

# **UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS**

**Task 7 Data Analysis  
and Evaluation Report**

**SPR 827**



# **UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS**

## **Task 7 Data Analysis and Evaluation Report**

**SPR 827**

by

Miguel Figliozi, Professor  
Avinash Unnikrishnan, Associate Professor  
Jaclyn Schaefer, Research Associate

Portland State University  
1930 SW 4th Avenue, Portland OR 97201

for

Oregon Department of Transportation  
Research Section  
555 13th Street NE, Suite 1  
Salem OR 97301

and

Federal Highway Administration  
1200 New Jersey Avenue SE  
Washington, DC 20590

June 2020



1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle  UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS: Task 7 Data Analysis and Evaluation Report		5. Report Date -month- -year-	
		6. Performing Organization Code	
7. Author(s) Miguel Figliozzi, Avinash Unnikrishnan, Jaclyn Schaefer		8. Performing Organization Report No.	
9. Performing Organization Name and Address  Oregon Department of Transportation Research Section 555 13 <sup>th</sup> Street NE, Suite 1 Salem, OR 97301		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address  Oregon Dept. of Transportation Research Section and Federal Highway Admin. 555 13 <sup>th</sup> Street NE, Suite 1 1200 New Jersey Avenue SE Salem, OR 97301 Washington, DC 20590		13. Type of Report and Period Covered  _____ Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract  This report presents a before and after analysis of speed data. Speed trends and characteristics on sites with PSL changes (treatment sites) and sites with no PSL change (control sites) are analyzed. Speed characteristics and patterns in relation to roadway functional classification are examined. Speed characteristics such as the mean, standard deviation, 85 <sup>th</sup> percentile, percent exceeding the posted speed limit, pace, and percent in pace are compared. Several hypothesis tests are performed on all data, as well as a subset of free-flow only data. Recommendations related to data collection, data analysis, and speed monitoring are provided.			
17. Key Words: posted speed limit, operating speed, speed compliance, active traveler, bicycle, pedestrian, data quality, speed characteristics		18. Distribution Statement  Copies available from NTIS, and online at <a href="http://www.oregon.gov/ODOT/TD/TP_RES/">http://www.oregon.gov/ODOT/TD/TP_RES/</a>	
19. Security Classification (of this report)  Unclassified	20. Security Classification (of this page)  Unclassified	21. No. of Pages  XXX	22. Price



## SI\* (MODERN METRIC) CONVERSION FACTORS

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
<b><u>LENGTH</u></b>					<b><u>LENGTH</u></b>				
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
<b><u>AREA</u></b>					<b><u>AREA</u></b>				
in <sup>2</sup>	square inches	645.2	millimeters squared	mm <sup>2</sup>	mm <sup>2</sup>	millimeters squared	0.0016	square inches	in <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	meters squared	m <sup>2</sup>	m <sup>2</sup>	meters squared	10.764	square feet	ft <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	meters squared	m <sup>2</sup>	m <sup>2</sup>	meters squared	1.196	square yards	yd <sup>2</sup>
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi <sup>2</sup>	square miles	2.59	kilometers squared	km <sup>2</sup>	km <sup>2</sup>	kilometers squared	0.386	square miles	mi <sup>2</sup>
<b><u>VOLUME</u></b>					<b><u>VOLUME</u></b>				
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 <sup>3</sup>	cubic feet	0.028	meters cubed	m <sup>3</sup>	m <sup>3</sup>	meters cubed	35.315	cubic feet	ft <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	meters cubed	m <sup>3</sup>	m <sup>3</sup>	meters cubed	1.308	cubic yards	yd <sup>3</sup>
NOTE: Volumes greater than 1000 L shall be shown in m <sup>3</sup> .									
<b><u>MASS</u></b>					<b><u>MASS</u></b>				
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
<b><u>TEMPERATURE (exact)</u></b>					<b><u>TEMPERATURE (exact)</u></b>				
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	$\frac{1.8C+32}{2}$	Fahrenheit	°F

\*SI is the symbol for the International System of Measurement





## **ACKNOWLEDGEMENTS**

## **DISCLAIMER**

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the view of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.



# TABLE OF CONTENTS

<b>1.0</b>	<b>INTRODUCTION.....</b>	<b>1</b>
<b>2.0</b>	<b>DATA DESCRIPTION .....</b>	<b>3</b>
2.1	DATA CLEANING.....	3
2.2	DATA CLASSIFICATION .....	4
2.3	ACTIVE TRAVEL.....	11
<b>3.0</b>	<b>IDENTIFICATION OF SPEED PATTERNS.....</b>	<b>20</b>
3.1	NEIGHBORHOOD GREENWAYS .....	20
3.2	NON-NEIGHBORHOOD GREENWAY STREETS.....	21
3.3	SUMMARY OF PATTERN IDENTIFICATION .....	23
<b>4.0</b>	<b>BEFORE AND AFTER SPEED COMPARISON .....</b>	<b>24</b>
4.1	TREATMENT SITES .....	24
4.2	CONTROL SITES .....	28
4.3	TREATMENT SITES WITH FREE-FLOW TRAFFIC CONDITIONS .....	33
4.4	CONTROL SITES WITH FREE-FLOW TRAFFIC CONDITIONS .....	39
4.5	TRENDS IN MOTORIZED VEHICLE VOLUMES.....	45
4.6	SUMMARY OF BEFORE AND AFTER SPEEDS.....	55
<b>5.0</b>	<b>HYPOTHESIS TESTING (FULL DATA) .....</b>	<b>58</b>
5.1	MEAN SPEEDS.....	58
5.1.1	<i>Hypothesis Test for Equality of Mean Speeds.....</i>	<i>59</i>
5.1.2	<i>Hypothesis Test for Decrease of Mean Speeds by 1.25 mph .....</i>	<i>60</i>
5.2	85 <sup>TH</sup> PERCENTILE SPEEDS.....	63
5.2.1	<i>Hypothesis Test for Equality of 85<sup>th</sup> Percentile Speeds.....</i>	<i>63</i>
5.2.2	<i>Hypothesis Test for Decrease of 85<sup>th</sup> Percentile Speeds by 1.25 mph .....</i>	<i>64</i>
5.3	VARIANCE OF SPEED.....	67
5.4	PROPORTIONS EXCEEDING THE SPEED THRESHOLD .....	70
5.5	SUMMARY OF HYPOTHESIS TESTING FULL DATASETS .....	76
<b>6.0</b>	<b>HYPOTHESIS TESTING (FREE-FLOW DATA).....</b>	<b>80</b>
6.1	MEAN SPEEDS.....	80
6.1.1	<i>Hypothesis Test for Equality of Mean Speeds.....</i>	<i>80</i>
6.1.2	<i>Hypothesis Test for Decrease of Mean Speeds by 1.25 mph .....</i>	<i>81</i>
6.2	85 <sup>TH</sup> PERCENTILE SPEEDS.....	82
6.2.1	<i>Hypothesis Test for Equality of 85<sup>th</sup> Percentile Speeds.....</i>	<i>82</i>
6.2.2	<i>Hypothesis Test for Decrease of 85<sup>th</sup> Percentile Speeds by 1.25 mph .....</i>	<i>83</i>
6.3	VARIANCE OF SPEED.....	84
6.4	PROPORTIONS EXCEEDING THE SPEED THRESHOLD .....	86
6.5	SUMMARY OF HYPOTHESIS TESTING FREE-FLOW DATASETS .....	88
<b>7.0</b>	<b>DATA COLLECTION RECOMMENDATIONS .....</b>	<b>90</b>
<b>8.0</b>	<b>SUMMARY AND DISCUSSION .....</b>	<b>96</b>

