.000	0.000	1.000	0.000	0.000	0.000
Division E of 116th WB	Feb 2017	Oct 2019	37.35	34.84	43	40	6.03	5.67	0.90	0.81	1.000	0.000	1.000	0.000	0.007	0.000
Division E of 116th WB	Feb 2017 b	Apr 2018	36.97	34.04	42	39	5.99	5.26	0.88	0.79	1.000	0.000	1.000	0.000	0.000	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	36.97	34.84	42	40	5.99	5.67	0.88	0.81	1.000	0.000	1.000	0.002	0.004	0.000
Willamette E of Chase EB	Jun 2015	Jul 2019	36.72	35.52	40	40	4.02	4.30	0.95	0.92	1.000	0.699	0.500	1.000	1.000	0.000

Table B.12: Hypothesis Test Results for 30-25 mph Free-flow Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Williams N of Going NB	Jan 2015	Jul 2019	28.92	27.90	33	32	4.62	4.80	0.80	0.72	1.000	0.968	1.000	0.905	0.981	0.000
Williams N of Hancock NB	Feb 2015	Sep 2019	29.35	26.47	34	31	5.35	4.86	0.79	0.61	1.000	0.000	1.000	0.000	0.000	0.000

Table B.13: Hypothesis Test Results for 25-20 mph Free-flow Treatment Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 28th EB	Oct 2016	Jul 2019	22.50	22.08	28	26	5.40	4.80	0.66	0.64	0.949	0.999	1.000	0.029	0.001	0.582
Alberta E of 28th WB	Oct 2016	Jul 2019	21.09	21.30	26	26	4.91	4.74	0.54	0.58	0.211	1.000	0.500	0.999	0.179	0.092
Alberta E of 28th WB	Sep 2016	Jul 2019	20.40	21.30	26	26	5.42	4.74	0.51	0.58	0.006	1.000	0.500	0.989	0.002	0.026
Alberta E of 28th WB	Sep 2016 b	Jul 2019	21.24	21.30	27	26	5.22	4.74	0.56	0.58	0.397	1.000	0.996	0.748	0.004	0.437

Table B.14: Hypothesis Test Results for 35 mph Free-flow Control Pair

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th WB	Feb 2017	Feb 2017b	37.35	36.97	43	42	6.03	5.99	0.66	0.64	0.984	1.000	1.000	0.823	0.366	0.122

Table B.15: Hypothesis Test Results for 30 mph Free-flow Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Division E of 116th EB	Apr 2018	Dec 2019	35.07	34.39	41	39	6.13	5.70	0.82	0.81	1.000	1.000	1.000	0.000	0.000	0.133
Division E of 116th WB	Apr 2018	Oct 2019	34.04	34.84	39	40	5.26	5.67	0.79	0.81	0.000	1.000	0.000	1.000	1.000	0.073

Table B.16: Hypothesis Test Results for 25 mph Free-flow Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 28th WB	Sep 2016	Sep 2016 b	20.40	21.24	26	27	5.42	5.22	0.19	0.21	0.008	1.000	0.029	1.000	0.186	0.513
Alberta E of 28th WB	Sep 2016	Oct 2016	20.40	21.09	26	26	5.42	4.91	0.19	0.19	0.025	1.000	0.500	0.989	0.016	0.907
Alberta E of 28th WB	Sep 2016 b	Oct 2016	21.24	21.09	27	26	5.22	4.91	0.21	0.19	0.728	1.000	0.997	0.754	0.035	0.291
Division E of 33rd EB	Jul 2015	Jul 2019 b	21.96	21.17	27	27	5.40	5.59	0.24	0.22	1.000	0.983	0.500	1.000	0.896	0.329
Division E of 33rd WB	Jul 2015	Jul 2019	21.39	20.30	27	26	5.35	5.37	0.21	0.16	1.000	0.787	0.999	0.786	0.558	0.000
Lincoln E of 50th WB	Apr 2011	Jun 2011	20.76	20.84	25	24	4.06	3.35	0.10	0.07	0.344	1.000	0.999	0.790	0.000	0.097

Table B.17: Hypothesis Test Results for 20 mph Free-flow Control Pairs

Site	Before	After	μ_B	μ_A	$\zeta_{85,B}$	$\zeta_{85,A}$	SD Before	SD After	Prop. Exc. Before	Prop. Exc. After	p-val. Hyp1	p-val. Hyp2	p-val. Hyp3	p-val. Hyp4	p-val. Hyp5	p-val. Hyp6
Alberta E of 14th EB	Jul 2019	Nov 2019	23.46	23.21	28	28	5.30	4.76	0.76	0.75	0.851	1.000	0.500	1.000	0.001	0.353
Alberta E of 14th WB	Jul 2019	Nov 2019	22.21	22.66	27	28	5.41	5.23	0.67	0.70	0.042	1.000	0.006	1.000	0.164	0.156
Fremont E of 46th EB	Feb 2018	Sep 2019	22.88	22.47	27	27	4.74	4.95	0.71	0.67	0.998	1.000	0.500	1.000	0.985	0.001
Fremont E of 46th WB	Feb 2018	Sep 2019	22.23	21.32	28	27	5.57	5.45	0.64	0.56	1.000	0.984	1.000	0.847	0.159	0.000
Fremont E of 48th WB	Dec 2014	Jul 2019	25.21	23.40	31	28	5.37	4.91	0.83	0.74	1.000	0.000	1.000	0.000	0.000	0.000

APPENDIX C

BEFORE AND AFTER SPEED COMPARISON

The first set of analyses performed involved multiple comparison methods between the 'before' and 'after' conditions for the treatment and control dataset pairs. Performance measures investigated included the mean and 85th percentile speeds, the standard deviation, the percent of observations exceeding three speed thresholds, the 10-mph pace minimum, and the percent of vehicles in the pace limits. The speed thresholds were defined as (i) the posted speed limit (PSL) in the 'after' condition, (ii) the PSL in the 'after' condition plus five miles per hour, and (iii) the PSL in the 'after' condition plus ten miles per hour.

Differences between the 'before' and 'after' groups were calculated two ways. In one method, performance measures were first averaged within groups of datasets defined by the PSL and neighborhood greenway status. The second method involved calculations between individual dataset pairs. Changes in the mean and standard deviation of speed with respect to the length of time between subsequent surveys were also investigated. For pairs that consisted of datasets displaying correlations between mean speed and gap time as discussed in Section C.3, the analyses were repeated when those datasets were limited to observations with gap times greater than their mean gap time to remove observations where speeds were potentially inhibited by congestion.

All statistics comparing 'before' and 'after observations were obtained by subtracting the 'before' value from the 'after' value. For example, if the mean speed of the 'after' condition was 20 mph and the mean speed of the 'before' condition was 21 mph, the difference is -1 mph. Negative differences represent a decrease in the speed statistic, and positive differences represent an increase in the speed statistic. All comparisons between individual dataset pairs can be seen in Appendix A.

C.1 TREATMENT SITES

One method of exploring the change across the performance measures is to calculate average values of the performance measures with the datasets in each group. Then, the values between the 'before' and 'after' conditions can be compared. The groups were determined by neighborhood greenway status, and 'before,' 'after' speed limits. As previously discussed, the sites located on designated neighborhood greenways displayed a more random and uncorrelated pattern with respect to speed, gap time, and traffic volume. For this reason, neighborhood greenway sites were segregated within the PSL groups. Table C.1 displays the results of the analysis for the datasets involved in each group of the treatment pairs. Since there were multiple repeated surveys at 13 of the 44 total sites, some datasets were paired more than once, so the number of 'before' datasets was not necessarily equal to the number of 'after' datasets in Table C.1.

Table C.1 shows that the percent in the pace limits increased for each speed group. Table C.1 also shows that the 25-20 mph neighborhood greenway group had consistent decreases in all other performance measure categories (this group also had the highest number of datasets to analyze, which were spread across 16 different sites). Similar trends were observed for non-neighborhood sites. The 35-30 mph and 30-25 mph groups displayed decreases for all performance measures except percent in pace, but due to the low number of datasets to compare for each speed group, a broad conclusion could not be drawn by speed group.

Table C.1: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for all datasets included in a treatment pair, grouped by PSL and greenway status.

Non-Neighborhood Greenways								
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
Before (N=6)	35	31.17	36.83	62.06	32.89	7.86	27.17	65.69
After (N=7)	30	30.85	36.00	60.66	22.42	4.10	27.14	69.33
Difference		*-0.32*	*-0.83*	*-1.40*	*-10.47*	*-3.76*	*-0.03*	*3.64*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
Before (N=2)	30	27.28	31.50	66.41	22.96	3.62	23.00	74.68
After (N=2)	25	25.34	29.50	48.02	10.76	1.43	20.50	77.68
Difference		*-1.94*	*-2.00*	*-18.39*	*-12.20*	*-2.20*	*-2.50*	*3.00*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=4)	25	20.26	25.25	47.78	14.25	2.05	15.50	70.35
After (N=2)	20	20.26	24.50	48.06	11.98	1.91	15.50	73.60
Difference		*0.00*	*-0.75*	*0.29*	*-2.28*	*-0.14*	*0.00*	*3.25*
Neighborhood Greenways								
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=22)	25	21.30	25.00	59.84	13.34	1.17	17.07	82.70
After (N=22)	20	19.51	23.06	39.74	7.02	0.63	15.00	82.85
Difference		*-1.78*	*-1.94*	*-20.10*	*-6.32*	*-0.53*	*-2.07*	*0.15*

N = the number of datasets averaged

Next, the differences in the mean speed and standard deviation of speed between the 'before' and 'after' condition were calculated for each treatment pair (N = 45). Figure C.1 displays a histogram of the differences in the means for all treatment pairs. From Figure C.1, it appears that the distribution of differences in mean speeds is somewhat normal and centered around -1.5 mph to -2 mph, indicating a decrease occurred in most dataset pairs. These results are on par with the research of *Elvik (2012)* and *OECD (2006, p.70)*, which suggests the average change in mean operating speed will be approximately one-quarter of the change in the speed limit when no other interventions have been performed. In this report PSL changes are all 5 mph, hence, the expected a priori reduction in mean speed for treatment sites is 1.25 mph.

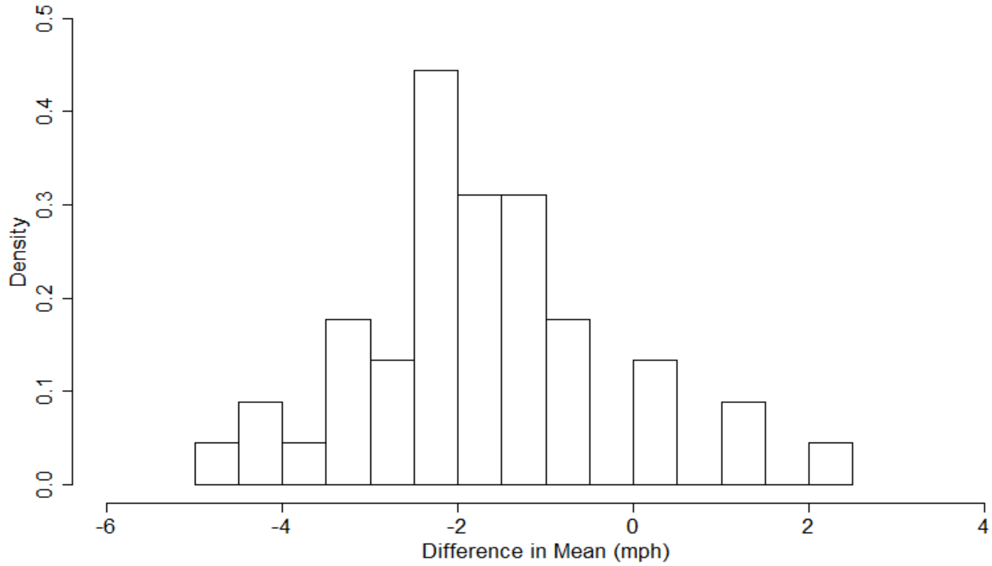

Figure C.1: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for all treatment pairs.

Figure C.2 displays the histogram of the differences in the standard deviation of speed for all treatment pairs. The histogram is centered just to the right of zero, indicating that, on average, the standard deviation decreased slightly in the ‘after’ condition.

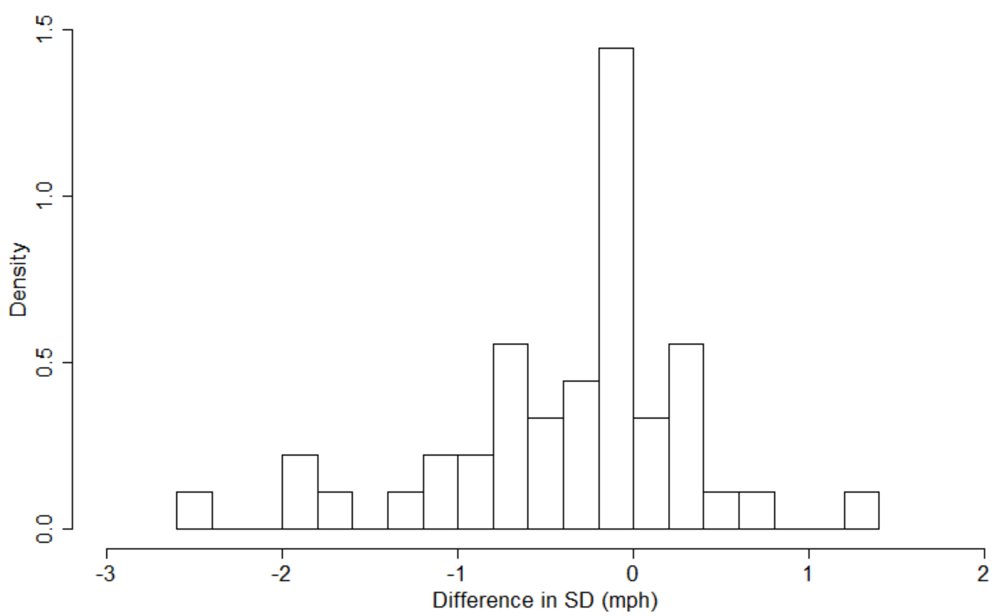

Figure C.2: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all treatment pairs.

After inspecting the magnitude of changes in the means and standard deviations, these changes were plotted against the amount of time between surveys to check for correlations. Figure C.3 shows a scatterplot of the difference in mean speed for each dataset pair (N = 45) versus the number of days elapsed between the start of the repeated surveys. From Figure C.3, there appears to be a slight negative correlation between the change in mean speed and the time elapsed between surveys, and the scatterplot clearly shows that the majority of sites did experience a decrease in the mean speed.

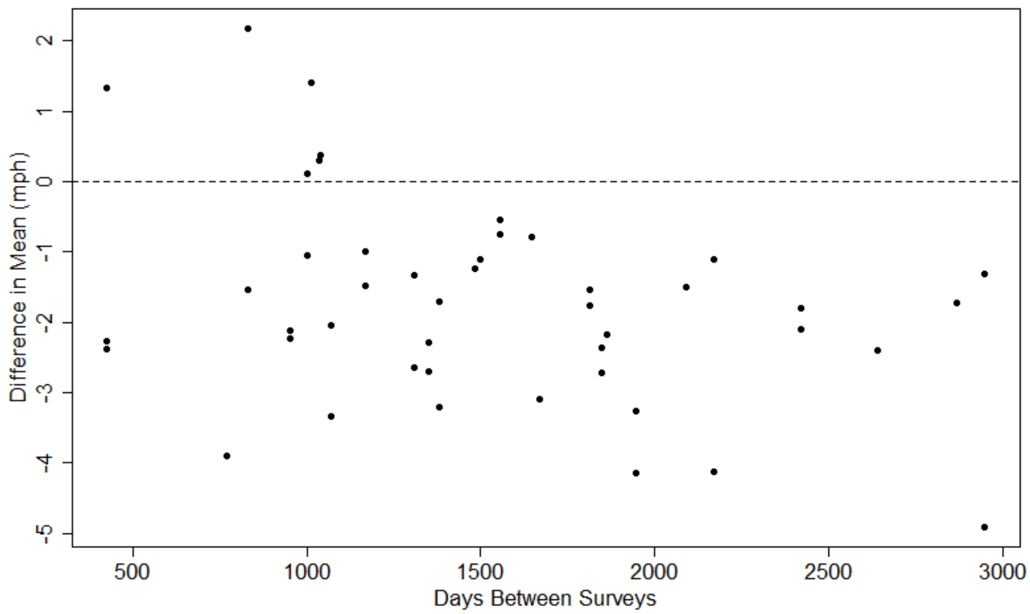

Figure C.3: Scatterplot of the difference in mean speed vs. the number of days elapsed between subsequent surveys for all treatment dataset pairs.

The scatterplot for the change in standard deviation versus the time between subsequent surveys for all treatment sites is provided in Figure C.4. In contrast to Figure C.3, there does not appear to be a significant correlation with time. Figure C.4 provides a more detailed view of the data than Figure C.2, showing the amount of change in the standard deviation for most sites was a decrease of zero to one mile per hour.

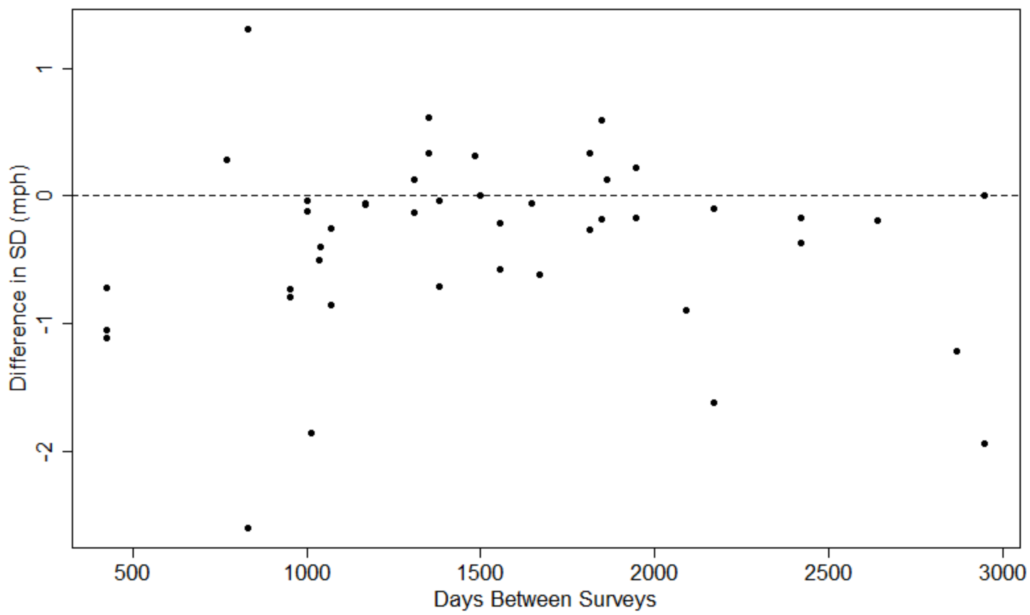

Figure C.4: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all treatment dataset pairs.