8.1	SUMMARY .....	96
8.2	DISCUSSION .....	97
<b>9.0</b>	<b>REFERENCES.....</b>	<b>99</b>

## LIST OF FIGURES

Figure 2.1: Class two speed distribution for Fremont east of 46th eastbound in February 2018. ....	4
Figure 2.2: Class two speed distribution for Lincoln east of 50th eastbound in March 2017. ....	4
Figure 2.3: Histogram of the differences between the mean and median of each dataset. ....	11
Figure 2.4: Example of a typical class one speed distribution with the posted speed limit (PSL) and 50 <sup>th</sup> and 85 <sup>th</sup> percentile speeds for a neighborhood greenway street where the majority of the class one vehicles appear to be non-motorized. ....	13
Figure 2.5: Example of a bimodal class one speed distribution with motorized and non-motorized vehicles along a neighborhood collector street. ....	13
Figure 2.6: Example of a class one speed distribution with the posted speed limit (PSL) and 50 <sup>th</sup> and 85 <sup>th</sup> percentile speeds along a district collector street where the class one vehicles appear to be predominantly motorized. ....	14
Figure 3.1: Typical example for a neighborhood greenway mean speed vs. mean gap scatterplot for the March 2014 eastbound Clinton west of 25th dataset. ....	20
Figure 3.2: Typical example for a neighborhood greenway mean speed vs. vehicle count scatterplot for the March 2014 eastbound Clinton west of 25th dataset. ....	21
Figure 3.3: Typical example for a non-neighborhood greenway mean speed vs. mean gap scatterplot for the December 2014 westbound Fremont east of 48th dataset. ....	22
Figure 3.4: Typical example for a non-neighborhood greenway mean speed vs. vehicle count scatterplot for the December 2014 westbound Fremont east of 48th dataset. ....	22
Figure 4.1: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for all treatment pairs. ....	26
Figure 4.2: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all treatment pairs. ....	26
Figure 4.3: Scatterplot of the difference in mean speed vs. the number of days elapsed between subsequent surveys for all treatment dataset pairs. ....	27
Figure 4.4: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all treatment dataset pairs. ....	28
Figure 4.5: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for all control pairs. ....	30
Figure 4.6: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all control pairs. ....	31
Figure 4.7: Scatterplot of the difference in mean speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs. ....	32
Figure 4.8: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs. ....	32
Figure 4.9: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow treatment pairs (N = 13). ....	35
Figure 4.10: 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). ....	35
Figure 4.11: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for free-flow treatment dataset pairs. ....	36
Figure 4.12: Scatterplot of the difference in standard deviation vs. the number of days elapsed between surveys for the gap-limited treatment dataset pairs. ....	37
Figure 4.13: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow control pairs (N = 14). ....	41
Figure 4.14: 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). ....	41
Figure 4.15: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for the free-flow control dataset pairs. ....	42
Figure 4.16: Scatterplot of the difference in standard deviation vs. the number of days elapsed between surveys for the free-flow control dataset pairs. ....	43
Figure 4.17: Histogram of ADT changes for non-neighborhood greenway treatment pairs. ....	47
Figure 4.18: Change in ADT vs. change in mean speed for non-neighborhood greenway treatment pairs. ....	48
Figure 4.19: Histogram of ADT changes for neighborhood greenway treatment pairs. ....	50

Figure 4.20: Change in ADT vs. change in mean speed for neighborhood greenway treatment pairs. ....	50
Figure 4.21: Histogram of ADT changes for non-neighborhood greenway control pairs. ....	52
Figure 4.22: Change in ADT vs. change in mean speed for non-neighborhood greenway control pairs. ....	52
Figure 4.23: Histogram of ADT changes for neighborhood greenway control pairs.....	54
Figure 4.24: Change in ADT vs. change in mean speed for the neighborhood greenway control pairs. ....	55
Figure 7.1: Mean speed vs. mean gap for eastbound Holgate east of 111th with data binned in 15-minute intervals. ....	90
Figure 7.2: Mean speed vs. vehicle count for eastbound Holgate east of 111th with data binned in 15-minute intervals. ....	91
Figure 7.3: Class two speed histogram for the February 2017 westbound Holgate east of 111th dataset. ....	92
Figure 7.4: Class two speed histogram for the June 2019 eastbound Holgate east of 111th dataset. ....	92
Figure 7.5: Location of data collection at Holgate east of 111th. ( <i>Google Maps</i> , 2020) .....	93

## LIST OF TABLES

Table 2.1: Summary of basic roadway characteristics for all datasets and pairs analyzed. ....	5
Table 2.2: Class two speed statistics for the 63 datasets from neighborhood greenway streets. ....	6
Table 2.3: Class two speed statistics for the 17 datasets along streets with bike lanes. ....	9
Table 2.4: Class two speed statistics for the 20 datasets along streets without bike facilities. ....	10
Table 2.5: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations with shared bicycle facilities. ....	14
Table 2.6: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations with bicycle lanes. ....	17
Table 2.7: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations without explicit bicycle facilities. ....	18
Table 4.1: 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. ....	25
Table 4.2: 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. ....	29
Table 4.3: 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. ....	34
Table 4.4: Comparison of all data and free-flow data from the before period for treatment datasets. ....	38
Table 4.5: Comparison of all data and free-flow data from the after period for treatment datasets. ....	38
Table 4.6: 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. ....	40
Table 4.7: Comparison of all data and free-flow data from the before period for control datasets. ....	44
Table 4.8: Comparison of all data and free-flow data from the after period for control datasets. ....	45
Table 4.9: Change in class two vehicle volumes for non-neighborhood greenway treatment pairs. ....	46
Table 4.10: Change in class two vehicle volumes for neighborhood greenway treatment pairs. ....	48
Table 4.11: Change in class two vehicle volumes for non-neighborhood greenway control pairs. ....	51
Table 4.12: Change in class two vehicle volumes for neighborhood greenway control pairs. ....	53
Table 5.1: Hypothesis test for equality of mean speeds significant results for treatment dataset pairs. ....	59
Table 5.2: Hypothesis test for equality of mean speeds significant results for control dataset pairs. ....	60
Table 5.3: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for treatment dataset pairs. ....	61
Table 5.4: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for control dataset pairs. ....	63
Table 5.5: Hypothesis test for equality of 85 <sup>th</sup> percentile speeds significant results for treatment dataset pairs. ....	64
Table 5.6: Hypothesis test for equality of 85 <sup>th</sup> percentile speeds significant results for control dataset pairs. ....	64
Table 5.7: Hypothesis test for decrease of 85 <sup>th</sup> percentile speeds by 1.25 mph significant results for treatment dataset pairs. ....	65
Table 5.8: Hypothesis test for decrease of 85 <sup>th</sup> percentile speeds by 1.25 mph significant results for control dataset pairs. ....	66
Table 5.9: Treatment pairs indicating a significant reduction in the standard deviation in the ‘after’ period. ....	67
Table 5.10: Treatment pairs indicating a significant increase in the standard deviation in the ‘after’ period. ....	68
Table 5.11: Control pairs indicating a significant decrease in standard deviation during the ‘after’ period. ....	69
Table 5.12: Control pairs indicating a significant increase in the standard deviation during the ‘after’ period. ....	70
Table 5.13: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 30 mph. ....	71
Table 5.14: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 25 mph. ....	72
Table 5.15: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 20 mph. ....	72
Table 5.16: Treatment pairs with a significant increase in the proportion of vehicles exceeding 30 mph. ....	74
Table 5.17: Control pairs with a significant decrease in the proportion of vehicles exceeding 25 mph. ....	74
Table 5.18: Control pairs with a significant decrease in the proportion of vehicles exceeding 20 mph. ....	75
Table 5.19: Control pair with a significant increase in the proportion of vehicles exceeding 30 mph. ....	75
Table 5.20: Control pairs with a significant increase in the proportion of vehicles exceeding 25 mph. ....	76
Table 5.21: Control pair with a significant increase in the proportion of vehicles exceeding 20 mph. ....	76
Table 5.22: Summary of treatment and control dataset pairs producing statistically significant results for the hypothesis tests. ....	77

Table 5.23: Summary of the percent of treatment and control dataset pairs producing statistically significant results for all hypothesis tests. ....	78
Table 6.1: Hypothesis test for equality of mean speeds significant results for free-flow treatment pairs. ....	81
Table 6.2: Hypothesis test for equality of mean speeds significant results for free-flow control pairs. ....	81
Table 6.3: Hypothesis test for decrease of mean speeds by 1.25 mph significant result for free-flow treatment pairs. ....	82
Table 6.4: Hypothesis test for decrease of mean speeds by 1.25 mph significant result for free-flow control dataset pairs. ....	82
Table 6.5: Hypothesis test for equality of 85 <sup>th</sup> percentile speeds significant result for free-flow treatment pairs. ....	83
Table 6.6: Hypothesis test for equality of 85 <sup>th</sup> percentile speeds significant result for free-flow control pairs. ....	83
Table 6.7: Hypothesis test for decrease of 85 <sup>th</sup> percentile speeds by 1.25 mph significant result for free-flow treatment pairs. ....	84
Table 6.8: Hypothesis test for decrease of 85 <sup>th</sup> percentile speeds by 1.25 mph significant result for free-flow control pairs. ....	84
Table 6.9: Free-flow treatment pairs indicating a significant reduction in the standard deviation. ....	85
Table 6.10: Free-flow treatment pairs with significant increases in the standard deviation. ....	85
Table 6.11: Free-flow control pairs with significant decreases in the standard deviation. ....	86
Table 6.12: Free-flow control pairs with significant increases in the standard deviation. ....	86
Table 6.13: Free-flow treatment pairs that reject the null hypothesis for the proportions test. ....	87
Table 6.14: Free-flow control datasets that reject the null hypothesis for the proportions test. ....	88
Table 6.15: Summary of free-flow dataset pairs producing significant results for the hypothesis tests. ....	89
Table 7.1: Basic speed statistics for sites within 500 ft. of a traffic control device compared to a nearby location on the segment. ....	95





# 1.0 INTRODUCTION

This report serves to document the data analysis of the speed survey data collected in previous SPR 827 tasks and satisfies the requirement for Task 7.

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.

Section 2 describes the collected data and provides basic speed statistics including mean speed, the standard deviation of speed, and the 5<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup>, and 95<sup>th</sup> percentile speeds for each dataset. Average daily traffic (ADT) is estimated, and levels of active travel are assessed at each site. Traffic volumes and the mean, standard deviation, 50<sup>th</sup>, and 85<sup>th</sup> percentile speeds are estimated for class one vehicles (including bicycles) from the survey data. Pedestrian usage is estimated based on the presence of bus lines and pedestrian district designations. A particular focus of this research is on roadways with a high percentage of active travelers. A high percentage of cyclists is present on shared used roadways that are neighborhood greenways. Hence, in the analysis performed in later section roadways are classified as neighborhood and non-neighborhood greenways.

Patterns in the speed data are explored in Section 3. Relationships between mean speed and gap time or traffic volume are compared for neighborhood greenway sites and non-neighborhood greenway sites.

Section 4 details a before and after analysis of the repeat surveys. The treatment and control pairs are analyzed separately. After grouping datasets according to their posted speed limits and neighborhood greenway status, the overall mean and 85<sup>th</sup> percentile speeds, standard deviation, the percent of vehicles exceeding defined speed thresholds, the 10-mph pace minimum speed, and the percent of vehicles within the pace limits are compared from before to after. Histograms and scatterplots of the individual differences in mean and standard deviation between each dataset pair are constructed for both the treatment and control datasets. Additional comparisons are performed for select datasets, which displayed a relationship between mean speed and mean gap time or traffic volume, as identified in Section 3. The additional analysis is performed only on observations with larger gap times, i.e., under free-flow conditions. Section 4 also discusses changes in traffic volumes compared to regional averages and in relation to changes in mean speeds between the dataset pairs.