C.2 CONTROL SITES

As with Table C.1 for the treatment sites, Table C.2 shows the control dataset pairs grouped by their speed limits and neighborhood greenway status. Average values for mean speed, 85th percentile speed, the percentage of observations exceeding the speeding thresholds that were defined previously, the 10-mph pace minimum, and the percent of vehicles in the pace limits were calculated for the datasets involved in the ‘before’ and ‘after’ conditions for each group.

Overall, the magnitude of the differences within the control ‘before’ and ‘after’ datasets are smaller than those of the treatment datasets, particularly when looking at the percentages exceeding the speed thresholds, suggesting the reductions seen with the treatment datasets are more likely to be caused by the reduced speed limits rather than by chance or the evolution of driver attitudes toward the speed limits.

Table C.2: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for all datasets included in a control pair, grouped by PSL and greenway status.

Non-Neighborhood Greenways								
	PSL	**Mean**	**85th**	**% Exc. 35 mph**	**% Exc. 40 mph**	**% Exc. 45 mph**	**Pace Min**	**% in Pace**
Before (N=1)	35	35.29	41.00	49.36	15.05	2.94	31.00	69.21
After (N=1)	35	35.18	40.00	48.47	14.10	2.49	31.00	69.07
Difference		*-0.11*	*-1.00*	*-0.89*	*-0.95*	*-0.45*	*0.00*	*-0.14*
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
Before (N=2)	30	32.76	37.50	71.60	26.94	5.65	28.50	73.18
After (N=2)	30	32.88	37.00	72.59	25.95	5.00	28.50	76.05
Difference		*0.12*	*-0.50*	*0.99*	*-0.98*	*-0.66*	*0.00*	*2.87*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
Before (N=4)	25	19.69	25.00	11.90	1.71	0.14	15.25	68.66
After (N=4)	25	19.28	24.25	10.45	1.44	0.16	14.50	70.08
Difference		*-0.41*	*-0.75*	*-1.45*	*-0.27*	*0.02*	*-0.75*	*1.42*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=5)	20	21.40	25.80	58.74	18.34	3.26	16.80	72.63
After (N=5)	20	20.95	25.40	55.20	15.41	2.22	16.60	74.13
Difference		*-0.45*	*-0.40*	*-3.54*	*-2.93*	*-1.04*	*-0.20*	*1.50*
Neighborhood Greenways								
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
Before (N=14)	25	20.23	23.93	7.74	0.47	0.04	15.93	83.41
After (N=14)	25	20.28	23.71	7.25	0.43	0.02	16.00	83.45
Difference		*0.05*	*-0.21*	*-0.48*	*-0.04*	*-0.02*	*0.07*	*0.04*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=7)	20	19.69	23.49	40.86	7.77	0.74	15.07	81.67
After (N=7)	20	19.38	22.91	38.17	6.80	0.73	15.07	81.05
Difference		*-0.31*	*-0.57*	*-2.69*	*-0.97*	*-0.01*	*0.00*	*-0.62*

N = the number of datasets averaged

Differences in the mean speed and standard deviation were calculated for each control dataset pair (N = 37), and histograms were constructed to show the distributions of the changes.

Figure C.5 displays the histogram for the differences in mean speeds from the 'before' to 'after' condition. The shape of the distribution is similar to that of Figure C.1 but is centered around zero, showing that on average, the change in mean speed for the control dataset pairs is less than the average change found in the treatment pairs.

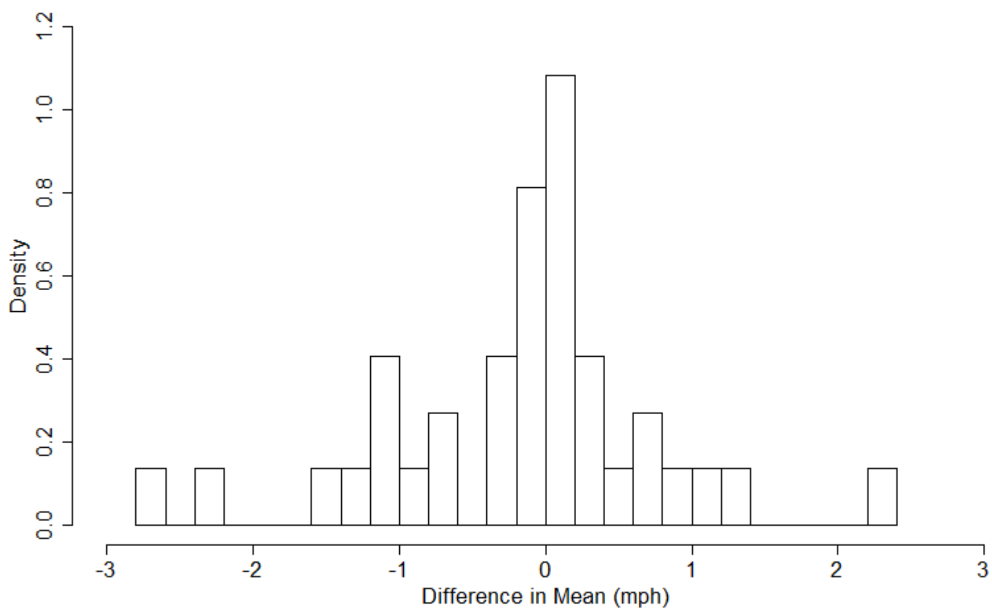

Figure C.5: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for all control pairs.

The histogram for the differences in the standard deviations for the control pairs is provided in Figure C.6. As with Figure C.5, the histogram is centered near zero, indicating that little to no change was produced from the 'before' to 'after' conditions in the control dataset pairs. Overall, the results indicate that the control group is behaving as expected, with the mode for mean and standard deviation differences located near zero.

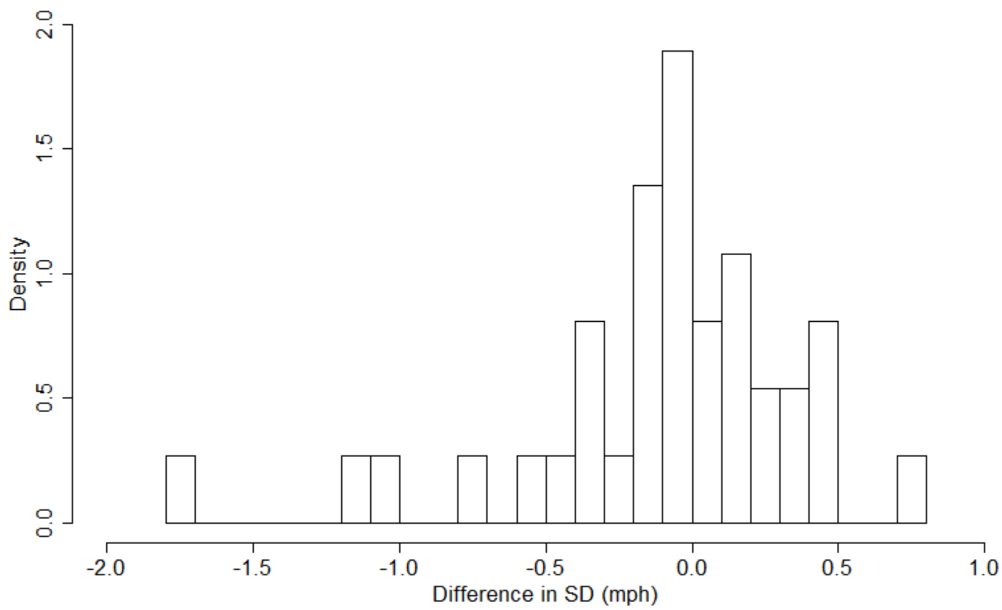

Figure C.6: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all control pairs.

Looking at the magnitude of changes in the mean speed with respect to the time between subsequent surveys, Figure C.7 indicates there may be a slight negative correlation with most surveys occurring more than 500 days after the initial survey showing decreases in mean speeds and those occurring within 500 days showing increases in mean speeds. Portland began engaging in a Vision Zero safety campaign in late 2015, coinciding with a portion of the data collection period. Among other safety enhancements, the campaign included a public education component about the relationship between speed and crash outcomes for vulnerable road users (*City of Portland, 2016*). Social marketing campaigns such as the one undertaken by the City of Portland in conjunction with Vision Zero have been suggested as a method to reduce speeds and improve speed limit compliance (*Toy et al, 2014; Tapp et al, 2015; Tapp et al, 2016*) and may have been a factor in the reduction of mean speeds over time for control sites as well as treatment sites.

As with Figure C.4, Figure C.8 indicates the absence of a relationship between the changes in the standard deviations of speed and the number of days between subsequent surveys. The data points are centered around zero, showing that, on average, little to no change in the standard deviation occurred at control sites, compared to the minor reduction seen on average with the treatment sites.

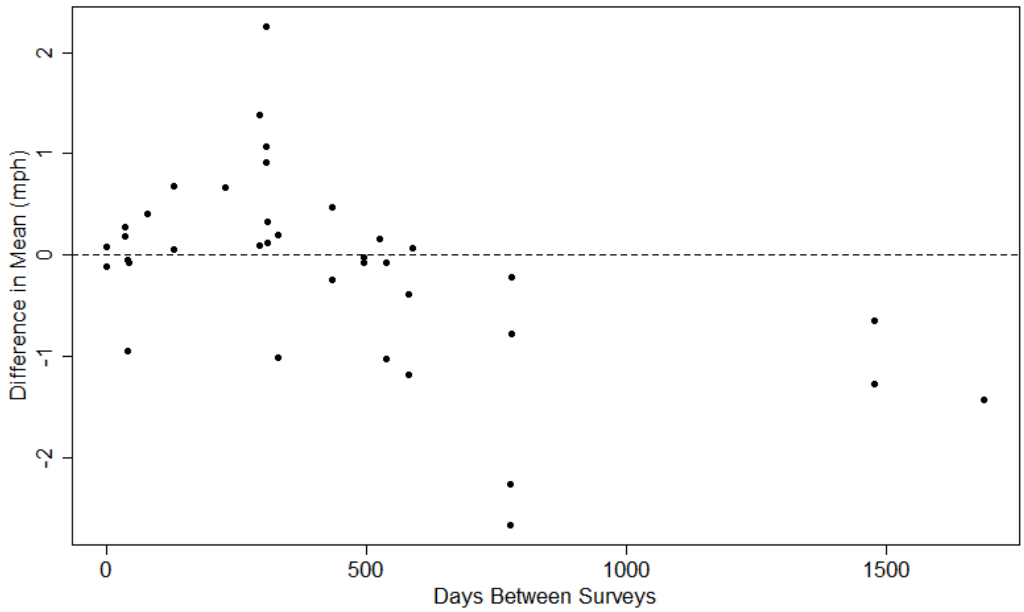

Figure C.7: Scatterplot of the difference in mean speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs.

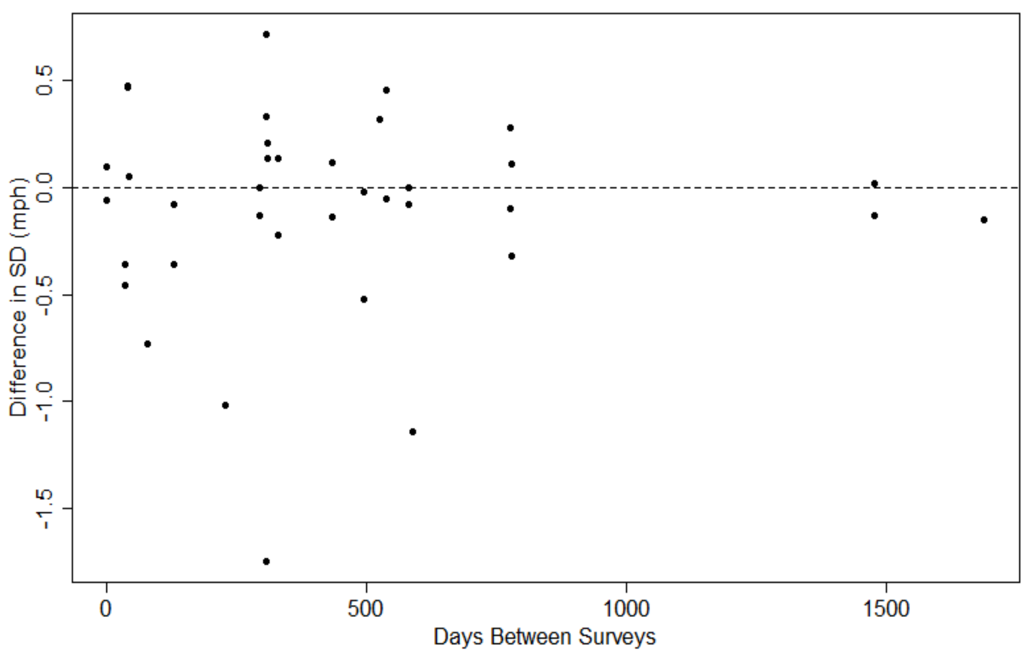

Figure C.8: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs.

C.3 TREATMENT SITES WITH FREE-FLOW TRAFFIC CONDITIONS

Thirteen of the 15 non-neighborhood treatment pairs were comprised of datasets displaying a relationship between mean gap time or vehicle count and mean speed when observations were binned in 15-minute intervals. The two treatment pairs from Holgate east of 111th were not included as they involved datasets that did not demonstrate the relationship pattern, and the site was too close to a traffic signal. The mean gap time of each dataset was calculated, and all observations greater than or equal to the mean gap time were retained for re-analysis. The mean gap time was chosen as the cutoff based on a visual inspection of the mean speed versus mean gap time plots, which were discussed in Section C.3. The plots show that as the 15-minute interval mean gap times increase past the overall mean gap time of the dataset, speeds are less constrained and may better represent free-flow conditions. Collecting data under free-flow conditions is common practice in traffic studies in order to remove possible effects from congestion and to capture the upper range of operating speeds (*Bassani et al, 2014; Bassani et al, 2016; Dinh & Kubota, 2013; Fitzpatrick et al, 2001; Gargoum & El Basyouny, 2016; Gargoum et al, 2016; Islam et al, 2014*). Guidelines for setting speed zones through engineering studies also recommend the use of free-flow speeds for determining speed distributions and 85th percentile speeds (*Forbes et al, 2012; ODOT, 2014*).

Table C.3 displays the average values for the mean and 85th percentile speeds, the percentages exceeding the speed thresholds, the 10-mph pace minimum, and the percent of vehicles within the pace limits for the datasets included in each speed limit group. Again, the number of datasets included in the 'before' condition may not be equal to the number included in the 'after' condition due to multiple repeated surveys at some sites.

When the treatment datasets are limited to free-flow gap times, the magnitude and direction of changes in the performance measure averages are largely in agreeance with the results of the analysis when all observations for all treatment datasets are included. For the 35-30 mph free-flow treatment pairs, decreases in performance measure averages were larger across nearly all categories than when all observations from all 35-30 mph treatment pairs were included. Further analysis retaining all observations of the 13 free-flow datasets revealed the additional decreases in the performance measure averages for the 35-30 mph treatment pairs were due to the exclusion of the datasets at Holgate east of 111th.

Table C.3: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for treatment datasets limited to observations with gap times greater than or equal to the mean gap time.

Treatment Datasets								
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
Before (N=4)	35	36.26	41.25	87.59	60.60	20.39	32.50	70.62
After (N=5)	30	34.77	39.80	83.08	45.21	12.27	30.60	71.19
Difference		*-1.49*	*-1.45*	*-4.51*	*-15.39*	*-8.12*	*-1.90*	*0.57*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
Before (N=2)	30	29.14	33.50	79.83	39.19	8.08	25.00	73.23
After (N=2)	25	27.19	31.50	66.16	22.83	4.11	22.50	74.14
Difference		*-1.95*	*-2.00*	*-13.67*	*-16.36*	*-3.97*	*-2.50*	*0.91*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=4)	25	21.31	26.75	56.62	21.76	3.91	16.63	66.07
After (N=2)	20	21.69	26.00	61.34	19.29	3.92	17.00	73.30
Difference		*0.38*	*-0.75*	*4.72*	*-2.47*	*0.01*	*0.37*	*7.23*

N = the number of datasets averaged

The differences in mean speed for each free-flow dataset pair are shown in the histogram of Figure C.9 (N = 13). Eight of the 13 treatment pairs showed decreases in mean speeds up to three miles per hour in the 'after' condition. The histogram in Figure C.10 demonstrates that the standard deviation decreased in nearly all the free-flow treatment pairs as well. These results are consistent with the changes observed in these 13 datasets when all observations are included.

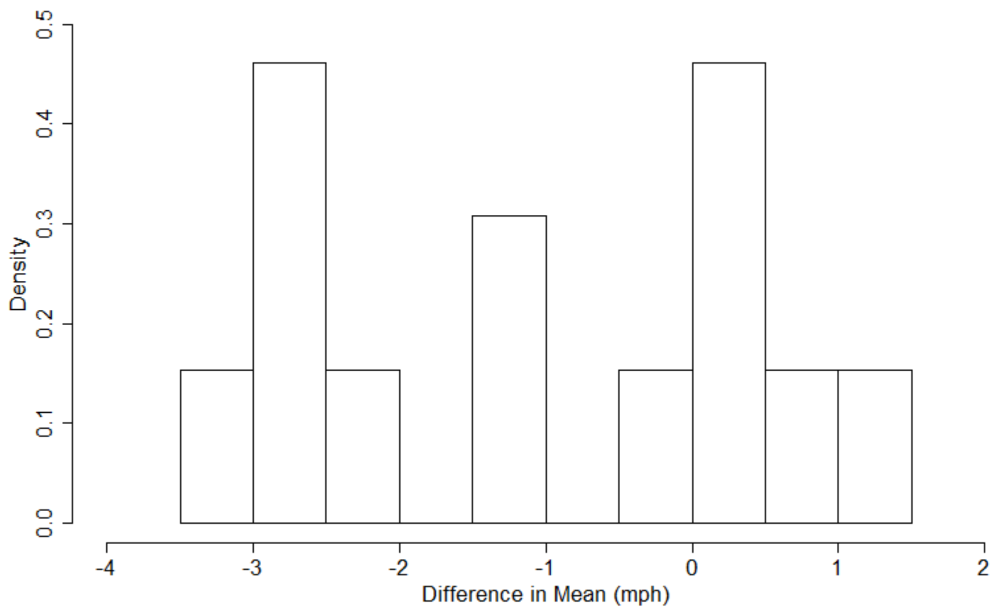

Figure C.9: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow treatment pairs (N = 13).