Hypothesis testing methods and results for all observations in all datasets are discussed in Section 5. A series of  $t$ -tests are performed on the mean speeds for all before and after dataset pairs, and a modified  $t$ -test is used to compare the 85<sup>th</sup> percentile speeds. An F-test is used to check for significant differences in the standard deviations, and a  $\chi^2$  (chi-square) test is used to compare the proportions of vehicles exceeding speed threshold categories. The hypothesis testing methods employed in Section 5 are repeated in Section 6 for the dataset pairs consisting of sites with speed-gap relationships identified in Section 3 when those datasets are limited to larger (free-flow) gap times.

Data collection locations in close proximity to traffic control devices are discussed in Section 7. Several repeat sites are identified, and speeds are compared with additional sites at further distances from a traffic control device. A recommendation is given regarding future data collection locations. Section 8 summarizes the findings of the analyses.

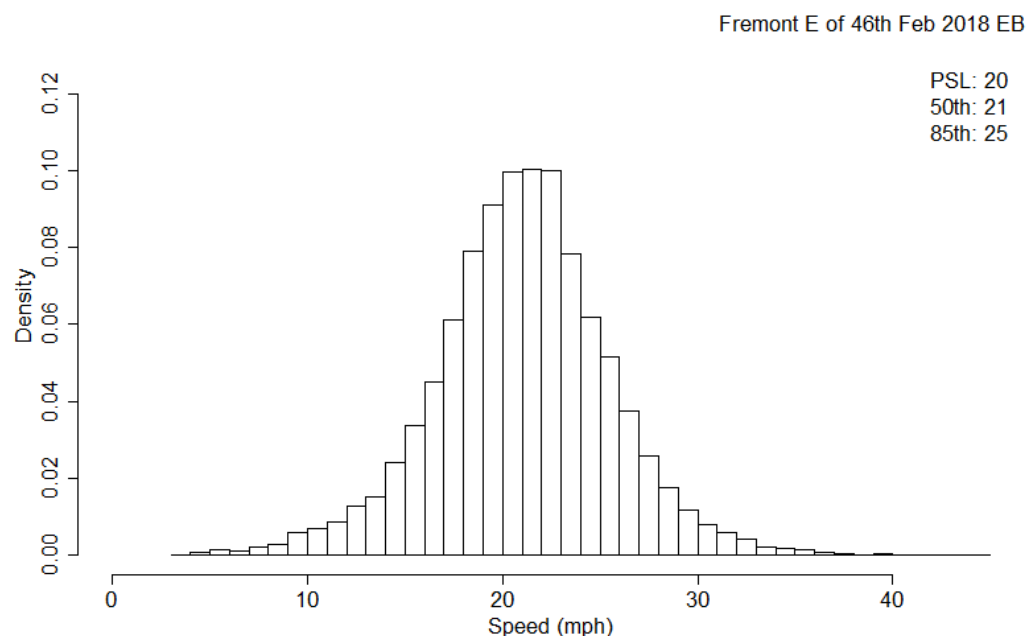
## 2.0 DATA DESCRIPTION

Speed surveys were collected by the Portland Bureau of Transportation (PBOT) from 2011 to 2019. Repeated speed surveys were performed at 44 sites, 13 of which were repeated more than once, constituting 106 unidirectional datasets. A total of 87 pairs of before and after data were produced – 47 treatment pairs in which PSLs changed between subsequent surveys and 40 control pairs in which PSLs did not change between surveys. PSL changes were determined from the original speed data files and verified by PBOT and by utilizing signage visible on Google Street View.

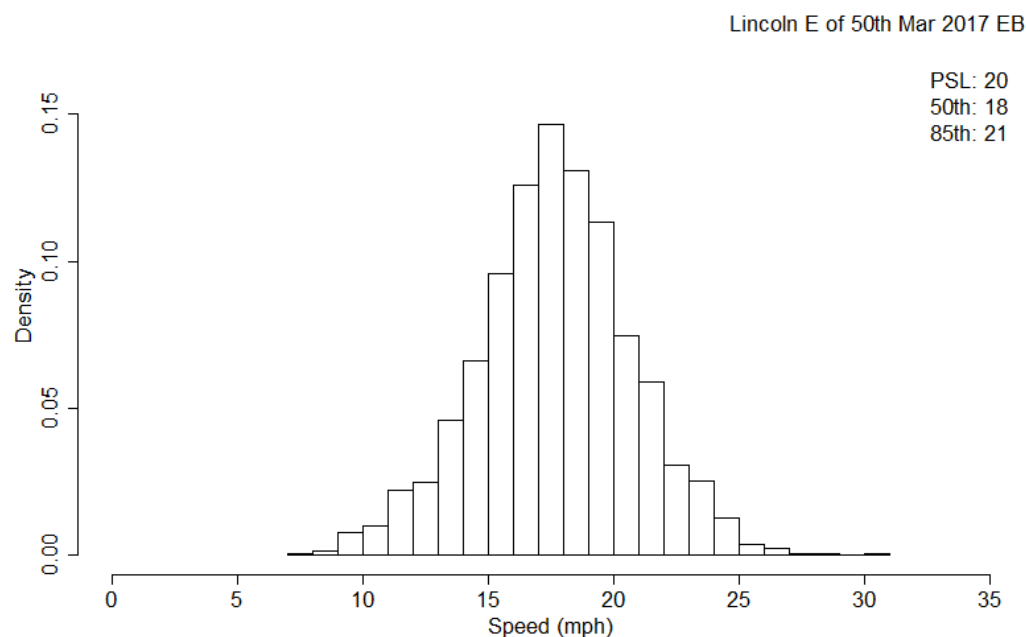
### 2.1 DATA CLEANING

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 the Portland Bureau of Transportation (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 2.1 and 2.2 provide representative examples of class two normal speed distributions for eastbound Fremont east of 46<sup>th</sup> in February 2018 and eastbound Lincoln east of 50<sup>th</sup> 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 (performed later in Section 4). Additionally, when datasets contain hundreds of observations, the distribution of the data can be ignored for most statistical analyses (performed in Section 5), 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 2.1: Class two speed distribution for Fremont east of 46th eastbound in February 2018.**



**Figure 2.2: Class two speed distribution for Lincoln east of 50th eastbound in March 2017.**

## 2.2 DATA CLASSIFICATION

The data were collected from roads with a variety of functional classes or traffic classes (*City of Portland, 2020a, p.101-105*), speed limits, and bicycle facilities. Table 2.1 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 (*City of Portland, 2020a, p.101-105*).

Table 2.1 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 (*City of Portland, 2020b*).

**Table 2.1: Summary of basic roadway characteristics for all datasets and pairs analyzed.**

	Treatment Pairs	Control Pairs	Total Pairs	Total Datasets
<b>Functional Class</b>				
Local	20	10	30	37
Urban Collector	18	24	42	54
Minor Arterial	1	0	1	2
Principal Arterial	6	3	9	7
<b>PBOT Traffic Class</b>				
Local Service	30	24	54	63
Neighborhood Collector	9	10	19	30
District Collector	6	3	9	7
<b>Bike Facilities</b>				
Shared	30	24	54	63
No Facility	4	10	14	20
Bike Lane*	11	3	14	17
<b>PSL:**</b>				
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 111<sup>th</sup>, 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.

Basic speed statistics for class two vehicles were computed for each dataset. These statistics can be seen in Table 2.2 for the neighborhood greenways (local service streets with shared bicycle facilities). Active travelers typically comprise a larger percentage of traffic on these streets. Table 2.3 shows the speed statistics for the 17 datasets from locations with bike lanes and Table 2.4 for the 20 datasets from locations without any specific bicycle facilities. The posted speed limit (PSL), estimated class two ADT, standard deviation (SD), mean, and the 5<sup>th</sup>, 15<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup>, and 95<sup>th</sup> percentile speeds are provided. All speeds are given in miles per hour.

**Table 2.2: Class two speed statistics for the 63 datasets from neighborhood greenway streets.**

<b>Dataset</b>	<b>PSL</b>	<b>ADT</b>	<b>SD</b>	<b>Mean</b>	<b>5th</b>	<b>15th</b>	<b>50th</b>	<b>85th</b>	<b>95th</b>
Clinton E of 17th Aug 2014 EB	25	683	3.33	21.46	16	18	22	25	27
Clinton E of 17th Aug 2014 WB	25	925	3.09	20.01	15	17	20	23	25
Clinton E of 17th Jul 2015 EB	25	569	3.11	20.44	15	17	21	23	25
Clinton E of 17th Jul 2015 WB	25	725	3.23	20.21	15	17	20	23	25
Clinton E of 23rd Apr 2019 EB	20	385	3.55	18.66	12	15	19	22	24
Clinton E of 23rd Apr 2019 WB	20	491	3.04	18.11	13	15	18	21	23
Clinton E of 23rd Jul 2015 EB	25	690	3.59	20.37	14	17	21	24	26
Clinton E of 23rd Jul 2015 WB	25	871	3.75	21.32	15	17	21	25	27
Clinton E of 23rd May 2016 EB	25	653	3.8	20.7	14	17	21	24	26
Clinton E of 23rd May 2016 WB	25	714	3.89	21.44	15	18	21	25	28
Clinton E of 29th Apr 2014 EB	25	1006	4.03	21.87	15	18	22	26	28
Clinton E of 29th Apr 2014 WB	25	990	3.96	21.27	15	17	21	25	28
Clinton E of 29th Jul 2019 EB	20	316	4.25	18.61	11	14	19	23	26
Clinton E of 29th Jul 2019 WB	20	308	3.79	17.12	11	13	17	21	23
Clinton E of 29th May 2016 EB	25	416	4.31	19.6	12	15	20	24	26

Clinton E of 29th May 2016 WB	25	320	3.86	18.6	12	15	19	22	25
Clinton W of 13th Jul 2015 EB	25	764	3.49	17.84	12	14	18	21	23
Clinton W of 13th Jul 2015 WB	25	369	3.36	18.52	13	15	19	22	24
Clinton W of 13th May 2016 EB	25	275	3.82	18.76	12	15	19	22	24
Clinton W of 13th May 2016 WB	25	578	4.08	20.78	14	16	21	25	27
Clinton W of 14th Aug 2014 EB	25	582	4.04	22.6	16	19	23	27	29
Clinton W of 14th Aug 2014 WB	25	1048	4.13	22.97	16	19	23	27	29
Clinton W of 14th Mar 2018 EB	20	267	3.91	19.96	13	16	20	24	26
Clinton W of 14th Mar 2018 WB	20	586	4.26	21.64	14	17	22	26	28
Clinton W of 14th May 2018 EB	20	288	4.38	19.91	13	16	20	24	27
Clinton W of 14th May 2018 WB	20	537	4.74	20.69	12	16	21	25	28
Clinton W of 14th Sep 2019 EB	20	221	3.86	19.88	13	16	20	23	26
Clinton W of 14th Sep 2019 WB	20	427	4.72	20.61	13	15	21	25	28
Clinton W of 25th Jun 2015 EB	25	841	3.51	20.12	14	17	20	24	25
Clinton W of 25th Jun 2015 WB	25	1115	3.72	21.51	15	18	22	25	27
Clinton W of 25th Mar 2014 EB	25	860	3.65	20.36	14	17	21	24	26
Clinton W of 25th Mar 2014 WB	25	971	3.6	21.04	15	17	21	25	27
Clinton W of 30th Aug 2014 EB	25	863	3.94	20.09	13	16	20	24	26
Clinton W of 30th Aug 2014 WB	25	1067	3.89	20.52	14	17	21	24	27
Clinton W of 30th Jun 2015 EB	25	769	3.94	21.48	15	17	22	25	28
Clinton W of 30th Jun 2015 WB	25	904	3.76	20.61	14	17	21	24	27
Harrison E of 25th Apr 2019 EB	20	646	3.35	16.83	11	14	17	20	22
Harrison E of 25th Feb 2017 EB	25	791	3.07	20.73	16	18	21	24	26