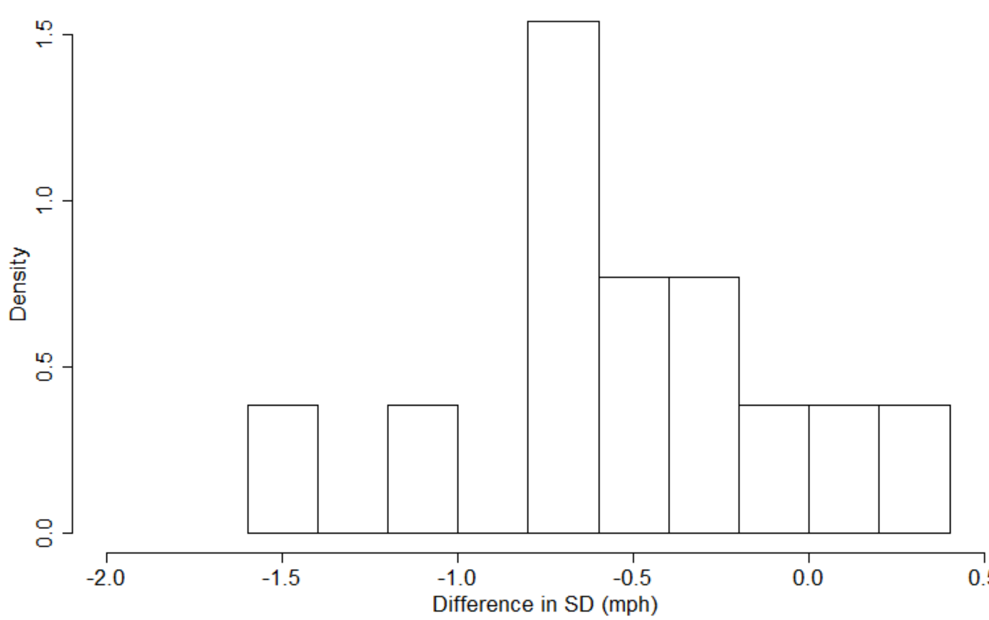

Figure C.10: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for the free-flow treatment pairs (N = 13).

A scatterplot showing the differences in mean speed versus the number of days elapsed between surveys can be seen in Figure C.11. The slight negative correlation observed when all observations from all treatment pairs are included (Figure C.3) does not appear in the plot of Figure C.11. However, thirteen data points may not be enough to detect a clear trend.

In Figure C.12, the scatterplot of the differences in standard deviation versus the number of days between subsequent surveys shows that standard deviations decreased slightly, approximately 0.5 mph on average for most free-flow treatment pairs. A positive trend is also apparent in Figure C.12, with greater decreases in standard deviation occurring when fewer days have elapsed between data collections. Again, this trend should be interpreted cautiously as there are only 13 data points, and no significant trend was observed when all datasets were plotted in Figure C.4.

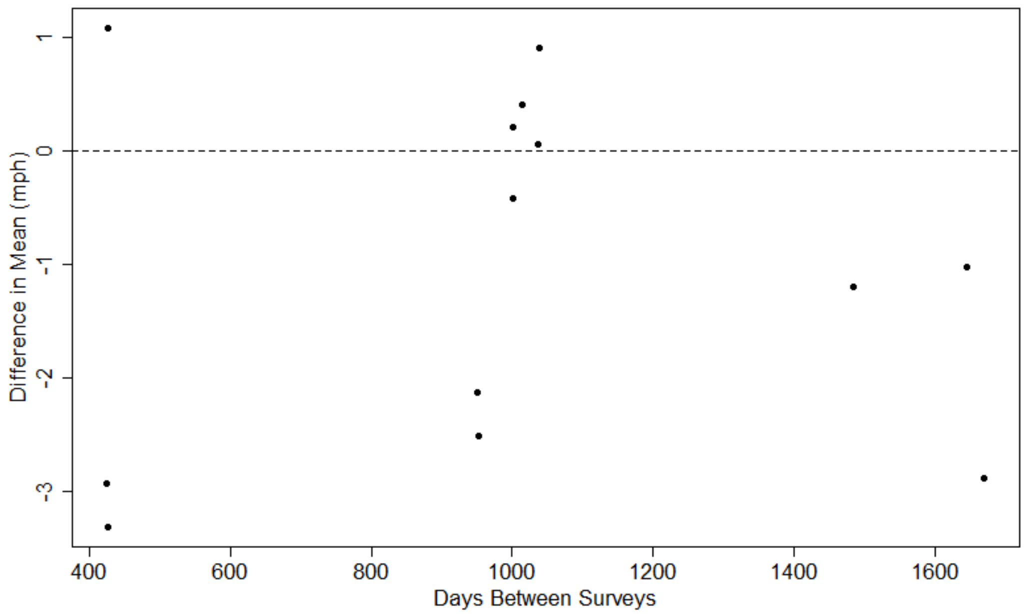

Figure C.11: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for free-flow treatment dataset pairs.

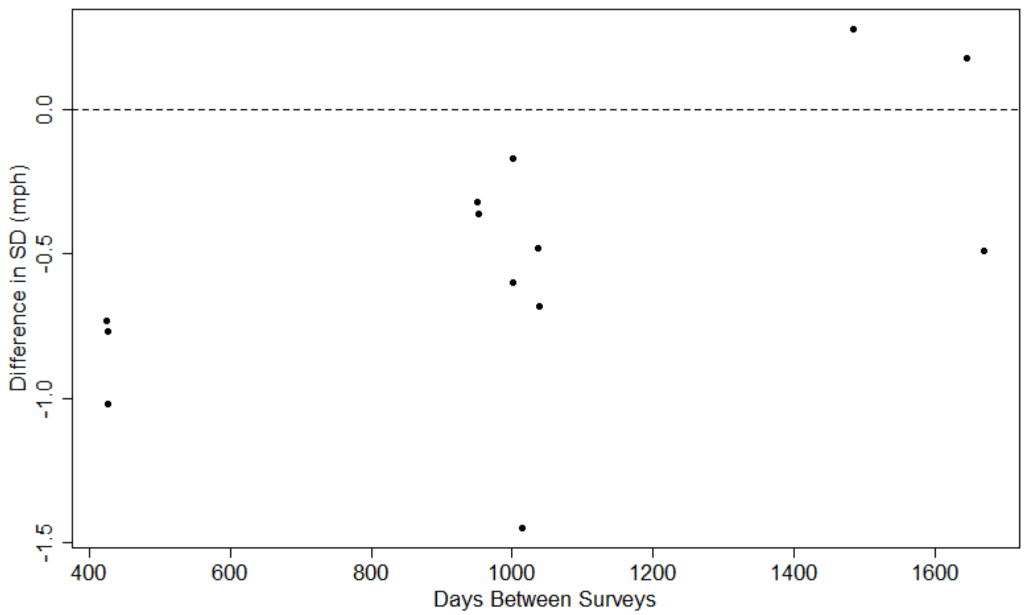

Figure C.12: Scatterplot of the difference in standard deviation vs. the number of days elapsed between surveys for the gap-limited treatment dataset pairs.

Table C.4 compares the performance measure averages of non-neighborhood greenway treatment datasets during the 'before' period when all data is included versus free-flow data only. Mean, 85th percentile, and minimum pace speeds and the percentage of vehicles exceeding the speed thresholds increased in each speed group when only free-flow data was considered. Mean, 85th percentile, and pace speeds were one to five miles per hour higher when only free-flow data were included.

Table C.5 displays the same comparisons as Table C.4 but for the non-neighborhood greenway treatment datasets during the 'after' period. Again, speeds and percentages of vehicles exceeding the speed thresholds increased in all speed groups when data were limited to free-flow conditions. Greater differences in these performance measure averages are seen when the PSL is higher for both the 'before' and 'after' periods.

Table C.4: Comparison of all data and free-flow data from the before period for treatment datasets.

Treatment Datasets (Before)								
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
All data	35	31.17	36.83	62.06	32.89	7.86	27.17	65.69
Free flow*	35	36.26	41.25	87.59	60.60	20.39	32.50	70.62
Difference		*5.09*	*4.42*	*25.53*	*27.71*	*12.53*	*5.33*	*4.93*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
All data	30	27.28	31.50	66.41	22.96	3.62	23.00	74.68
Free flow	30	29.14	33.50	79.83	39.19	8.08	25.00	73.23
Difference		*1.86*	*2.00*	*13.42*	*16.23*	*4.46*	*2.00*	*-1.45*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
All data	25	20.26	25.25	47.78	14.25	2.05	15.50	70.35
Free flow	25	21.31	26.75	56.62	21.76	3.91	16.63	66.07
Difference		*1.05*	*1.50*	*8.84*	*7.51*	*1.86*	*1.13*	*-4.28*

*Free flow does not include Holgate sites.

Table C.5: Comparison of all data and free-flow data from the after period for treatment datasets.

Treatment Datasets (After)								
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
All data	30	30.85	36.00	60.66	22.42	4.10	27.14	69.33
Free flow	30	34.77	39.80	83.08	45.21	12.27	30.60	71.19
Difference		*3.92*	*3.80*	*22.42*	*22.79*	*8.17*	*3.46*	*1.86*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
All data	25	25.34	29.50	48.02	10.76	1.43	20.50	77.68
Free flow	25	27.19	31.50	66.16	22.83	4.11	22.50	74.14
Difference		*1.85*	*2.00*	*18.14*	*12.07*	*2.68*	*2.00*	*-3.54*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
All data	20	20.26	24.50	48.06	11.98	1.91	15.50	73.60
Free flow	20	21.69	26.00	61.34	19.29	3.92	17.00	73.30
Difference		*1.43*	*1.50*	*13.28*	*7.31*	*2.01*	*1.50*	*-0.30*

*Free flow does not include Holgate sites.

C.4 CONTROL SITES WITH FREE-FLOW TRAFFIC CONDITIONS

Fourteen control dataset pairs were comprised of datasets which displayed a relationship between mean speed and mean gap time or vehicle count when data were aggregated into 15-minute intervals. As with the treatment datasets showing the same type of correlations, the mean gap time for each control dataset was calculated, and observations with associated gap times greater than or equal to that mean gap time were retained for analysis in an attempt to remove possible effects from congestion and non-free-flow conditions.

The average values for the mean and 85th percentile speeds, the percentages exceeding the speed thresholds, the 10-mph pace minimum, and the percent of vehicles in the pace limits for the free-flow control datasets included in each speed limit group are displayed in Table C.6. Minor to negligible reductions in the mean, 85th percentile, and the 10-mph pace minimum speeds were observed with the free-flow control datasets. Small decreases in the percentages of vehicles exceeding the speed thresholds were also found for most of the limited datasets.

Comparing the changes in the performance measures from the free-flow datasets to the full datasets, no significant differences were found. In both conditions, the changes across the performance measures were small or negligible.

Table C.6: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for control datasets limited to observations with gap times greater than or equal to the mean gap time.

Control Datasets								
	PSL	**Mean**	**85th**	**% Exc. 35 mph**	**% Exc. 40 mph**	**% Exc. 45 mph**	**Pace Min**	**% in Pace**
Before (N=1)	35	37.35	43.00	66.32	28.24	6.75	33.00	66.63
After (N=1)	35	36.97	42.00	64.15	26.12	5.51	33.00	67.19
Difference		*-0.38*	*-1.00*	*-2.17*	*-2.12*	*-1.24*	*0.00*	*0.56*
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
Before (N=2)	30	34.56	40.00	80.77	43.69	12.61	30.50	68.75
After (N=2)	30	34.62	39.50	81.08	44.82	12.34	30.50	69.11
Difference		*0.06*	*-0.50*	*0.31*	*1.14*	*-0.27*	*0.00*	*0.36*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
Before (N=5)	25	21.15	26.40	18.89	3.39	0.41	16.40	68.60
After (N=5)	25	20.93	26.00	17.01	2.81	0.40	16.50	70.20
Difference		*-0.22*	*-0.40*	*-1.88*	*-0.58*	*-0.02*	*0.10*	*1.60*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
Before (N=5)	20	23.20	28.20	72.44	31.75	7.96	19.00	69.98
After (N=5)	20	22.61	27.60	68.24	27.34	5.60	18.00	70.97
Difference		*-0.59*	*-0.60*	*-4.20*	*-4.41*	*-2.36*	*-1.00*	*0.99*

N = the number of datasets averaged

Differences in mean speed between individual dataset pairs are shown in the histogram in Figure C.13 (N = 14). More than half of the control pairs experienced slight decreases in mean speed from the 'before' to 'after' condition.

The changes in standard deviation from the 'before' to the 'after' condition were similar for the free-flow control pairs, with most seeing slight to negligible decreases. A histogram of these changes is provided in Figure C.14 (N = 14).

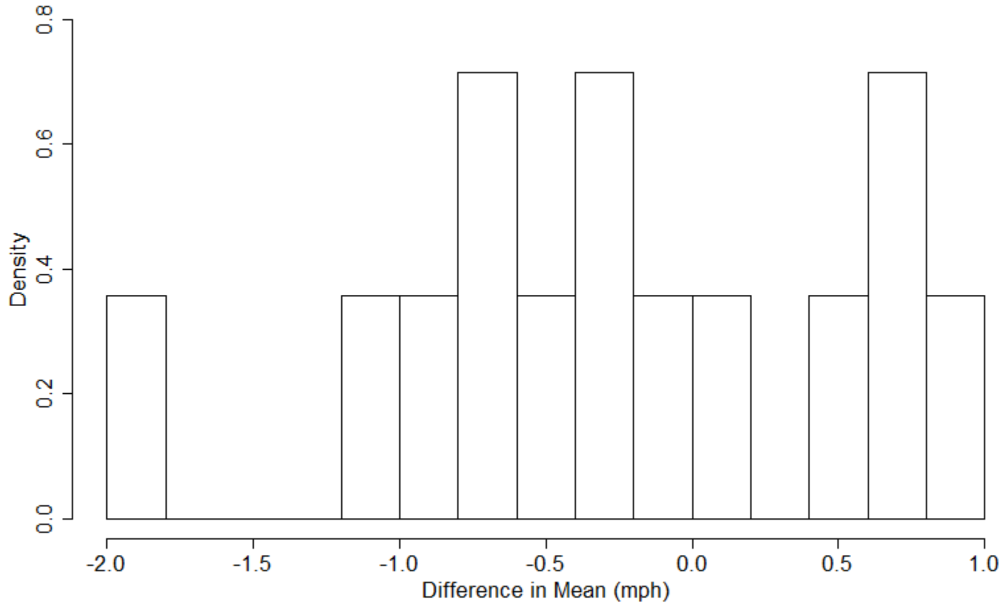

Figure C.13: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow control pairs (N = 14).

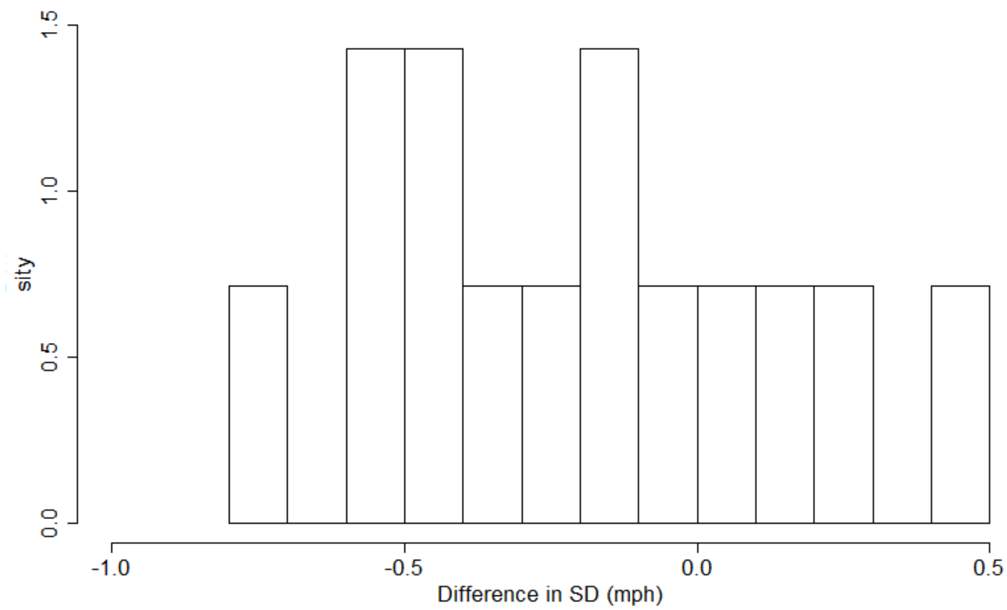

Figure C.14: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for the free-flow control pairs (N = 14).

Similar to the scatterplot in Figure C.7, including all control dataset pairs, the scatterplot in Figure C.15 shows a negative trend between the change in mean speed and the amount of time that occurred between repeated surveys. It bears reiterating that there are only 14 data points in the plot of Figure C.15, therefore caution should be taken in interpreting the trends noted. The data seem to suggest that decreases in mean speed become larger as the number of days elapsed between surveys increase. Again, the educational speed-safety campaign, which began in conjunction with Vision Zero during the data collection period, may have contributed to the decreases in mean speed at control sites even though the posted speed limits did not change. This finding highlights the importance of analyzing control sites in addition to treatment sites, so the effects of other countermeasures present at all sites are not misattributed to the reduced posted speed limit countermeasures at treatment sites.

The change in standard deviations versus the number of days between successive traffic surveys for each free-flow control pair can be seen in Figure C.16. Decreases in the standard deviation were typically 0.5 mph or less. The same positive correlation between the change in the standard deviation and the time elapsed between surveys appears in Figure C.16 as it did for the free-flow treatment pairs in Figure C.14.

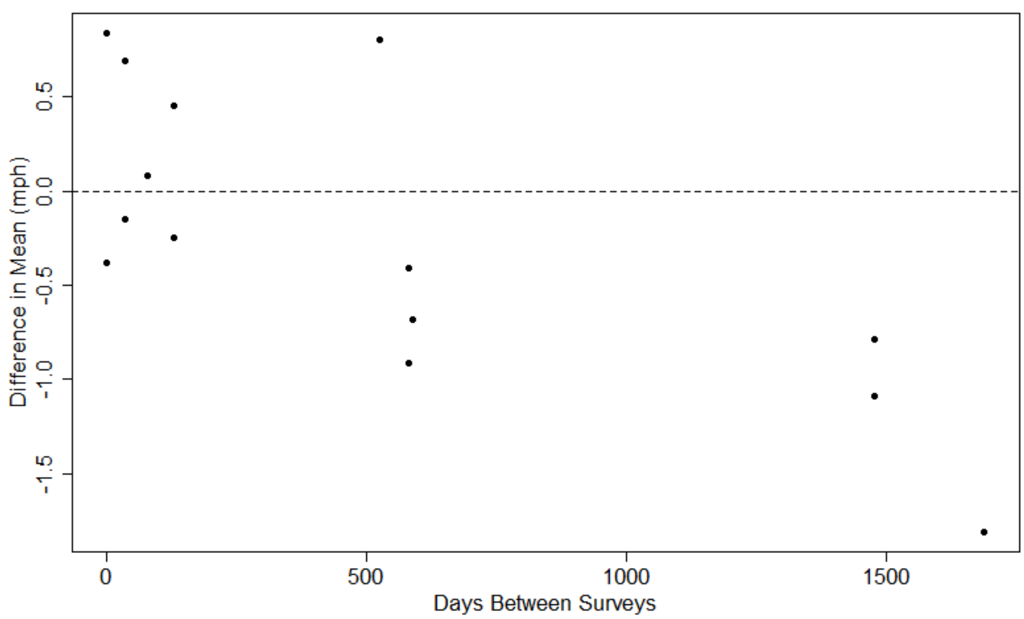

Figure C.15: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for the free-flow control dataset pairs.