Harrison E of 25th Feb 2017 WB	25	445	3.36	19.12	13	16	19	23	24
Lincoln E of 30th Apr 2019 WB	20	742	3.33	19.9	14	17	20	23	25
Lincoln E of 30th Feb 2019 WB	20	582	3.28	19.98	15	17	20	23	25
Lincoln E of 45th Jul 2019 EB	20	201	3.75	20.07	14	16	20	24	26
Lincoln E of 45th Jul 2019 WB	20	288	3.34	20.15	15	17	20	23	25
Lincoln E of 45th Nov 2012 EB	25	424	3.92	22.16	16	18	22	26	28
Lincoln E of 45th Nov 2012 WB	25	618	3.71	21.94	16	19	22	26	28
Lincoln E of 48th Jan 2017 EB	20	610	3.83	21.56	15	18	22	25	28
Lincoln E of 48th Jan 2017 WB	20	559	3.88	21.71	16	18	22	25	28
Lincoln E of 48th Oct 2012 EB	25	515	4.4	22.1	15	18	22	26	29
Lincoln E of 48th Oct 2012 WB	25	533	4.09	22.45	15	19	23	26	29
Lincoln E of 50th Apr 2011 EB	25	1105	3.14	21.81	17	19	22	25	27
Lincoln E of 50th Apr 2011 WB	25	1362	4.8	19.1	10	14	19	24	26
Lincoln E of 50th Feb 2012 WB	25	1078	3.05	20.17	15	17	20	23	25
Lincoln E of 50th Jun 2011 WB	25	1093	4.07	19.5	12	16	20	23	25
Lincoln E of 50th Mar 2017 EB	20	1078	3.04	17.68	13	15	18	21	23
Lincoln E of 50th Mar 2017 WB	20	710	3.18	18	13	15	18	21	23
Lincoln E of 50th May 2019 EB	20	224	3.15	16.9	11	14	17	20	22
Lincoln E of 50th May 2019 WB	20	496	2.86	17.78	13	15	18	20	22
Lincoln W of 41st Jan 2017 WB	20	808	4.15	21.02	14	17	21	25	27
Lincoln W of 41st Nov 2012 WB	25	725	4.15	22.13	16	18	22	26	29
Lincoln W of 57th Feb 2012 EB	25	832	3.72	22.92	17	20	23	26	29
Lincoln W of 57th Feb 2012 WB	25	748	3.19	22.75	18	20	23	26	28

Lincoln W of 57th Jan 2017 EB	20	730	3.46	21.16	16	18	21	24	27
Lincoln W of 57th Jan 2017 WB	20	961	3.53	21.22	15	17	21	25	27

**Table 2.3: Class two speed statistics for the 17 datasets along streets with bike lanes.**

<b>Dataset</b>	<b>PSL</b>	<b>ADT</b>	<b>SD</b>	<b>Mean</b>	<b>5th</b>	<b>15th</b>	<b>50th</b>	<b>85th</b>	<b>95th</b>
Division E of 116th Apr 2018 EB	30	8898	5.92	32.61	22	27	33	38	42
Division E of 116th Apr 2018 WB	30	10573	4.35	32.91	26	29	33	37	40
Division E of 116th Dec 2019 EB	30	7739	4.78	32.68	25	28	33	37	40
Division E of 116th Feb 2017 EB	35	7114	6.64	31.27	18	25	32	37	40
Division E of 116th Feb 2017 WB	35	9215	5.46	35.29	26	30	35	41	44
Division E of 116th Feb 2017 WB b	35	9939	5.4	35.18	26	30	35	40	44
Division E of 116th Oct 2019 WB	30	8891	4.67	33.07	26	29	33	37	41
Holgate E of 111th Feb 2017 EB	35	4675	7.1	21.11	10	14	21	28	33
Holgate E of 111th Feb 2017 WB	35	5169	7.74	28.44	13	19	29	36	40
Holgate E of 111th Jun 2019 EB	30	5124	8.41	23.29	10	14	23	33	36
Holgate E of 111th Jun 2019 WB	30	6907	5.14	26.9	19	22	26	32	36
Willamette E of Chase Jul 2019 EB	30	6203	4.3	34.49	28	31	35	38	41
Willamette E of Chase Jun 2015 EB	35	6742	3.98	35.73	29	32	36	39	42
Williams N of Going Jan 2015 NB	30	4409	4.2	26.99	20	23	27	31	34
Williams N of Going Jul 2019 NB	25	4093	4.14	26.2	20	22	26	30	33
Williams N of Hancock Feb 2015 NB	30	5883	5.1	27.56	19	22	28	32	35
Williams N of Hancock Sep 2019 NB	25	5617	4.48	24.47	17	20	24	29	32

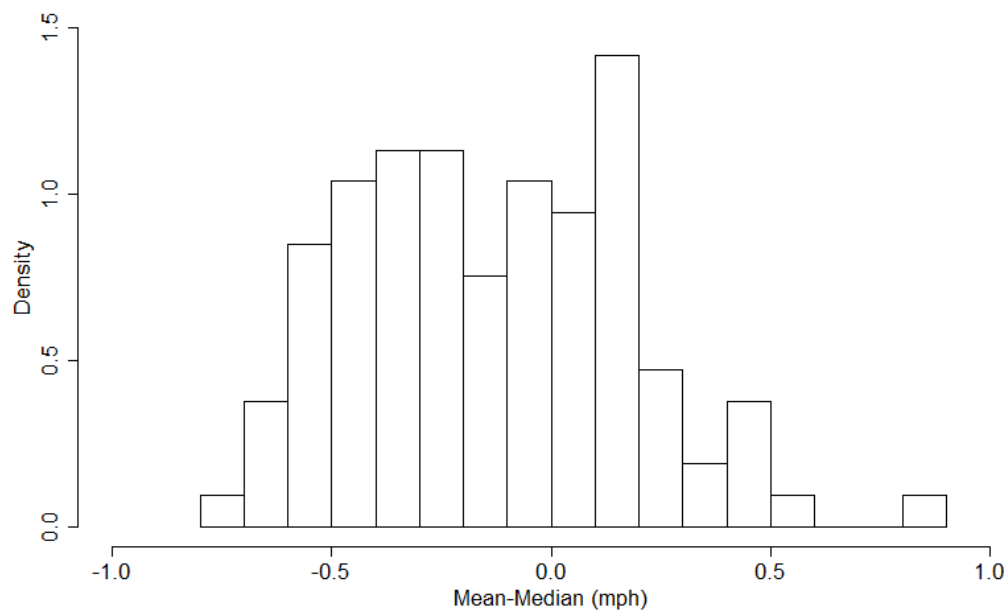
**Table 2.4: Class two speed statistics for the 20 datasets along streets without bike facilities.**