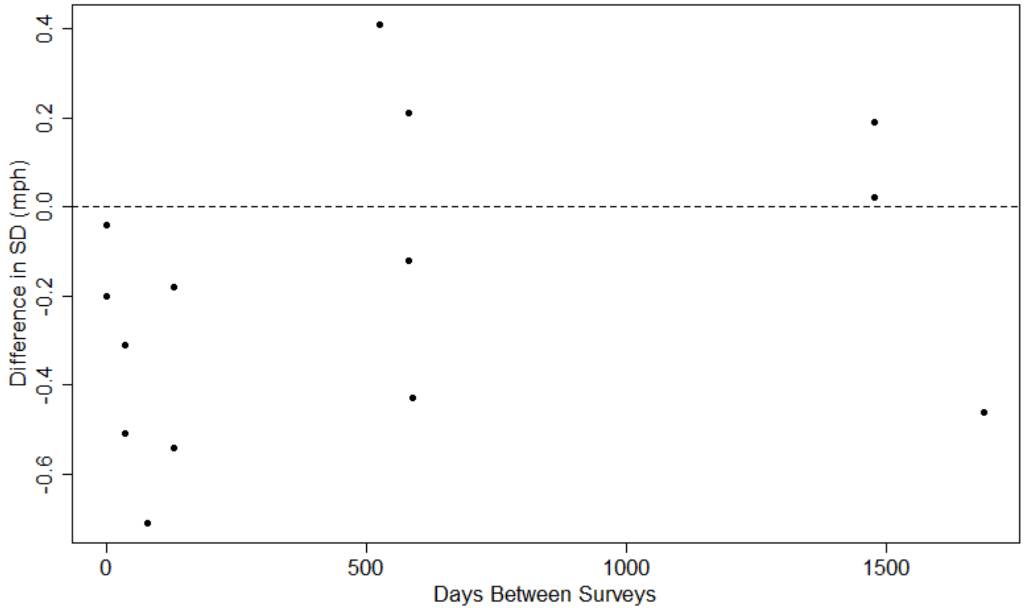

Figure C.16: Scatterplot of the difference in standard deviation vs. the number of days elapsed between surveys for the free-flow control dataset pairs.

Performance measure averages including all non-neighborhood greenway data are compared to those of the free-flow data in Table C.7 for control datasets during the 'before' period. Similar to the comparisons for treatment datasets shown in Table C.4, the mean, 85th percentile, and pace speeds are higher for free-flow data, although by a smaller magnitude, ranging from one to two miles per hour. The percent of vehicles exceeding the speed thresholds is also higher when only free-flow data is included for control datasets.

Table C.8 displays the differences in performance measure averages during the 'after' period for all non-neighborhood control datasets and the free flow control datasets. Differences in the mean, 85th percentile, and pace speeds were one to two miles per hour higher for free-flow datasets than when all non-neighborhood observations were included.

able C.7: Comparison of all data and free-flow data from the before period for control datasets.

Control Datasets Before								
	PSL	**Mean**	**85th**	**% Exc. 35 mph**	**% Exc. 40 mph**	**% Exc. 45 mph**	**Pace Min**	**% in Pace**
All Data	35	35.29	41.00	49.36	15.05	2.94	31.00	69.21
Free Flow	35	37.35	43.00	66.32	28.24	6.75	33.00	66.63
Difference		*2.06*	*2.00*	*16.96*	*13.19*	*3.81*	*2.00*	*-2.58*
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
All Data	30	32.76	37.50	71.60	26.94	5.65	28.50	73.18
Free Flow	30	34.56	40.00	80.77	43.69	12.61	30.50	68.75
Difference		*1.80*	*2.50*	*9.17*	*16.75*	*6.96*	*2.00*	*-4.43*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
All Data	25	19.69	25.00	11.90	1.71	0.14	15.25	68.66
Free Flow	25	21.15	26.40	18.89	3.39	0.41	16.40	68.60
Difference		*1.46*	*1.40*	*6.99*	*1.68*	*0.27*	*1.15*	*-0.06*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
All Data	20	21.40	25.80	58.74	18.34	3.26	16.80	72.63
Free Flow	20	23.20	28.20	72.44	31.75	7.96	19.00	69.98
Difference		*1.80*	*2.40*	*13.70*	*13.41*	*4.70*	*2.20*	*-2.65*

Table C.8: Comparison of all data and free-flow data from the after period for control datasets.

Control Datasets After								
	PSL	**Mean**	**85th**	**% Exc. 35 mph**	**% Exc. 40 mph**	**% Exc. 45 mph**	**Pace Min**	**% in Pace**
All Data	35	35.18	40.00	48.47	14.10	2.49	31.00	69.07
Free Flow	35	36.97	42.00	64.15	26.12	5.51	33.00	67.19
Difference		*1.79*	*2.00*	*15.68*	*12.02*	*3.02*	*2.00*	*-1.88*
	PSL	**Mean**	**85th**	**% Exc. 30 mph**	**% Exc. 35 mph**	**% Exc. 40 mph**	**Pace Min**	**% in Pace**
All Data	30	32.88	37.00	72.59	25.95	5.00	28.50	76.05
Free Flow	30	34.62	39.50	81.08	44.82	12.34	30.50	69.11
Difference		*1.74*	*2.50*	*8.49*	*18.87*	*7.34*	*2.00*	*-6.94*
	PSL	**Mean**	**85th**	**% Exc. 25 mph**	**% Exc. 30 mph**	**% Exc. 35 mph**	**Pace Min**	**% in Pace**
All Data	25	19.28	24.25	10.45	1.44	0.16	14.50	70.08
Free Flow	25	20.93	26.00	17.01	2.81	0.40	16.50	70.20
Difference		*1.65*	*1.75*	*6.56*	*1.37*	*0.24*	*2.00*	*0.12*
	PSL	**Mean**	**85th**	**% Exc. 20 mph**	**% Exc. 25 mph**	**% Exc. 30 mph**	**Pace Min**	**% in Pace**
All Data	20	20.95	25.40	55.20	15.41	2.22	16.60	74.13
Free Flow	20	22.61	27.60	68.24	27.34	5.60	18.00	70.97
Difference		*1.66*	*2.20*	*13.04*	*11.93*	*3.38*	*1.40*	*-3.16*

C.5 TRENDS IN MOTORIZED VEHICLE VOLUMES

Changes in class two vehicle volumes for each 'before' and 'after' dataset pair were calculated and compared to changes in regional VMT throughout the time period of the data collection to assess whether traffic diversion was taking place at treatment sites. The change in volume was calculated as the ADT of the 'after' dataset minus the ADT of the 'before' dataset divided by the ADT of the 'before' dataset and converted to a percent. Tables C.9-C.12 display the class two ADT and the percent change in ADT for each dataset pair for the non-neighborhood greenway treatment pairs, the neighborhood greenway treatment pairs, the non-neighborhood greenway control pairs, and the neighborhood greenway control pairs, respectively.

Table C.9 shows the class two vehicle volumes at non-neighborhood treatment sites decreased 4-16% in more than half of the dataset pairs. Increases in the remaining pairs ranged from 4% to 34%. The average change in class two volume for these dataset pairs was an increase of 0.7%.

Table C.9: Change in class two vehicle volumes for non-neighborhood greenway treatment pairs.

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Division E of 116th EB	Feb 2017	Dec 2019	35	30	9231	7737	-16.2
Division E of 116th EB	Feb 2017	Apr 2018	35	30	9231	8897	-3.6
Division E of 116th WB	Feb 2017	Oct 2019	35	30	9336	8915	-4.5
Division E of 116th WB	Feb 2017	Apr 2018	35	30	9336	10571	13.2
Division E of 116th WB	Feb 2017 b	Oct 2019	35	30	9920	8915	-10.1
Division E of 116th WB	Feb 2017 b	Apr 2018	35	30	9920	10571	6.6
Holgate E of 111th EB	Feb 2017	Jun 2019	35	30	4672	5122	9.6
Holgate E of 111th WB	Feb 2017	Jun 2019	35	30	5166	6903	33.6
Willamette E of Chase EB	Jun 2015	Jul 2019	35	30	6760	6201	-8.3
Williams N of Going NB	Jan 2015	Jul 2019	30	25	4408	4093	-7.1
Williams N of Hancock NB	Feb 2015	Sep 2019	30	25	5880	5456	-7.2
Alberta E of 28th EB	Oct 2016	Jul 2019	25	20	2213	2309	4.3
Alberta E of 28th WB	Oct 2016	Jul 2019	25	20	2256	2030	-10.0
Alberta E of 28th WB	Sep 2016	Jul 2019	25	20	1765	2030	15.0
Alberta E of 28th WB	Sep 2016 b	Jul 2019	25	20	2121	2030	-4.3

Figure C.17 provides a visual representation of the changes in ADT occurring between the 'before' and 'after' conditions in the non-neighborhood treatment pairs. The histogram shows that the ADT decreased in more than half of the dataset pairs.

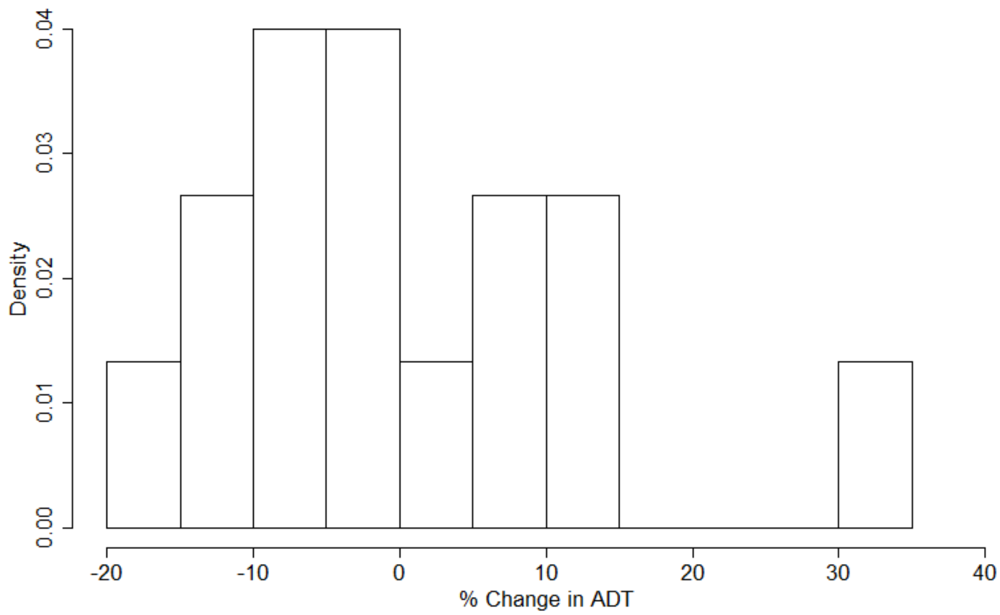

Figure C.17: Histogram of ADT changes for non-neighborhood greenway treatment pairs.

The change in ADT vs the change in the mean speed for the non-neighborhood greenway treatment pairs is shown in the scatterplot of Figure C.18. Based on visual analysis of these 15 datapoints, there does not appear to be any trend associated with the change in ADT and the change in mean speed for this group of dataset pairs.

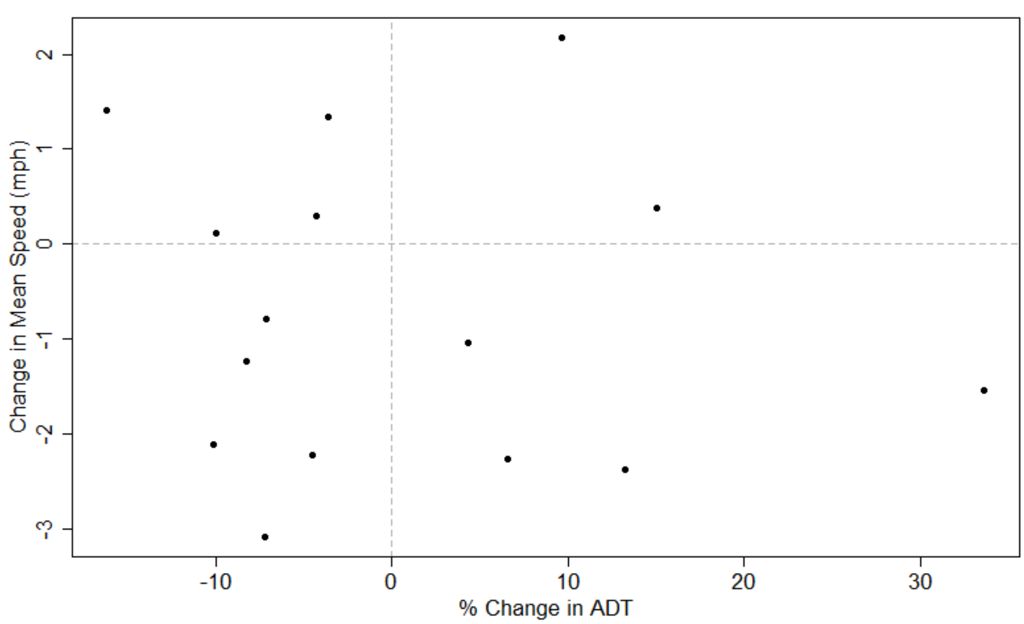

Figure C.18: Change in ADT vs. change in mean speed for non-neighborhood greenway treatment pairs.

For the neighborhood greenway treatment pairs, Table C.10 and the histogram in Figure C.19 show that class two ADT decreased significantly among most dataset pairs. Very sharp decreases of up to 60% to 80% were seen in several treatment pairs. The average change in ADT for the neighborhood greenway treatment pairs was a decrease of approximately 36%.

Table C.10: Change in class two vehicle volumes for neighborhood greenway treatment pairs.

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Clinton E of 23rd EB	Jul 2015	Apr 2019	25	20	693	385	-44.4
Clinton E of 23rd WB	Jul 2015	Apr 2019	25	20	873	491	-43.7
Clinton E of 23rd EB	May 2016	Apr 2019	25	20	655	385	-41.2
Clinton E of 23rd WB	May 2016	Apr 2019	25	20	716	491	-31.4
Clinton E of 29th EB	Apr 2014	Jul 2019	25	20	1006	317	-68.5
Clinton E of 29th WB	Apr 2014	Jul 2019	25	20	991	308	-69.0
Clinton E of 29th EB	May 2016	Jul 2019	25	20	415	317	-23.8
Clinton E of 29th WB	May 2016	Jul 2019	25	20	320	308	-3.7
Clinton W of 14th EB	Aug 2014	Sep 2019	25	20	582	221	-62.0
Clinton W of 14th EB	Aug 2014	Mar 2018	25	20	582	263	-54.8
Clinton W of 14th EB	Aug 2014	May 2018	25	20	582	288	-50.5
Clinton W of 14th WB	Aug 2014	Sep 2019	25	20	1048	428	-59.2
Clinton W of 14th WB	Aug 2014	May 2018	25	20	1048	537	-48.8
Clinton W of 14th WB	Aug 2014	Mar 2018	25	20	1048	578	-44.9
Harrison E of 25th EB	Feb 2017	Apr 2019	25	20	792	647	-18.3
Lincoln E of 45th EB	Nov 2012	Jul 2019	25	20	424	201	-52.6
Lincoln E of 45th WB	Nov 2012	Jul 2019	25	20	618	289	-53.3
Lincoln E of 48th EB	Oct 2012	Jan 2017	25	20	513	611	19.0
Lincoln E of 48th WB	Oct 2012	Jan 2017	25	20	532	560	5.2

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Lincoln E of 50th EB	Apr 2011	May 2019	25	20	1108	225	-79.7
Lincoln E of 50th EB	Apr 2011	Mar 2017	25	20	1108	1079	-2.6
Lincoln E of 50th WB	Apr 2011	May 2019	25	20	1368	496	-63.7
Lincoln E of 50th WB	Apr 2011	Mar 2017	25	20	1368	711	-48.0
Lincoln E of 50th WB	Feb 2012	May 2019	25	20	1070	496	-53.6
Lincoln E of 50th WB	Feb 2012	Mar 2017	25	20	1070	711	-33.6
Lincoln E of 50th WB	Jun 2011	May 2019	25	20	1093	496	-54.6
Lincoln E of 50th WB	Jun 2011	Mar 2017	25	20	1093	711	-35.0
Lincoln W of 41st WB	Nov 2012	Jan 2017	25	20	726	809	11.4
Lincoln W of 57th EB	Feb 2012	Jan 2017	25	20	833	730	-12.4
Lincoln W of 57th WB	Feb 2012	Jan 2017	25	20	748	960	28.4

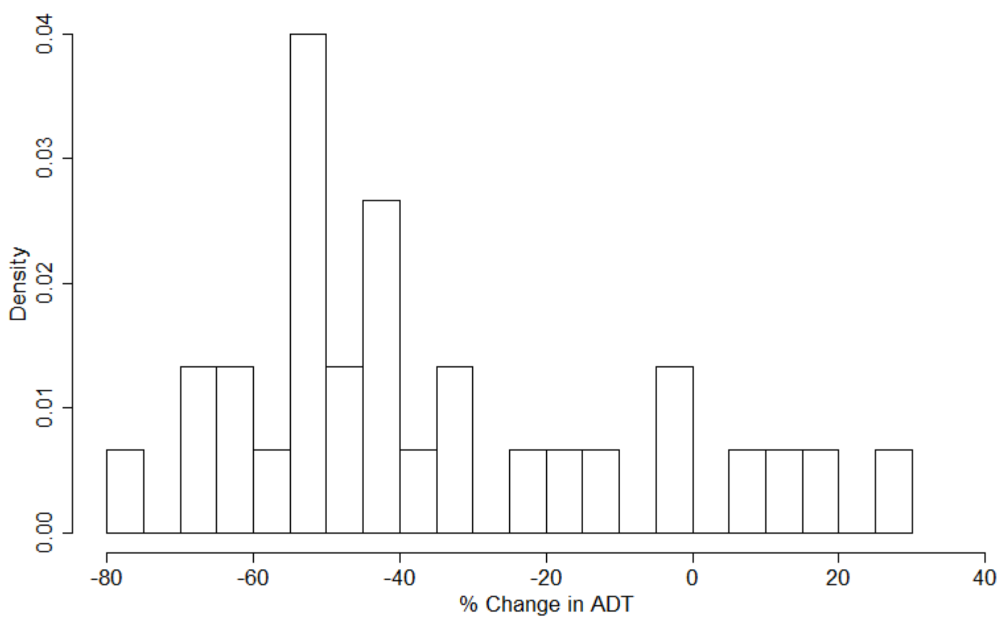

Figure C.19: Histogram of ADT changes for neighborhood greenway treatment pairs.

The scatterplot of Figure C.20 for the change in ADT versus the change in mean speed for neighborhood greenway treatment pairs indicates there may be a relationship between the two measures with larger decreases in mean speed being correlated to higher reductions in ADT.

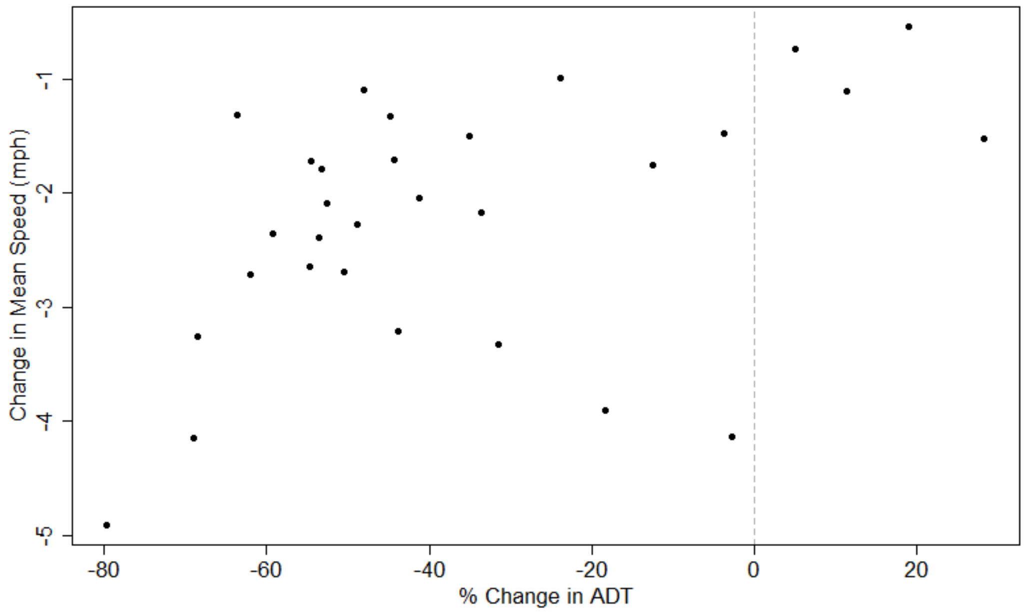

Figure C.20: Change in ADT vs. change in mean speed for neighborhood greenway treatment pairs.

Non-neighborhood greenway control pairs displayed changes in ADT that ranged from a decrease of nearly 17% to an increase of about 28% (Table C.11). The histogram in Figure C.21 indicates modest decreases were found in about half of the dataset pairs. Overall, the average change in ADT at non-neighborhood greenway control pairs was an increase of 2.1%.

Table C.11: Change in class two vehicle volumes for non-neighborhood greenway control pairs.

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Division E of 116th WB	Feb 2017	Feb 2017 b	35	35	9336	9920	6.3
Division E of 116th EB	Apr 2018	Dec 2019	30	30	8897	7737	-13.0
Division E of 116th WB	Apr 2018	Oct 2019	30	30	10571	8915	-15.7
Alberta E of 28th WB	Sep 2016	Sep 2016 b	25	25	1765	2121	20.1
Alberta E of 28th WB	Sep 2016	Oct 2016	25	25	1765	2256	27.8
Alberta E of 28th WB	Sep 2016 b	Oct 2016	25	25	2121	2256	6.4
Division E of 33rd EB	Jul 2015	Jul 2019 b	25	25	4127	3603	-12.7
Division E of 33rd WB	Jul 2015	Jul 2019	25	25	4620	3846	-16.7
Alberta E of 14th EB	Jul 2019	Nov 2019	20	20	3287	3074	-6.5
Alberta E of 14th WB	Jul 2019	Nov 2019	20	20	2959	2668	-9.8
Fremont E of 46th EB	Feb 2018	Sep 2019	20	20	3773	3926	4.1
Fremont E of 46th WB	Feb 2018	Sep 2019	20	20	3654	4020	10.0
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	3503	4465	27.5

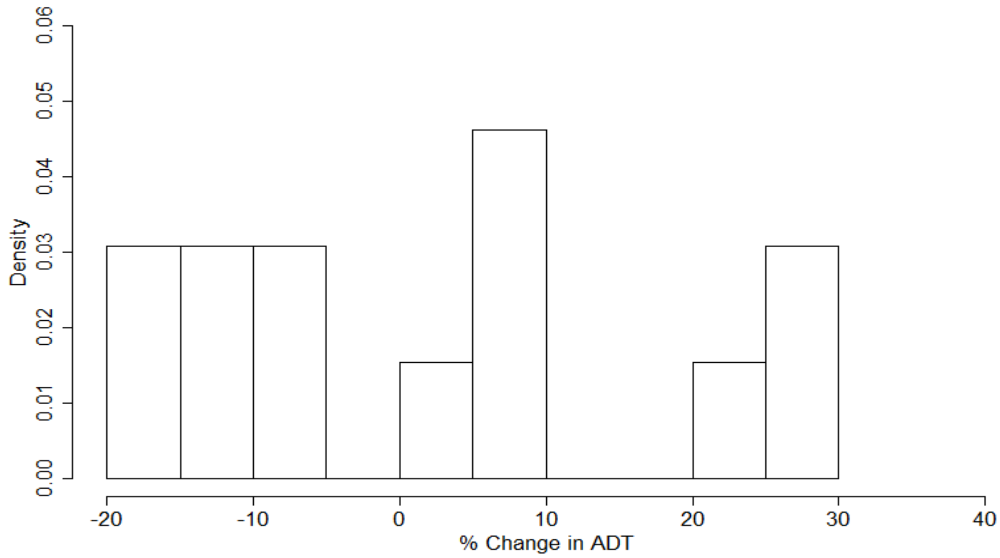

Figure C.21: Histogram of ADT changes for non-neighborhood greenway control pairs.

Similar to the scatterplot in Figure C.18 for the non-neighborhood greenway treatment pairs, the scatterplot in Figure C.22 for the non-neighborhood greenway control pairs does not appear to display a correlation between the change in ADT and the change in mean speed.

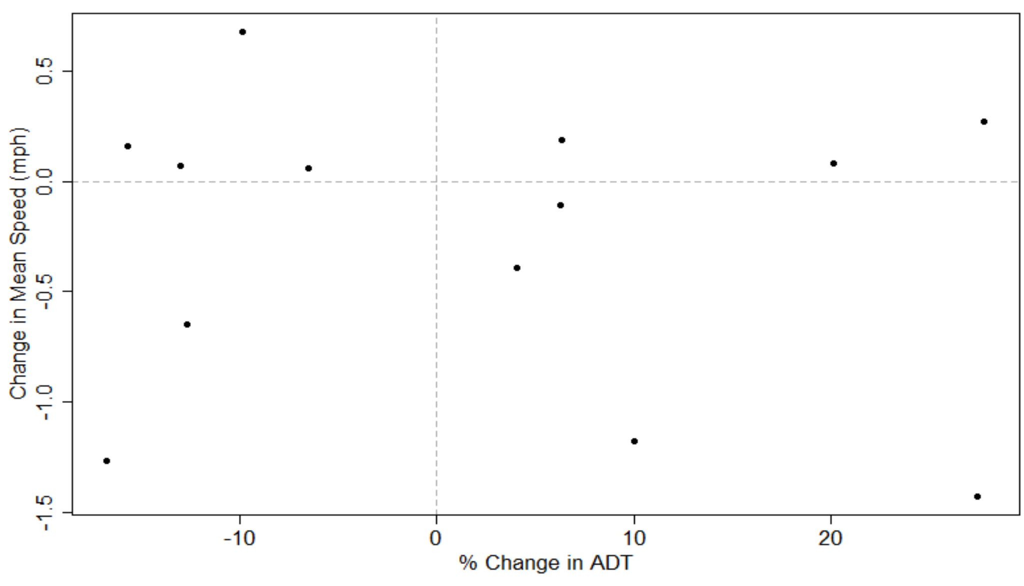

Figure C.22: Change in ADT vs. change in mean speed for non-neighborhood greenway control pairs.

Changes in ADT for neighborhood greenway control pairs, shown in Table C.12 and the histogram of Figure C.23, ranged from a decrease of 79% to an increase of 57%. Like the neighborhood greenway treatment sites, most dataset pairs displayed decreases in ADT, and sharp decreases were observed in a few pairs. The average change in ADT among the neighborhood greenway control pairs was a decrease of approximately 20%.

Table C.12: Change in class two vehicle volumes for neighborhood greenway control pairs.

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Clinton E of 17th EB	Aug 2014	Jul 2015	25	25	682	569	-16.5
Clinton E of 17th WB	Aug 2014	Jul 2015	25	25	924	725	-21.4
Clinton E of 23rd EB	Jul 2015	May 2016	25	25	693	655	-5.4
Clinton E of 23rd WB	Jul 2015	May 2016	25	25	873	716	-18.0
Clinton E of 29th EB	Apr 2014	May 2016	25	25	1006	415	-58.7
Clinton E of 29th WB	Apr 2014	May 2016	25	25	991	320	-67.8
Clinton W of 13th EB	Jul 2015	May 2016	25	25	764	276	-63.9
Clinton W of 13th WB	Jul 2015	May 2016	25	25	369	580	57.3
Clinton W of 25th EB	Mar 2014	Jun 2015	25	25	1169	841	-28.1
Clinton W of 25th WB	Mar 2014	Jun 2015	25	25	1319	1115	-15.5
Clinton W of 30th EB	Aug 2014	Jun 2015	25	25	863	769	-10.9
Clinton W of 30th WB	Aug 2014	Jun 2015	25	25	1067	904	-15.3
Lincoln E of 50th WB	Apr 2011	Feb 2012	25	25	1368	1070	-21.7
Lincoln E of 50th WB	Apr 2011	Jun 2011	25	25	1368	1093	-20.1
Lincoln E of 50th WB	Jun 2011	Feb 2012	25	25	1093	1070	-2.0
Clinton W of 14th EB	Mar 2018	Sep 2019	20	20	263	221	-16.0
Clinton W of 14th EB	Mar 2018	May 2018	20	20	263	288	9.5
Clinton W of 14th WB	Mar 2018	Sep 2019	20	20	578	428	-26.0
Clinton W of 14th WB	Mar 2018	May 2018	20	20	578	537	-7.1
Clinton W of 14th EB	May 2018	Sep 2019	20	20	288	221	-23.2
Clinton W of 14th WB	May 2018	Sep 2019	20	20	537	428	-20.3
Lincoln E of 30th WB	Feb 2019	Apr 2019	20	20	582	742	27.5

Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Lincoln E of 50th EB	Mar 2017	May 2019	20	20	1079	225	-79.2
Lincoln E of 50th WB	Mar 2017	May 2019	20	20	711	496	-30.2

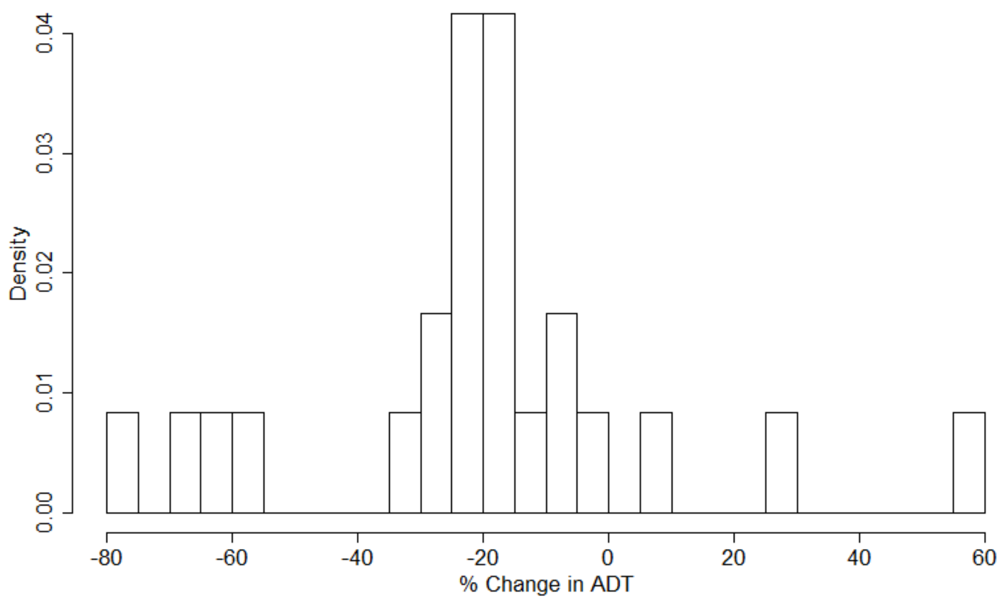

Figure C.23: Histogram of ADT changes for neighborhood greenway control pairs.

A scatterplot of the change in ADT versus the change in mean speed for the neighborhood greenway control pairs is shown in Figure C.24. Visual inspection of the 24 datapoints suggests a positive correlation between changes in ADT and changes in mean speed for this group of dataset pairs. A similar trend was found with the neighborhood greenway treatment pairs (Figure C.20).

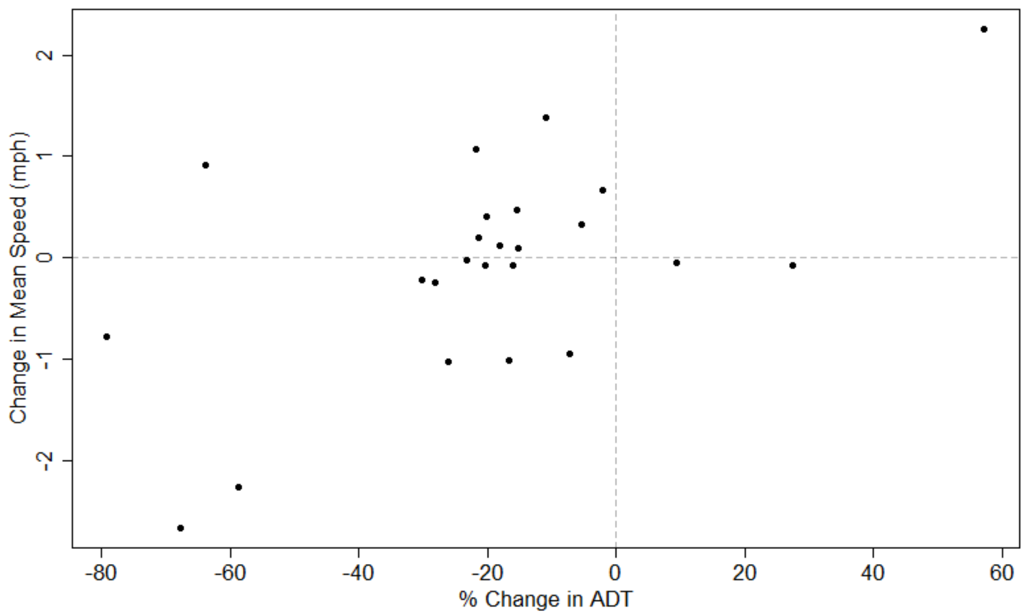

Figure C.24: Change in ADT vs. change in mean speed for the neighborhood greenway control pairs.

The changes in class two vehicle volume were compared to changes in regional VMT based on data from the Texas A&M Transportation Institute's (TTI) 2019 Urban Mobility Report (*Shrank et al, 2019*) and data collected for state highways by the Oregon Department of Transportation (ODOT) (*Oregon Department of Transportation, 2020*). From 2014 to 2017, the TTI report indicated that VMT increased by approximately 5% on freeways and 2.5% on arterials in the Portland urban area. Data from ODOT also showed an increase in VMT on state highways in Multnomah county (within which all data collection sites in this report are located) of almost 4% from 2014 to 2017. The average increase in ADT of 2.1% for non-neighborhood greenway control pairs is consistent with the increased arterial VMT found in the TTI report. The average increase in ADT was near 0.7% for non-neighborhood greenway treatment pairs. However, the percentual average traffic volume decreases seen at both treatment (-36%) and control (-20%) neighborhood greenway sites are in stark contrast to the increases in the region's VMT. This finding suggests that a significant volume of class two traffic has been diverted off these neighborhood greenways. Priority is given to cyclists and other non-motorized users on neighborhood greenways and traffic calming measures are frequently used by the Portland Bureau of Transportation (PBOT) to manage motorized vehicle speeds and volumes on these streets.

C.6 SUMMARY OF BEFORE AND AFTER SPEEDS

When all observations are considered across all datasets, the results of the before and after analysis indicate that treatment sites experience larger decreases in mean and 85th percentile speeds than control sites – on the order of 1.5 mph to 2 mph on average for all 45 treatment pairs compared to small or negligible changes for the 37 control pairs. Treatment sites also appear to have larger decreases in the 10-mph pace minimum speeds and larger increases in the percent of vehicles within the pace limits than control sites.

A negative correlation between the amount of time elapsed between the 'before' and 'after' conditions and the change in mean speed was seen in both the treatment and control groups when all observations were analyzed. This finding suggests that speeds are declining slightly with time regardless of any changes to the posted speed limit, potentially as an effect of the educational speed-safety campaign undertaken by the City of Portland during the data collection period.

The plots for changes in standard deviations versus the number of days between subsequent surveys did not reveal any apparent correlations for either the treatment or control group when all observations from all datasets were analyzed.

The additional free-flow analysis of 13 treatment pairs produced results that were generally consistent with the results found when all full datasets were included for the 25-20 mph and 30-25 mph PSL groups. Marginally larger decreases were seen across all performance measure categories except the percent within the pace limits in the 35-30 mph speed limit group.

Free-flow control datasets also produced results that were highly consistent with the overall trend seen when all control datasets with all observations were included, producing negligible differences in mean speed and standard deviation between the 'before' and 'after' conditions.

The statistics for mean, 85th percentile, and minimum pace speeds and percentages exceeding the speed thresholds were found to be significantly higher when utilizing only the free-flow data for both the treatment and control groups and differences between the performance measure averages for all data versus free-flow data were greater for the treatment group than the control group.