<b>Dataset</b>	<b>PSL</b>	<b>ADT</b>	<b>SD</b>	<b>Mean</b>	<b>5th</b>	<b>15th</b>	<b>50th</b>	<b>85th</b>	<b>95th</b>
Alberta E of 14th Jul 2019 EB	20	3289	5.15	21.37	12	16	22	26	29
Alberta E of 14th Jul 2019 WB	20	2960	4.97	20.78	12	16	21	25	29
Alberta E of 14th Nov 2019 EB	20	3169	4.79	21.43	13	17	22	26	29
Alberta E of 14th Nov 2019 WB	20	2562	4.89	21.46	13	17	22	26	29
Alberta E of 28th Jul 2019 EB	20	2308	4.79	20.38	13	15	20	25	28
Alberta E of 28th Jul 2019 WB	20	2031	4.52	20.14	13	16	20	24	28
Alberta E of 28th Oct 2016 EB	25	2208	4.91	21.42	13	17	21	26	29
Alberta E of 28th Oct 2016 WB	25	2252	4.56	20.03	13	15	20	25	28
Alberta E of 28th Sep 2016 WB	25	1791	4.92	19.76	12	15	20	25	28
Alberta E of 28th Sep 2016 WB b	25	2121	5.02	19.84	12	15	20	25	28
Division E of 33rd Jul 2015 EB	25	4107	5.34	19.3	10	14	20	25	28
Division E of 33rd Jul 2015 WB	25	4622	4.76	19.86	12	15	20	25	28
Division E of 33rd Jul 2019 EB b	25	3602	5.21	18.65	10	13	19	24	27
Division E of 33rd Jul 2019 WB	25	3845	4.78	18.59	11	14	18	23	27
Fremont E of 46th Feb 2018 EB	20	3773	4.45	21.03	14	17	21	25	28
Fremont E of 46th Feb 2018 WB	20	3654	4.82	20.75	13	16	21	25	29
Fremont E of 46th Sep 2019 EB	20	3927	4.45	20.64	13	16	21	25	28
Fremont E of 46th Sep 2019 WB	20	4021	4.74	19.57	12	15	20	24	27
Fremont E of 48th Dec 2014 WB	20	3487	4.83	23.07	15	18	23	28	31
Fremont E of 48th Jul 2019 WB	20	4466	4.68	21.64	14	17	22	26	29

Tables 2.2-2.4 show that 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 seen at non-neighborhood greenway sites without bicycle facilities. However, the 85<sup>th</sup> percentile speeds at greenway sites (20-27 mph) appear to be slightly lower than 85<sup>th</sup> 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 85<sup>th</sup> 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 2.3. 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.



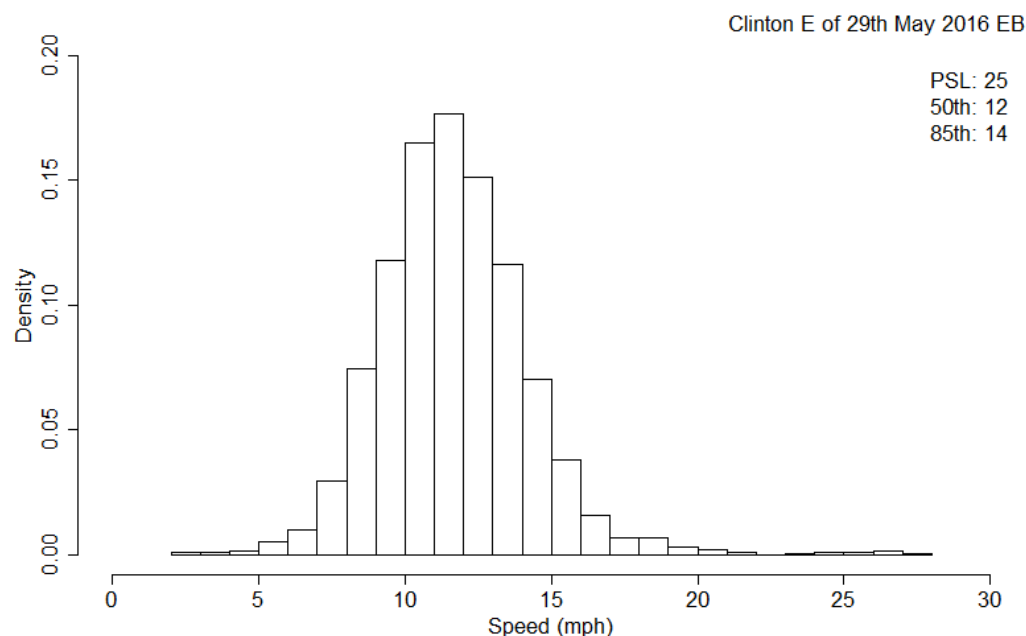
**Figure 2.3: Histogram of the differences between the mean and median of each dataset.**

## 2.3 ACTIVE TRAVEL

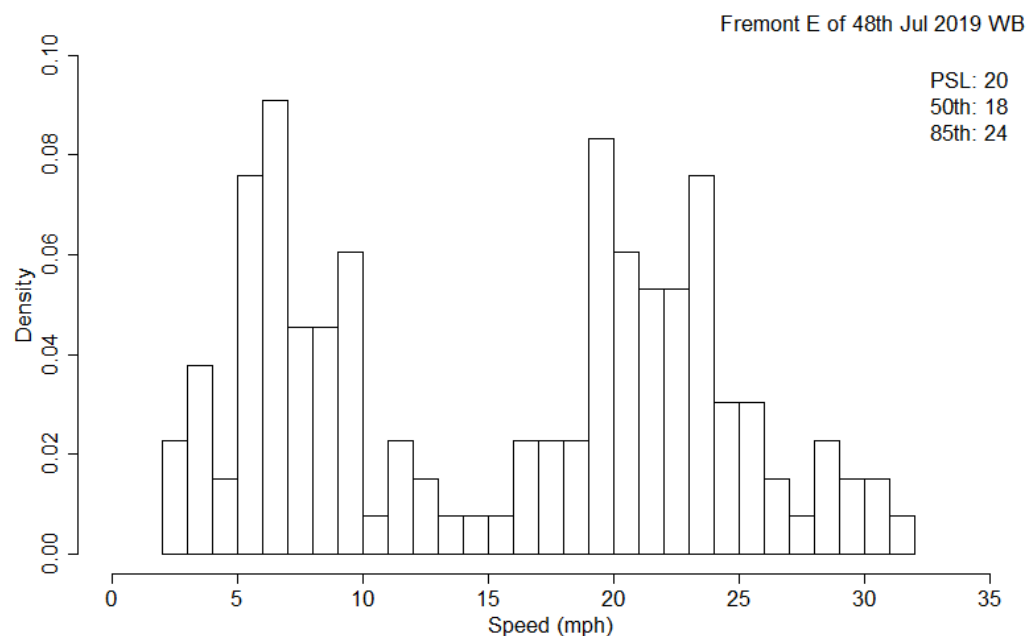
This research is primarily interested in locations that have high percentages of active travelers. However, as discussed with the TAC, some sites with low active travel activity were included to

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 appears 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<sup>th</sup>, 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% (*City of Portland, 2019*).