The free-flow dataset pairs for both the treatment and control groups seem to indicate there is a relationship between the change in standard deviation and the number of days that elapse between subsequent data collections. However, more data points are needed to form a more confident conclusion, particularly considering this trend was not seen when all datasets were included in the analysis. Since the free-flow dataset pairs were almost entirely comprised of non-neighborhood greenway sites, it is possible this correlation does not occur at greenway sites, and thus, the trend was not apparent when all datasets were plotted together.

The trend of mean speeds decreasing over time was also found with the free-flow control pairs. A higher level of confidence is instilled in this finding as it is supported by similar trends seen when all observations from all treatment and control pairs were analyzed.

The analysis of changes in class two ADT across dataset pairs revealed that on average, non-neighborhood greenway pairs experienced small increases. In contrast, the neighborhood greenway pairs displayed significant decreases in volume on average. ADT was reduced more on average at neighborhood greenway treatment pairs than control pairs. In non-neighborhood greenway pairs, the average increase in ADT was greater for control pairs than treatment pairs and was consistent with changes in the region's VMT from 2014 to 2017 based on data from TTI.

Scatterplots of the change in ADT versus the change in mean speed revealed a possible positive correlation for the neighborhood greenway treatment and control dataset pairs. This trend was absent for both the treatment and control non-neighborhood greenway plots. Efforts by PBOT to manage speeds and volumes on neighborhood greenways may have contributed to the trends found.

APPENDIX D

D.1 MEAN SPEEDS

The statistical significance of differences in mean speeds from the 'before' condition to the 'after' condition was assessed using Welch two-sample *t*-tests. Using a 95% confidence interval, if $p < 0.05$, the null hypothesis is rejected. If $p \geq 0.05$, the sample data fail to reject the null. Two hypotheses were tested for all dataset pairs in the treatment and control groups.

The first null hypothesis tested states that the mean speed in the 'before' condition is equal to the mean speed in the 'after' condition, H_0: $\mu_B - \mu_A = 0$, where the subscripts B and A symbolize the 'before' and 'after' conditions, respectively. The alternative hypothesis is that the mean speed in the 'after' condition is greater than the mean speed of the 'before' condition, H_A: $\mu_B - \mu_A < 0$. A statistically significant result, when the null is rejected, would suggest that the mean speed was higher in the 'after' period.

The second null hypothesis tested states that the mean speed in the 'before' condition is equal to 1.25 mph plus the mean speed in the 'after' condition, H_0: $\mu_B - \mu_A = 1.25$. The alternative hypothesis is that the mean speed of the 'before' condition is more than 1.25 mph greater than the mean speed of the 'after' condition, H_A: $\mu_B - \mu_A > 1.25$. A rejection of the null hypothesis ($p < 0.05$) would indicate that the mean speed decreased by more than 1.25 mph in the 'after' period. The value of 1.25 mph was chosen as the threshold for the second null hypothesis based on research by *Elvik (2012)*, which concluded that a 1:4 ratio of the change in mean operating speed to the change in posted speed limit (PSL) could be expected for a 5 mph reduction in the PSL.

D.1.1 Hypothesis Test for Equality of Mean Speeds

The first null hypothesis tested, stating the means of the 'before' and 'after' periods are equal, H_0: $\mu_B - \mu_A = 0$, H_A: $\mu_B - \mu_A < 0$, produced significant results for five out of the 45 treatment pairs tested (11.1%). The results indicate that mean speeds increased in the 'after' period, despite a decrease in the PSL as can be seen in Table D.1. Increases in mean speeds ranged from 0.3 mph to 2.2 mph. All five results rejecting the null occurred at sites which are not designated as neighborhood greenways. Bike lanes are present at both Division and Holgate with an extra buffer space separating the bike and motor vehicle lanes on Holgate. No bicycle facilities are present on Alberta. Division is a four lane with a two-way left turn (TWLT) lane roadway and Holgate has a TWLT lane with one through lane in each direction.

Table D.13: Hypothesis test for equality of mean speeds significant results for treatment dataset pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value	Facility
Alberta E of 28th WB	Sep 2016	Jul 2019	25	20	19.76	20.14	0.016	NN
Alberta E of 28th WB	Sep 2016 b	Jul 2019	25	20	19.84	20.14	0.009	NN
Division E of 116th EB	Feb 2017	Apr 2018	35	30	31.27	32.61	0.000	NN
Division E of 116th EB	Feb 2017	Dec 2019	35	30	31.27	32.68	0.000	NN
Holgate E of 111th EB	Feb 2017	Jun 2019*	35	30	21.11	23.29	0.000	NN

Facility: NN = non-neighborhood greenway
*Normal-mixture distribution

From Table D.1, it can be seen that two of the significant results were from the westbound Alberta east of 28th site. The traffic surveys in the ‘before’ period at this site were both conducted in September 2016, and the same ‘after’ survey was compared to both. It can be noted how little difference there is between the mean speeds of both September 2016 surveys.

Table D.1 also shows that two of the significant results were found at the eastbound Division east of 116th site in which the same ‘before’ dataset was compared to ‘after’ datasets from April 2018 and December 2019. The mean speeds of the April 2018 and Dec 2019 datasets are nearly equal.

In the control group, there were 11 dataset pairs out of 37 tested (29.7%) that rejected the null hypothesis, suggesting an increase in mean speeds was experienced in the ‘after’ period. Increases ranged from only 0.2 mph up to 2.3 mph. The results are shown in Table D.2. Nine of the 11 significant results were from locations carrying a neighborhood greenway designation. All neighborhood greenways are classified as local roads and have one lane in each direction. Three of the significant results on these neighborhood greenways occurred at the westbound Lincoln east of 50th site. Three traffic studies were conducted at this site between 2011 and 2012 and from Table D.2, it appears as though the mean speed increased with each of these successive surveys.

Table D.14: Hypothesis test for equality of mean speeds significant results for control dataset pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value	Facility
Alberta E of 14th WB	Jul 2019	Nov 2019	20	20	20.78	21.46	0.000	NN
Clinton E of 17th WB	Aug 2014	Jul 2015	25	25	20.01	20.21	0.010	G
Clinton E of 23rd EB	Jul 2015	May 2016	25	25	20.37	20.70	0.013	G
Clinton W of 13th EB	Jul 2015	May 2016	25	25	17.84	18.76	0.000	G
Clinton W of 13th WB	Jul 2015	May 2016	25	25	18.52	20.78	0.000	G
Clinton W of 25th WB	Mar 2014	Jun 2015	25	25	21.04	21.51	0.000	G
Clinton W of 30th EB	Aug 2014	Jun 2015	25	25	20.09	21.48	0.000	G
Division E of 116th WB	Apr 2018	Oct 2019	30	30	32.91	33.07	0.002	NN
Lincoln E of 50th WB	Apr 2011	Feb 2012	25	25	19.10	20.17	0.000	G
Lincoln E of 50th WB	Apr 2011	Jun 2011	25	25	19.10	19.50	0.002	G
Lincoln E of 50th WB	Jun 2011	Feb 2012	25	25	19.50	20.17	0.000	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

D.1.2 Hypothesis Test for Decrease of Mean Speeds by 1.25 mph

Testing of the second null hypothesis which states the mean speed of the 'before' condition is 1.25 mph greater than the mean speed of the 'after' condition, H_0: $\mu_B - \mu_A = 1.25$ (H_A: $\mu_B - \mu_A > 1.25$), yielded significant results for 28 of the 45 treatment pairs, or 62.2 %, of which 22 were located on designated neighborhood greenways. Table D.3 displays the results of these 28 treatment pairs that rejected the null hypothesis. Decreases in mean speed up to approximately four and five miles per hour were detected at a few locations.

Mean speeds at Clinton east of 23rd experienced significant decreases of more than 1.25 mph compared to two 'before' periods in July 2015 and May 2016. Mean speeds also significantly decreased in the three 'after' periods at eastbound Clinton west of 14th compared to one 'before' survey and decreased in two 'after' periods in the westbound direction at the same location.

Westbound Division east of 116th also saw decreased mean speeds in both the April 2018 and October 2019 surveys compared to two surveys conducted in February 2017.

Table D.15: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for treatment dataset pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value	Facility
Clinton E of 23rd EB	Jul 2015	Apr 2019	25	20	20.37	18.66	0.003	G
Clinton E of 23rd WB	Jul 2015	Apr 2019	25	20	21.32	18.11	0.000	G
Clinton E of 23rd EB	May 2016	Apr 2019	25	20	20.70	18.66	0.000	G
Clinton E of 23rd WB	May 2016	Apr 2019	25	20	21.44	18.11	0.000	G
Clinton E of 29th EB	Apr 2014	Jul 2019	25	20	21.87	18.61	0.000	G
Clinton E of 29th WB	Apr 2014	Jul 2019	25	20	21.27	17.12	0.000	G
Clinton W of 14th EB	Aug 2014	Mar 2018	25	20	22.60	19.96	0.000	G
Clinton W of 14th EB	Aug 2014	May 2018	25	20	22.60	19.91	0.000	G
Clinton W of 14th EB	Aug 2014	Sep 2019	25	20	22.60	19.88	0.000	G
Clinton W of 14th WB	Aug 2014	May 2018	25	20	22.97	20.69	0.000	G
Clinton W of 14th WB	Aug 2014	Sep 2019	25	20	22.97	20.61	0.000	G
Division E of 116th WB	Feb 2017	Apr 2018	35	30	35.29	32.91	0.000	NN
Division E of 116th WB	Feb 2017	Oct 2019	35	30	35.29	33.07	0.000	NN
Division E of 116th WB	Feb 2017 b	Apr 2018	35	30	35.18	32.91	0.000	NN
Division E of 116th WB	Feb 2017 b	Oct 2019	35	30	35.18	33.07	0.000	NN
Harrison E of 25th EB	Feb 2017	Apr 2019	25	20	20.73	16.83	0.000	G
Holgate E of 111th WB	Feb 2017*	Jun 2019	35	30	28.44	26.90	0.009	NN
Lincoln E of 45th EB	Nov 2012	Jul 2019	25	20	22.16	20.07	0.001	G
Lincoln E of 45th WB	Nov 2012	Jul 2019	25	20	21.94	20.15	0.004	G
Lincoln E of 50th EB	Apr 2011	Mar 2017	25	20	21.81	17.68	0.000	G
Lincoln E of 50th EB	Apr 2011	May 2019	25	20	21.81	16.90	0.000	G
Lincoln E of 50th WB	Feb 2012	Mar 2017	25	20	20.17	18.00	0.000	G

Site	Before	After	PSL Before	PSL After	μB	μA	p-value	Facility
Lincoln E of 50th WB	Feb 2012	May 2019	25	20	20.17	17.78	0.000	G
Lincoln E of 50th WB	Jun 2011	May 2019	25	20	19.50	17.78	0.001	G
Lincoln E of 50th WB	Jun 2011	Mar 2017	25	20	19.50	18.00	0.007	G
Lincoln W of 57th EB	Feb 2012	Jan 2017	25	20	22.92	21.16	0.003	G
Lincoln W of 57th WB	Feb 2012	Jan 2017	25	20	22.75	21.22	0.047	G
Williams N of Hancock NB	Feb 2015	Sep 2019	30	25	27.56	24.47	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
*Normal-mixture distribution

Lastly, at Lincoln east of 50th, surveys conducted in March 2017 and May 2019 showed mean speeds were significantly reduced compared to the April 2011 survey in the eastbound direction and as compared to the June 2011 and February 2012 surveys in the westbound direction. A speed hump was installed approximately 150 ft. east of the intersection with 50th sometime after July 2011 and before August 2014 according to archived street view images, which may have contributed to the speed reductions observed at this location.

In comparison to the large number of significant results in the treatment group, only three out of 37 dataset pairs from the control group (8.1%) yielded significant results for the second null hypothesis, suggesting that mean speeds did not decrease by more than 1.25 mph at most sites. Control pairs presenting significant reductions are displayed in Table D.4. Both directions at Clinton east of 29th experienced reduced mean speeds of more than 1.25 mph. The westbound direction at Fremont east of 48th, a two-lane neighborhood collector without bicycle facilities, also showed a decrease in mean speed of more than 1.25 mph.

Table D.16: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for control dataset pairs.

Site	Before	After	PSL Before	PSL After	μB	μA	p-value	Facility
Clinton E of 29th EB	Apr 2014	May 2016	25	25	21.87	19.60	0.000	G
Clinton E of 29th WB	Apr 2014	May 2016	25	25	21.27	18.60	0.000	G
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	23.07	21.64	0.005	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

D.2 85TH PERCENTILE SPEEDS

The 85th percentile operating speed has traditionally been used as an important input when setting speed limits, thus, the magnitude or direction of change in the 85th percentile speed is of interest to this study. A modified *t*-test was used to determine the significance of differences in the 85th percentile speeds from the 'before' condition to the 'after' condition. Details of the test can be found in *Hou et al.* (*2012*).

As with the hypothesis tests for the mean speeds, a 95% confidence level was used, and two null hypotheses were tested. The first null hypothesis states that the 85th percentile speed in the 'before' condition is equal to the 85th percentile speed in the 'after' condition, H_0: $\zeta_{85,B} - \zeta_{85,A} = 0$. The alternative hypothesis is that the mean speed in the 'after' condition is greater than the mean speed of the 'before' condition, H_A: $\zeta_{85,B} - \zeta_{85,A} < 0$. A statistically significant result ($p < 0.05$) would imply that 85th percentile speeds were higher in the 'after' period.

The second null hypothesis tested states that the 85th percentile speed in the 'before' condition is equal to 1.25 mph greater than the 85th percentile speed in the 'after' condition, H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$. The alternative hypothesis states that the 85th percentile speed of the 'before' condition is more than 1.25 mph greater than the 85th percentile speed of the 'after' condition (H_A: $\zeta_{85,B} - \zeta_{85,A} > 1.25$). A rejection of the second null hypothesis ($p < 0.05$) would suggest that 85th percentile speeds decreased by more than 1.25 mph (one-quarter of the change in the PSL for treatment pairs) from the 'before' period to the 'after' period.

D.2.1 Hypothesis Test for Equality of 85th Percentile Speeds

Only two of the 45 treatment pairs (4.4%) showed statistically significant increases in the 85th percentile speeds, rejecting the null hypothesis that the 'before' and 'after' 85th percentile speeds were equal. Their results are shown in Table D.5. Both dataset pairs also rejected the first null hypothesis for mean speeds, H_0: $\mu_B - \mu_A = 0$ (see Section D.1.1). For the eastbound Division east of 116th site, an increase of one mile per hour was observed, and at the eastbound Holgate east of 111th site, the data indicate the 85th percentile speed increased by five miles per hour despite reducing the posted speed limit by five miles per hour. Recall that the 'after' dataset from June 2019 at eastbound Holgate east of 111th was one of two datasets displaying a normal-mixture distribution.

Table D.17: Hypothesis test for equality of 85th percentile speeds significant results for treatment dataset pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value	Facility
Division E of 116th EB	Feb 2017	Apr 2018	35	30	37	38	0.000	NN
Holgate E of 111th EB	Feb 2017	Jun 2019*	35	30	28	33	0.000	NN

Facility: NN = non-neighborhood greenway
*Normal-mixture distribution

Four of 37 control dataset pairs (10.8%) yielded significant results for the first null hypothesis for the 85th percentile speeds, three of which are designated as neighborhood greenways (Table D.6). All four of these control pairs also produced significant results for the first null hypothesis for mean speeds (refer to Section D.1.1). Increases in 85th percentile speeds of one mile per hour were observed at three sites and an increase of three miles per hour was observed at the westbound Clinton west of 13th site between July 2015 and May 2016.

Table D.18: Hypothesis test for equality of 85th percentile speeds significant results for control dataset pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value	Facility
Alberta E of 14th WB	Jul 2019	Nov 2019	20	20	25	26	0.000	NN
Clinton W of 13th EB	Jul 2015	May 2016	25	25	21	22	0.000	G
Clinton W of 13th WB	Jul 2015	May 2016	25	25	22	25	0.000	G
Clinton W of 30th EB	Aug 2014	Jun 2015	25	25	24	25	0.000	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

D.2.2 Hypothesis Test for Decrease of 85th Percentile Speeds by 1.25 mph

The second null hypothesis for 85th percentile speeds states that the 85th percentile speed 'before' is 1.25 mph higher that the 85th percentile speed 'after'. A total of 28 of the 45 treatment dataset pairs (62.2%) generated statistically significant results, rejecting the null hypothesis. These results would indicate the 85th percentile speeds in the 'after' condition were reduced by more than 1.25 mph. Table D.7 shows that 22 of the treatment pairs that rejected the null were located on designated neighborhood greenways.

Nearly all significant dataset pairs (26 of 28) also had significant decreases in mean speed (see Section D.1.2). For the 85th percentile speeds, all combinations of the three 'before' datasets for westbound Lincoln east of 50th from April 2011, June 2011, and February 2012 and both 'after' datasets from March 2017 and May 2019 yielded significant results. Both 'after' datasets at this location in the eastbound direction also produced significant results compared to the April 2011 eastbound dataset. Other key locations where significant decreases in the 85th percentile speed of more than 1.25 mph were observed include Clinton east of 23rd, Clinton west of 14th, and westbound Division east of 116th.

Decreases in 85th percentile speeds for treatment pairs ranged from two to five miles per hour.

Table D.19: Hypothesis test for decrease of 85th percentile speeds by 1.25 mph significant results for treatment dataset pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value	Facility
Clinton E of 23rd EB	Jul 2015	Apr 2019	25	20	24	22	0.002	G
Clinton E of 23rd WB	Jul 2015	Apr 2019	25	20	25	21	0.000	G
Clinton E of 23rd EB	May 2016	Apr 2019	25	20	24	22	0.002	G
Clinton E of 23rd WB	May 2016	Apr 2019	25	20	25	21	0.000	G
Clinton E of 29th EB	Apr 2014	Jul 2019	25	20	26	23	0.000	G
Clinton E of 29th WB	Apr 2014	Jul 2019	25	20	25	21	0.000	G
Clinton W of 14th EB	Aug 2014	Mar 2018	25	20	27	24	0.000	G
Clinton W of 14th EB	Aug 2014	May 2018	25	20	27	24	0.000	G
Clinton W of 14th EB	Aug 2014	Sep 2019	25	20	27	23	0.000	G
Clinton W of 14th WB	Aug 2014	Sep 2019	25	20	27	25	0.001	G
Division E of 116th WB	Feb 2017	Apr 2018	35	30	41	37	0.000	NN
Division E of 116th WB	Feb 2017	Oct 2019	35	30	41	37	0.000	NN
Division E of 116th WB	Feb 2017 b	Apr 2018	35	30	40	37	0.000	NN
Division E of 116th WB	Feb 2017 b	Oct 2019	35	30	40	37	0.000	NN
Harrison E of 25th EB	Feb 2017	Apr 2019	25	20	24	20	0.000	G
Holgate E of 111th WB	Feb 2017*	Jun 2019	35	30	36	32	0.000	NN
Lincoln E of 45th EB	Nov 2012	Jul 2019	25	20	26	24	0.033	G
Lincoln E of 45th WB	Nov 2012	Jul 2019	25	20	26	23	0.000	G
Lincoln E of 50th EB	Apr 2011	Mar 2017	25	20	25	21	0.000	G
Lincoln E of 50th EB	Apr 2011	May 2019	25	20	25	20	0.000	G
Lincoln E of 50th WB	Apr 2011	May 2019	25	20	24	20	0.000	G
Lincoln E of 50th WB	Apr 2011	Mar 2017	25	20	24	21	0.000	G

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value	Facility
Lincoln E of 50th WB	Feb 2012	Mar 2017	25	20	23	21	0.000	G
Lincoln E of 50th WB	Feb 2012	May 2019	25	20	23	20	0.000	G
Lincoln E of 50th WB	Jun 2011	May 2019	25	20	23	20	0.000	G
Lincoln E of 50th WB	Jun 2011	Mar 2017	25	20	23	21	0.000	G
Lincoln W of 57th EB	Feb 2012	Jan 2017	25	20	26	24	0.004	G
Williams N of Hancock NB	Feb 2015	Sep 2019	30	25	32	29	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
*Normal-mixture distribution

Only five of the 37 control dataset pairs (13.5%) rejected the second null hypothesis for 85th percentile speeds, shown in Table D.8. Statistically significant decreases in mean speed of more than 1.25 mph were also found in three of these control pairs (refer to Section D.1.2). Decreases in 85th percentile speeds of two to three miles per hour were observed.

Table D.20: Hypothesis test for decrease of 85th percentile speeds by 1.25 mph significant results for control dataset pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value	Facility
Clinton E of 17th EB	Aug 2014	Jul 2015	25	25	25	23	0.000	G
Clinton E of 29th EB	Apr 2014	May 2016	25	25	26	24	0.005	G
Clinton E of 29th WB	Apr 2014	May 2016	25	25	25	22	0.000	G
Division E of 33rd WB	July 2015	Jul 2019	25	25	25	23	0.000	NN
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	28	26	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

D.3 VARIANCE OF SPEED

The variance of speeds (the square of standard deviation) for the 'before' and 'after' datasets were analyzed using an F-test. The null hypothesis for variance states that the speed variance of the 'before' dataset is equal to the speed variance of the 'after' dataset, H_0: $\sigma_B^2 = \sigma_A^2$. The alternative hypothesis is that the variance in the 'after' condition is not equal to the variance in the 'before' condition, H_A: $\sigma_B^2 \neq \sigma_A^2$. For a *p*-value less than 0.05, the null hypothesis is rejected which suggests that the standard deviation of speed either increased or decreased in the 'after' condition.

Only 21 of the 45 treatment dataset pairs, or 46.7%, were found to have standard deviations in the ‘after’ period that were significantly lower than those in the ‘before’ period. These results are displayed in Table D.9. Of these 21 treatment pairs, ten were collected from non-neighborhood greenways. Thirteen of the treatment pairs in Table D.9 also displayed significantly reduced mean speeds by more than 1.25 mph, notably at westbound Division east of 116^{th} (refer to Section D.1.2). Four of the treatment pairs found in Table D.9 – two at westbound Alberta east of 28^{th} and two at eastbound Division east of 116^{th} – also experienced significantly increased mean speeds (refer to Section D.1.1).

Table D.21: Treatment pairs indicating a significant reduction in the standard deviation in the 'after' period.

Site	Before	After	SD Before	SD After	Ratio	*p*-value	Facility
Alberta E of 28th WB	Sep 2016	Jul 2019	4.92	4.52	1.184	0.001	NN
Alberta E of 28th WB b	Sep 2016 b	Jul 2019	5.02	4.52	1.233	0.000	NN
Clinton E of 23rd WB	Jul 2015	Apr 2019	3.75	3.04	1.523	0.000	G
Clinton E of 23rd EB	May 2016	Apr 2019	3.80	3.55	1.146	0.020	G
Clinton E of 23rd WB	May 2016	Apr 2019	3.89	3.04	1.642	0.000	G
Division E of 116th EB	Feb 2017	Apr 2018	6.64	5.92	1.258	0.000	NN
Division E of 116th EB	Feb 2017	Dec 2019	6.64	4.78	1.925	0.000	NN
Division E of 116th WB	Feb 2017	Apr 2018	5.46	4.35	1.571	0.000	NN
Division E of 116th WB	Feb 2017	Oct 2019	5.46	4.67	1.366	0.000	NN
Division E of 116th WB	Feb 2017 b	Apr 2018	5.40	4.35	1.541	0.000	NN
Division E of 116th WB	Feb 2017 b	Oct 2019	5.40	4.67	1.340	0.000	NN
Holgate E of 111th WB	Feb 2017*	Jun 2019	7.74	5.14	2.264	0.000	NN
Lincoln E of 45th WB	Nov 2012	Jul 2019	3.71	3.34	1.231	0.006	G
Lincoln E of 48th EB	Oct 2012	Jan 2017	4.40	3.83	1.316	0.000	G
Lincoln E of 48th WB	Oct 2012	Jan 2017	4.09	3.88	1.110	0.018	G
Lincoln E of 50th WB	Apr 2011	May 2019	4.80	2.86	2.821	0.000	G
Lincoln E of 50th WB	Apr 2011	Mar 2017	4.80	3.18	2.269	0.000	G
Lincoln E of 50th WB	Jun 2011	May 2019	4.07	2.86	2.035	0.000	G
Lincoln E of 50th WB	Jun 2011	Mar 2017	4.07	3.18	1.637	0.000	G
Lincoln W of 57th EB	Feb 2012	Jan 2017	3.72	3.46	1.159	0.022	G
Williams N of Hancock NB	Feb 2015	Sep 2019	5.10	4.48	1.294	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
Ratio = σ_B^2 / σ_A^2
*Normal-mixture distribution

Table D.10 displays the eight of 45 treatment pairs (17.8%) that experienced a significant increase in standard deviation from the 'before' to 'after' periods. One of these treatment pairs, eastbound Holgate east of 111th, also experienced a significant increase in mean speed (Section D.1.1) while the six neighborhood greenway treatment pairs in Table D.10 were found to have significantly decreased mean speeds in the 'after' period (Section D.1.2).

Table D.22: Treatment pairs indicating a significant increase in the standard deviation in the 'after' period.

Site	Before	After	SD Before	SD After	Ratio	*p*-value	Facility
Clinton E of 29th EB	Apr 2014	Jul 2019	4.03	4.25	0.898	0.026	G
Clinton W of 14th EB	Aug 2014	May 2018	4.04	4.38	0.849	0.003	G
Clinton W of 14th WB	Aug 2014	May 2018	4.13	4.74	0.757	0.000	G
Clinton W of 14th WB	Aug 2014	Sep 2019	4.13	4.72	0.765	0.000	G
Harrison E of 25th EB	Feb 2017	Apr 2019	3.07	3.35	0.838	0.004	G
Holgate E of 111th EB	Feb 2017	Jun 2019*	7.10	8.41	0.713	0.000	NN
Lincoln W of 57th WB	Feb 2012	Jan 2017	3.19	3.53	0.814	0.002	G
Willamette E of Chase EB	Jun 2015	Jul 2019	3.98	4.30	0.857	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
Ratio = σ_B^2 / σ_A^2
*Normal-mixture distribution

Twelve of the 37 control dataset pairs (32.4%) resulted in a rejection of the variance null hypothesis in favor of a decrease in the standard deviation during the 'after' period. These results are shown in Table D.11. One of these control pairs (westbound Fremont east of 48th) also experienced a significant reduction in mean speed by more than 1.25 mph (see Section D.1.2). Three pairs – all at westbound Lincoln east of 50th, also showed that mean speeds significantly increased from the 'before' period to the 'after' period (see Section D.1.1).

Table D.23: Control pairs indicating a significant decrease in standard deviation during the 'after' period.

Site	Before	After	SD Before	SD After	Ratio	*p*-value	Facility
Alberta E of 14th EB	Jul 2019	Nov 2019	5.15	4.79	1.154	0.000	NN
Alberta E of 28th WB	Sep 2016	Oct 2016	4.92	4.56	1.164	0.002	NN
Alberta E of 28th WB	Sep 2016 b	Oct 2016	5.02	4.56	1.212	0.000	NN
Clinton E of 17th EB	Aug 2014	Jul 2015	3.33	3.11	1.145	0.001	G
Clinton W of 14th EB	May 2018	Sep 2019	4.38	3.86	1.290	0.000	G
Division E of 116th EB	Apr 2018	Dec 2019	5.92	4.78	1.531	0.000	NN
Division E of 33rd EB	Jul 2015	Jul 2019 b	5.34	5.21	1.049	0.045	NN
Fremont E of 48th WB	Dec 2014	Jul 2019	4.83	4.68	1.068	0.001	NN
Lincoln E of 50th WB	Apr 2011	Feb 2012	4.80	3.05	2.478	0.000	G
Lincoln E of 50th WB	Apr 2011	Jun 2011	4.80	4.07	1.386	0.000	G
Lincoln E of 50th WB	Jun 2011	Feb 2012	4.07	3.05	1.787	0.000	G
Lincoln E of 50th WB	Mar 2017	May 2019	3.18	2.86	1.243	0.002	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
Ratio = σ_B^2 / σ_A^2

Table D.12 displays the nine of 37 control datasets (24.3%) in which the standard deviation of speed significantly increased from the 'before' to 'after' periods. Five of these control pairs also showed increases in mean speeds in the 'after' period (refer to Section D.1.1) while one control pair experienced a decrease in mean speed in the 'after' period (refer to Section D.1.2).

Table D.24: Control pairs indicating a significant increase in the standard deviation during the 'after' period.

Site	Before	After	SD Before	SD After	Ratio	*p*-value	Facility
Clinton E of 17th WB	Aug 2014	Jul 2015	3.09	3.23	0.913	0.008	G
Clinton E of 23rd EB	Jul 2015	May 2016	3.59	3.8	0.895	0.025	G
Clinton E of 29th EB	Apr 2014	May 2016	4.03	4.31	0.873	0.018	G
Clinton W of 13th EB	Jul 2015	May 2016	3.49	3.82	0.834	0.002	G
Clinton W of 13th WB	Jul 2015	May 2016	3.36	4.08	0.678	0.000	G
Clinton W of 14th EB	Mar 2018	May 2018	3.91	4.38	0.794	0.001	G
Clinton W of 14th WB	Mar 2018	May 2018	4.26	4.74	0.807	0.000	G
Clinton W of 14th WB	Mar 2018	Sep 2019	4.26	4.72	0.815	0.000	G
Division E of 116th WB	Apr 2018	Oct 2019	4.35	4.67	0.869	0.000	NN

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway
Ratio = σ_B^2 / σ_A^2

D.4 PROPORTIONS EXCEEDING THE SPEED THRESHOLD

The proportions of vehicles exceeding a defined speed threshold were compared for all treatment and control dataset pairs using a chi-square test. In the chi-square test, the null hypothesis states that the proportion of class two vehicles exceeding the speed threshold in the 'before' condition is equal to the proportion of class two vehicles exceeding the speed threshold in the 'after' condition, H_0: $P_B - P_A = 0$. The alternative hypothesis is that the proportion of vehicles exceeding the speed threshold in the 'before' condition is not equal to the proportion exceeding the threshold in the 'after' condition, H_A: $P_B - P_A \neq 0$. A statistically significant result ($p < 0.05$) would indicate that the percent of vehicles traveling at speeds higher than the threshold either decreased or increased in the 'after' period. The posted speed limit (PSL) of the dataset from the 'after' condition was chosen as the speed threshold. Thus, for control pairs, the speed threshold is also equal to the PSL of the 'before' dataset.

Six of the nine 35-30 mph treatment pairs saw a significant reduction in the proportion of vehicles exceeding the 30-mph threshold (Table D.13). Four of these pairs were from the westbound Division east of 116th site, a district collector (and principal arterial) where bike lanes are present. The other two locations, Holgate and Willamette, are considered neighborhood collectors by PBOT and have bike lanes with increased buffer space between the bike and motor vehicle lanes.

Table D.25: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 30 mph.

30 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Division E of 116th WB	Feb 2017	Oct 2019	0.84	0.74	0.000	NN
Division E of 116th WB	Feb 2017	Apr 2018	0.84	0.74	0.000	NN
Division E of 116th WB	Feb 2017 b	Oct 2019	0.83	0.74	0.000	NN
Division E of 116th WB	Feb 2017 b	Apr 2018	0.83	0.74	0.000	NN
Holgate E of 111th WB	Feb 2017*	Jun 2019	0.41	0.24	0.000	NN
Willamette E of Chase EB	Jun 2015	Jul 2019	0.92	0.87	0.000	NN

Facility: NN = non-neighborhood greenway
*Normal-mixture distribution

Two 30-25 mph treatment pairs had statistically significant reductions in the proportion of vehicles exceeding 25 mph, displayed in Table D.14. Williams is considered a neighborhood collector and carries one-way traffic through one motor vehicle lane and one buffered bike lane.

The null hypothesis for proportions was rejected ($p < 0.05$) for 31 of the 34 treatment pairs with a 25 mph 'before' and 20 mph 'after' PSL (Table D.15). These 31 treatment pairs had significant decreases in the proportion of vehicles exceeding 20 mph. The three treatment pairs that did not experience a significant reduction in the proportion of vehicles exceeding 20 mph were collected from the westbound direction of Alberta east of 28^{th}. In total, 39 of 45 treatment pairs (86.7%) exhibited a 4% to 58% (average 25%) reduction of vehicles exceeding the speed threshold.

Table D.26: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 25 mph.

25 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Williams N of Going NB	Jan 2015	Jul 2019	0.65	0.56	0.000	NN
Williams N of Hancock NB	Feb 2015	Sep 2019	0.68	0.40	0.000	NN

Facility: NN = non-neighborhood greenway

Table D.27: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 20 mph.

20 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Alberta E of 28th EB	Oct 2016	Jul 2019	0.58	0.50	0.000	NN
Clinton E of 23rd EB	Jul 2015	Apr 2019	0.51	0.30	0.000	G
Clinton E of 23rd EB	May 2016	Apr 2019	0.59	0.21	0.000	G
Clinton E of 23rd WB	Jul 2015	Apr 2019	0.55	0.30	0.000	G
Clinton E of 23rd WB	May 2016	Apr 2019	0.61	0.21	0.000	G
Clinton E of 29th EB	Apr 2014	Jul 2019	0.66	0.32	0.000	G
Clinton E of 29th EB	May 2016	Jul 2019	0.57	0.17	0.000	G
Clinton E of 29th WB	Apr 2014	Jul 2019	0.44	0.32	0.000	G
Clinton E of 29th WB	May 2016	Jul 2019	0.30	0.17	0.000	G
Clinton W of 14th EB	Aug 2014	Sep 2019	0.73	0.44	0.000	G
Clinton W of 14th EB	Aug 2014	May 2018	0.73	0.45	0.000	G
Clinton W of 14th EB	Aug 2014	Mar 2018	0.73	0.46	0.000	G
Clinton W of 14th WB	Aug 2014	Sep 2019	0.75	0.52	0.000	G
Clinton W of 14th WB	Aug 2014	May 2018	0.75	0.54	0.000	G
Clinton W of 14th WB	Aug 2014	Mar 2018	0.75	0.62	0.000	G
Harrison E of 25th EB	Feb 2017	Apr 2019	0.51	0.12	0.000	G
Lincoln E of 45th EB	Nov 2012	Jul 2019	0.70	0.45	0.000	G
Lincoln E of 45th WB	Nov 2012	Jul 2019	0.66	0.48	0.000	G
Lincoln E of 48th EB	Oct 2012	Jan 2017	0.67	0.63	0.018	G
Lincoln E of 48th WB	Oct 2012	Jan 2017	0.71	0.64	0.000	G
Lincoln E of 50th EB	Apr 2011	May 2019	0.70	0.13	0.000	G

20 mph Threshold						
Lincoln E of 50th EB	Apr 2011	Mar 2017	0.70	0.17	0.000	G
Lincoln E of 50th WB	Apr 2011	May 2019	0.41	0.14	0.000	G
Lincoln E of 50th WB	Apr 2011	Mar 2017	0.41	0.19	0.000	G
Lincoln E of 50th WB	Jun 2011	May 2019	0.45	0.14	0.000	G
Lincoln E of 50th WB	Jun 2011	Mar 2017	0.45	0.19	0.000	G
Lincoln E of 50th WB	Feb 2012	May 2019	0.43	0.14	0.000	G
Lincoln E of 50th WB	Feb 2012	Mar 2017	0.43	0.19	0.000	G
Lincoln W of 41st WB	Nov 2012	Jan 2017	0.67	0.56	0.000	G
Lincoln W of 57th EB	Feb 2012	Jan 2017	0.78	0.63	0.000	G
Lincoln W of 57th WB	Feb 2012	Jan 2017	0.78	0.60	0.000	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

The proportion of vehicles exceeding the speed threshold increased for three of the 45 treatment pairs (6.7%) – two for the eastbound direction at Division east of 116th and one at eastbound Holgate east of 111th. Increases ranged from 7% to 16%. All three dataset pairs had a 30-mph speed threshold and are displayed in Table D.16.

Table D.28: Treatment pairs with a significant increase in the proportion of vehicles exceeding 30 mph.

30 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Division E of 116th EB	Feb 2017	Apr 2018	0.62	0.69	0.000	NN
Division E of 116th EB	Feb 2017	Dec 2019	0.62	0.72	0.000	NN
Holgate E of 111th EB	Feb 2017	Jun 2019*	0.10	0.26	0.000	NN

Facility: NN = non-neighborhood greenway
*Normal-mixture distribution

Table D.17 presents the six 25-mph control pairs (of 20 total) in which the proportion of vehicles exceeding a 25-mph threshold was significantly reduced in the 'after' condition. Four of the control pairs were located on neighborhood greenway streets. The remaining two were collected from Division east of 33rd, a two-lane urban collector without bicycle facilities.

Table D.29: Control pairs with a significant decrease in the proportion of vehicles exceeding 25 mph.

25 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Clinton E of 17th EB	Aug 2014	Jul 2015	0.11	0.05	0.000	G
Clinton E of 29th EB	Apr 2014	May 2016	0.16	0.07	0.000	G
Clinton E of 29th WB	Apr 2014	May 2016	0.13	0.04	0.000	G
Division E of 33rd EB	Jul 2015	Jul 2019 b	0.11	0.09	0.002	NN
Division E of 33rd WB	Jul 2015	Jul 2019	0.11	0.08	0.000	NN
Lincoln E of 50th WB	Apr 2011	Feb 2012	0.06	0.04	0.003	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

Table D.18 displays the six 20-mph control pairs (of 14 total) which demonstrated a decrease in the proportion of vehicles exceeding the 20-mph threshold. Three of these control pairs were located on neighborhood greenway streets. No control pairs with speed thresholds of 30 mph or 35 mph showed statistically significant decreases in the proportion of vehicles exceeding those thresholds. Overall, the proportion of vehicles exceeding the speed threshold was reduced by 2% to 12% in 12 of the 37 (32.4%) of the control dataset pairs.

Table D.30: Control pairs with a significant decrease in the proportion of vehicles exceeding 20 mph.

20 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Clinton W of 14th WB	Mar 2018	Sep 2019	0.62	0.52	0.000	G
Clinton W of 14th WB	Mar 2018	May 2018	0.62	0.54	0.000	G
Fremont E of 46th EB	Feb 2018	Sep 2019	0.56	0.51	0.000	NN
Fremont E of 46th WB	Feb 2018	Sep 2019	0.53	0.42	0.000	NN
Fremont E of 48th WB	Dec 2014	Jul 2019	0.71	0.62	0.000	NN
Lincoln E of 50th WB	Mar 2017	May 2019	0.19	0.14	0.018	G

Facility: NN = non-neighborhood greenway, G = designated neighborhood greenway

Significant increases in the proportion of vehicles exceeding the speed thresholds were found in seven of the 37 control pairs (18.9%) and can be seen in Tables D.19-D.21 for the 30 mph, 25 mph, and 20 mph thresholds, respectively. Increases of 1% to 8% were observed.

Table D.31: Control pair with a significant increase in the proportion of vehicles exceeding 30 mph.

30 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Division E of 116th EB	Apr 2018	Dec 2019	0.69	0.72	0.000	NN

Facility: NN = non-neighborhood greenway

Table D.32: Control pairs with a significant increase in the proportion of vehicles exceeding 25 mph.

25 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Clinton E of 17th WB	Aug 2014	Jul 2015	0.03	0.04	0.015	G
Clinton W of 13th EB	Jul 2015	May 2016	0.01	0.03	0.003	G
Clinton W of 13th WB	Jul 2015	May 2016	0.02	0.10	0.000	G
Clinton W of 25th WB	Mar 2014	Jun 2015	0.10	0.12	0.044	G
Clinton W of 30th EB	Aug 2014	Jun 2015	0.06	0.12	0.000	G

Facility: G = designated neighborhood greenway

Table D.33: Control pair with a significant increase in the proportion of vehicles exceeding 20 mph.

20 mph Threshold						
Site	**Before**	**After**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**	**Facility**
Alberta E of 14th WB	Jul 2019	Nov 2019	0.54	0.62	0.000	NN

Facility: NN = non-neighborhood greenway

APPENDIX E

E.1 MEAN SPEEDS

A Welch two-sample *t*-test was used to test two null hypotheses for the mean speeds of the free-flow dataset pairs.

The first null hypothesis tested states that the mean speed in the 'before' condition is equal to the mean speed in the 'after' condition, H_0: $\mu_B - \mu_A = 0$, with the subscripts B and A representing the 'before' and 'after' conditions, respectively. The alternate hypothesis states that the mean speed of the 'after' dataset is greater than the mean speed of the 'before' dataset, H_A: $\mu_B - \mu_A < 0$. Statistically significant results ($p < 0.05$) would indicate that the mean speed increased in the 'after' period.

The second null hypothesis tested states that the difference in mean speeds is equal to 1.25 mph, H_0: $\mu_B - \mu_A = 1.25$. The alternative hypothesis is that the difference in mean speeds is greater than 1.25 mph, H_A: $\mu_B - \mu_A > 1.25$. A statistically significant result would indicate that the mean speed was reduced by more than 1.25 mph in the 'after' period, or more than one-quarter the amount of the reduction in the PSL for treatment pairs.

E.1.1 Hypothesis Test for Equality of Mean Speeds

The three treatment pairs of the 13 tested (23.1%) that rejected the first null hypothesis for mean speeds (H_0: $\mu_B - \mu_A = 0$; H_A: $\mu_B - \mu_A < 0$) are displayed in Table E.1. All three treatment pairs also produced significant results when all observations were considered in Section D.1.1. Mean speeds at westbound Alberta east of 28th and eastbound Division east of 116th appear to have increased around one-half to one mile per hour between surveys, despite a five mile per hour reduction in the PSL.

Four of the 14 control pairs tested (28.6%) also rejected the first null hypothesis for mean speeds, suggesting that speeds increased in the 'after' period. The results are shown in Table E.2. The westbound Alberta east of 14th and westbound Division east of 116th dataset pairs also rejected the null hypothesis when all observations were included (Section D.1.1). The other two control pairs were located at westbound Alberta east of 28th and involved the same 'before' dataset as in the treatment pair in Table E.1. Increases in mean speeds for the control pairs were less than one mile per hour.

Table E.34: Hypothesis test for equality of mean speeds significant results for free-flow treatment pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value
Alberta E of 28th WB	Sep 2016	Jul 2019	25	20	20.40	21.30	0.006
Division E of 116th EB	Feb 2017	Apr 2018	35	30	33.99	35.07	0.000
Division E of 116th EB	Feb 2017	Dec 2019	35	30	33.99	34.39	0.013

Table E.35: Hypothesis test for equality of mean speeds significant results for free-flow control pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value
Alberta E of 14th WB	Jul 2019	Nov 2019	20	20	22.21	22.66	0.042
Alberta E of 28th WB	Sep 2016	Sep 2016 b	25	25	20.40	21.24	0.008
Alberta E of 28th WB	Sep 2016	Oct 2016	25	25	20.40	21.09	0.025
Division E of 116th WB	Apr 2018	Oct 2019	30	30	34.04	34.84	0.000

E.1.2 Hypothesis Test for Decrease of Mean Speeds by 1.25 mph

For the second null hypothesis for mean speeds (H_0: μ_B - μ_A = 1.25; H_A: μ_B - μ_A > 1.25), five of 13 treatment pairs (38.5%) and one control pair of the 14 tested (7.1%) presented significant results when observations were limited to larger gap times (Tables E.3 and E.4, respectively). The mean speeds decreased 2.1 mph to 3.3 mph for the free-flow treatment pairs and dropped 1.8 mph for the free-flow control pair. All dataset pairs also presented significantly reduced mean speeds of 1.25 mph or more when all observations were considered.

Table E.36: Hypothesis test for decrease of mean speeds by 1.25 mph significant result for free-flow treatment pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value
Division E of 116th WB	Feb 2017	Apr 2018	35	30	37.35	34.04	0.000
Division E of 116th WB	Feb 2017	Oct 2019	35	30	37.35	34.84	0.000
Division E of 116th WB	Feb 2017 b	Apr 2018	35	30	36.97	34.04	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	35	30	36.97	34.84	0.000
Williams N of Hancock NB	Feb 2015	Sep 2019	30	25	29.35	26.47	0.000

Table E.37: Hypothesis test for decrease of mean speeds by 1.25 mph significant result for free-flow control dataset pairs.

Site	Before	After	PSL Before	PSL After	μ_B	μ_A	*p*-value
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	25.21	23.40	0.000

E.2 85TH PERCENTILE SPEEDS

The modified *t*-tests were also used to compare 85th percentile speeds for the free-flow dataset pairs. The first null hypothesis says that the 85th percentile speed in the 'before' condition is equal to the 85th percentile speed of the 'after' condition, H_0: $\zeta_{85,B} - \zeta_{85,A} = 0$. The alternative hypothesis is that the difference in the 85th percentile speeds is less than zero, H_A: $\zeta_{85,B} - \zeta_{85,A} < 0$. A statistically significant result ($p < 0.05$) would suggest that the 85th percentile speeds increased in the 'after' period.

The second null hypothesis tested states that the difference in 85th percentile speeds is equal to 1.25 mph, H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$. The alternative hypothesis is that the difference in 85th percentile speeds is greater than 1.25 mph, H_A: $\zeta_{85,B} - \zeta_{85,A} > 1.25$. Again, a *p*-value less than 0.05 would indicate that 85th percentile speeds decreased by more than one-quarter of the amount of the PSL reduction for treatment pairs.

E.2.1 Hypothesis Test for Equality of 85th Percentile Speeds

One of the free-flow treatment pairs (7.7%), at eastbound Division east of 116th, displayed a significant increase of one mile per hour in the 85th percentile speed (Table E.5). This dataset pair also displayed a significant increase when all observations were included.

Table E.38: Hypothesis test for equality of 85th percentile speeds significant result for free-flow treatment pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value
Division E of 116th EB	Feb 2017	Apr 2018	35	30	40	41	0.000

Table E.6 exhibits the three free-flow control pairs (of 14, or 21.4%) that reject the first null hypothesis for 85th percentile speeds. The 85th percentile speeds increased by one mile per hour in all three control pairs.

Table E.39: Hypothesis test for equality of 85th percentile speeds significant result for free-flow control pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value
Alberta E of 14th WB	Jul 2019	Nov 2019	20	20	27	28	0.006
Alberta E of 28th WB	Sep 2016	Sep 2016 b	25	25	26	27	0.029
Division E of 116th WB	Apr 2018	Oct 2019	30	30	39	40	0.000

E.2.2 Hypothesis Test for Decrease of 85th Percentile Speeds by 1.25 mph

Six of the 13 free-flow treatment pairs (46.2%) rejected the second null hypothesis for 85th percentile speeds, H_0: $\zeta_{85,B} - \zeta_{85,A} = 1.25$, and can be seen in Table E.7. Reductions of two to four miles per hour were observed. All free-flow treatment dataset pairs except for eastbound Alberta east of 28th also experienced significantly reduced 85th percentile speeds when all observations were analyzed.

Table E.40: Hypothesis test for decrease of 85th percentile speeds by 1.25 mph significant result for free-flow treatment pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value
Alberta E of 28th EB	Oct 2016	Jul 2019	25	20	28	26	0.029
Division E of 116th WB	Feb 2017	Apr 2018	35	30	43	39	0.000
Division E of 116th WB	Feb 2017	Oct 2019	35	30	43	40	0.000
Division E of 116th WB	Feb 2017 b	Apr 2018	35	30	42	39	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	35	30	42	40	0.002
Williams N of Hancock NB	Feb 2015	Sep 2019	30	25	34	31	0.000

Two of the 14 free-flow control pairs (14.3%) also resulted in a rejection of the second null hypothesis for 85th percentile speeds, seen in Table E.8. Speeds appear to have decreased two to three miles per hour between subsequent surveys. The westbound Fremont east of 48th dataset pair also produced significant results when all gap times were included.

Table E.41: Hypothesis test for decrease of 85th percentile speeds by 1.25 mph significant result for free-flow control pairs.

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	*p*-value
Division E of 116th EB	Apr 2018	Dec 2019	30	30	41	39	0.000
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	31	28	0.000

E.3 VARIANCE OF SPEED

An F-test was employed to analyze the variance of speed, or the square of the standard deviation (SD) for the 'before' and 'after' treatment and control dataset pairs. The null hypothesis for variance states that the speed variance of the 'before' dataset is equal to the speed variance of the 'after' dataset, H_0: $\sigma_B^2 = \sigma_A^2$. The null hypothesis is rejected if the *p*-value is less than 0.05 in favor of the alternate hypothesis, which states the speed variance in the 'after' condition is not equal to the speed variance in the 'before' condition, H_A: $\sigma_B^2 \neq \sigma_A^2$.

The results of the F-test indicate the speed variance (standard deviation, σ) decreased significantly between subsequent traffic surveys for 10 of the 13 treatment pairs (76.9%), shown in Table E.9. Three of these six treatment pairs also had significantly increased mean speeds when observations were limited to larger gap times (refer to Section E.1.1), while five pairs experienced significantly reduced mean speeds (refer to Section E.1.2). Nine of the ten free-flow treatment pairs in Table E.9 also resulted in a rejection of the null hypothesis for variance when all observations were included.

Table E.42: Free-flow treatment pairs indicating a significant reduction in the standard deviation.

Site	Before	After	SD Before	SD After	Ratio	*p*-value
Alberta E of 28th EB	Oct 2016	Jul 2019	5.40	4.80	1.27	0.001
Alberta E of 28th WB	Sep 2016	Jul 2019	5.42	4.74	1.31	0.002
Alberta E of 28th WB	Sep 2016 b	Jul 2019	5.22	4.74	1.21	0.004
Division E of 116th EB	Feb 2017	Apr 2018	7.15	6.13	1.36	0.000
Division E of 116th EB	Feb 2017	Dec 2019	7.15	5.70	1.58	0.000
Division E of 116th WB	Feb 2017	Apr 2018	6.03	5.26	1.31	0.000
Division E of 116th WB	Feb 2017	Oct 2019	6.03	5.67	1.13	0.007
Division E of 116th WB	Feb 2017 b	Apr 2018	5.99	5.26	1.30	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	5.99	5.67	1.12	0.004
Williams N of Hancock NB	Feb 2015	Sep 2019	5.35	4.86	1.21	0.000

Ratio = σ_B^2 / σ_A^2

The standard deviation of speed increased significantly in only two of the free-flow treatment pairs (15.4%), shown in Table 6.10. Neither dataset pair produced significant results for previous hypothesis tests.

Table E.43: Free-flow treatment pairs with significant increases in the standard deviation.

Site	Before	After	SD Before	SD After	Ratio	*p*-value
Willamette E of Chase EB	Jun 2015	Jul 2019	4.02	4.30	0.871	0.000
Williams N of Going NB	Jan 2015	Jul 2019	4.62	4.80	0.925	0.019

Ratio = σ_B^2 / σ_A^2

Table E.11 displays the six control pairs (of 14, or 42.9%) in which standard deviation decreased from the 'before' to the 'after' period when observations were limited to larger gap times. Similar to the free-flow treatment pairs, three of these six control pairs also exhibited increased mean speeds (refer to Section E.1.1), and one control pair experienced a decrease in mean speed of more than 1.25 mph (refer to Section E.1.2). All control pairs in Table E.11 also produced significant results for the F-tests when all observations were analyzed.

Table E.44: Free-flow control pairs with significant decreases in the standard deviation.

Site	Before	After	SD Before	SD After	Ratio	*p*-value
Alberta E of 14th EB	Jul 2019	Nov 2019	5.30	4.76	1.237	0.001
Alberta E of 28th WB	Sep 2016	Oct 2016	5.42	4.91	1.222	0.016
Alberta E of 28th WB	Sep 2016 b	Oct 2016	5.22	4.91	1.129	0.035
Division E of 116th EB	Apr 2018	Dec 2019	6.13	5.70	1.158	0.000
Fremont E of 48th WB	Dec 2014	Jul 2019	5.37	4.91	1.196	0.000
Lincoln E of 50th WB	Apr 2011	Jun 2011	4.06	3.35	1.471	0.000

Ratio = σ_B^2 / σ_A^2

The standard deviation was significantly greater in the 'after' period for two of the 14 free-flow control pairs (14.3%). Table E.12 displays their results. The westbound Division east of 116th control pair also experienced significant increases in mean and 85th percentile speeds (refer to Sections E.1.1 and E.2.1).

Table E.45: Free-flow control pairs with significant increases in the standard deviation.

Site	Before	After	SD Before	SD After	Ratio	*p*-value
Division E of 116th WB	Apr 2018	Oct 2019	5.26	5.67	0.861	0.000
Fremont E of 46th EB	Feb 2018	Sep 2019	4.74	4.95	0.915	0.015

Ratio = σ_B^2 / σ_A^2

E.4 PROPORTIONS EXCEEDING THE SPEED THRESHOLD

A chi-square test was used to compare the proportions of vehicles exceeding a defined speed threshold for the free-flow treatment and control dataset pairs. The null hypothesis states that the proportion of class two vehicles exceeding the speed threshold in the 'before' condition is equal to the proportion of class two vehicles exceeding the speed threshold in the 'after' condition, H_0: $P_B – P_A = 0$. The alternative hypothesis is that the difference in the proportions of vehicles exceeding the speed threshold is not equal to zero, H_0: $P_B – P_A \neq 0$. The null is rejected if $p < 0.05$. The speed threshold was chosen to be the posted speed limit (PSL) of the dataset from the 'after' condition. Thus, for control pairs, the speed threshold is also equal to the PSL of the 'before' dataset.

Table E.13 shows the significant results ($p < 0.05$) of the chi-square test for the free-flow treatment pairs. The results indicate the proportion of class two vehicles exceeding the speed threshold decreased 3-19% for seven of the 13 free-flow treatment pairs (53.8%). Table E.13 also shows that the proportion of vehicles exceeding the speed threshold increased 2-8% in 23.1% of treatment pairs (3 of 13) – the same three that experienced increased mean speeds in Table 6.1. Both Williams dataset pairs and all Division dataset pairs produced significant results of the same direction when all observations were analyzed.

Table E.46: Free-flow treatment pairs that reject the null hypothesis for the proportions test.

Decrease						
Site	**Before**	**After**	**Threshold**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**
Division E of 116th WB	Feb 2017	Apr 2018	30	0.90	0.79	0.000
Division E of 116th WB	Feb 2017	Oct 2019	30	0.90	0.81	0.000
Division E of 116th WB	Feb 2017 b	Apr 2018	30	0.88	0.79	0.000
Division E of 116th WB	Feb 2017 b	Oct 2019	30	0.88	0.81	0.000
Willamette E of Chase EB	Jun 2015	Jul 2019	30	0.95	0.92	0.000
Williams N of Going NB	Jan 2015	Jul 2019	25	0.80	0.72	0.000
Williams N of Hancock NB	Feb 2015	Sep 2019	25	0.79	0.61	0.000
Increase						
Site	**Before**	**After**	**Threshold**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**
Alberta E of 28th WB	Sep 2016	Jul 2019	20	0.51	0.58	0.026
Division E of 116th EB	Feb 2017	Apr 2018	30	0.79	0.82	0.000
Division E of 116th EB	Feb 2017	Dec 2019	30	0.79	0.81	0.047

Four of the 14 free-flow control pairs (28.6%) showed significant decreases of 5-10% in the proportion of vehicles exceeding the speed threshold, seen in Table E.14. All control pairs in Table E.14 also had significant reductions in the proportion of vehicles exceeding the speed threshold when all observations were included.

Table E.47: Free-flow control datasets that reject the null hypothesis for the proportions test.

Decrease						
Site	**Before**	**After**	**Threshold**	**Prop. Exc. Before**	**Prop. Exc. After**	***p*-value**
Division E of 33rd WB	Jul 2015	Jul 2019	25	0.21	0.16	0.000
Fremont E of 46th EB	Feb 2018	Sep 2019	20	0.71	0.67	0.001
Fremont E of 46th WB	Feb 2018	Sep 2019	20	0.64	0.56	0.000
Fremont E of 48th WB	Dec 2014	Jul 2019	20	0.83	0.74	0.000