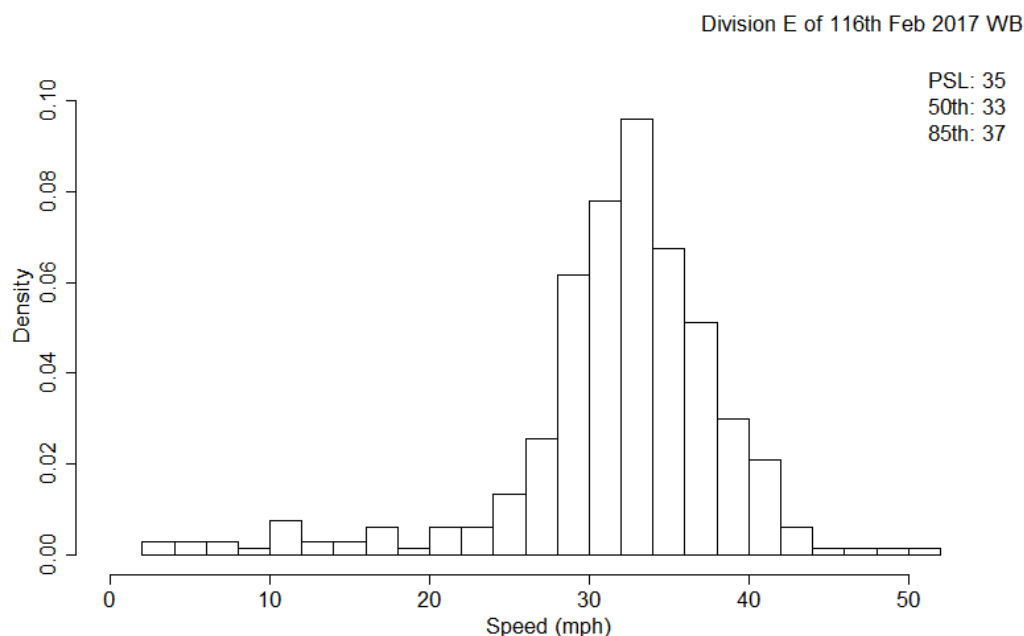
Studies in the U.S. have estimated typical average bicyclist speeds to range from 12-15 mph, and 85<sup>th</sup> percentile speeds in Sweden have been reported as 10-17 mph (*Hummer et al, 2006*). The class one speed distributions for datasets located on neighborhood greenways tend to be unimodal and appear to be predominantly non-motorized vehicles (bicycles). Figure 2.4 shows a typical example of a class one speed distribution for a neighborhood greenway street, at eastbound Clinton east of 29<sup>th</sup> from the May 2016 survey. The 50<sup>th</sup> and 85<sup>th</sup> 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 2.5 shows an example of a bimodal class one distribution indicating the presence of both motorized and non-motorized vehicles for westbound Fremont east of 48<sup>th</sup> 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 2.6 shows one such distribution, from westbound Division east of 116<sup>th</sup> in February 2017. Speeds at this location are clearly much higher than is typically achievable by a pedal cyclist.



**Figure 2.4: Example of a typical class one speed distribution with the posted speed limit (PSL) and 50<sup>th</sup> and 85<sup>th</sup> percentile speeds for a neighborhood greenway street where the majority of the class one vehicles appear to be non-motorized.**



**Figure 2.5: Example of a bimodal class one speed distribution with motorized and non-motorized vehicles along a neighborhood collector street.**



**Figure 2.6: Example of a class one speed distribution with the posted speed limit (PSL) and 50<sup>th</sup> and 85<sup>th</sup> percentile speeds 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 (*City of Portland, 2020, p.72-73*) 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*). Tables 2.5, 2.6, and 2.7 show an overview of class one traffic volumes and speeds with pedestrian proxies for surveys performed on roads with shared bicycle facilities (neighborhood greenways), bicycle lanes, and no explicit bicycle facilities, respectively. Based on the interactive map (*"Interactive map: Portland-area density", 2020*), the population densities appear to be higher for locations along the neighborhood greenways and lower for locations where bicycle lanes are present.

**Table 2.5: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations with shared bicycle facilities.**

Dataset	ADT	Traffic %	SD	Mean	50th	85th	Bus	Ped Dist.
Clinton E of 17th Aug 2014 EB	18	2.15	7.44	20.66	23	27	N	N
Clinton E of 17th Aug 2014 WB	51	4.48	4.06	19.04	20	23	N	N
Clinton E of 17th Jul 2015 EB	386	37.52	2.89	12.37	12	15	N	N
Clinton E of 17th Jul 2015 WB	452	35.11	3.02	14.70	15	17	N	N
Clinton E of 23rd Apr 2019 EB	413	46.13	3.44	11.81	11	14	Y	N

Clinton E of 23rd Apr 2019 WB	290	32.25	2.62	16.72	17	19	Y	N
Clinton E of 23rd Jul 2015 EB	884	52.43	3.63	11.31	11	14	Y	N
Clinton E of 23rd Jul 2015 WB	943	46.84	3.04	16.76	17	19	Y	N
Clinton E of 23rd May 2016 EB	733	48.58	3.19	11.13	11	14	Y	N
Clinton E of 23rd May 2016 WB	810	47.96	2.67	16.94	17	19	Y	N
Clinton E of 29th Apr 2014 EB	10	0.80	11.54	24.64	25	34	N	N
Clinton E of 29th Apr 2014 WB	19	1.51	7.17	20.90	22	28	N	N
Clinton E of 29th Jul 2019 EB	734	66.53	2.93	11.55	11	14	N	N
Clinton E of 29th Jul 2019 WB	573	61.79	3.24	15.72	16	19	N	N
Clinton E of 29th May 2016 EB	938	65.01	2.54	11.68	12	14	N	N
Clinton E of 29th May 2016 WB	829	68.29	2.72	16.00	16	19	N	N
Clinton W of 13th Jul 2015 EB	435	30.33	2.98	13.33	13	16	N	N
Clinton W of 13th Jul 2015 WB	339	42.35	2.67	13.19	13	16	N	N
Clinton W of 13th May 2016 EB	670	65.90	2.85	13.76	14	16	N	N
Clinton W of 13th May 2016 WB	813	52.11	2.75	14.50	14	17	N	N
Clinton W of 14th Aug 2014 EB	14	1.94	7.69	20.60	22	28	N	N
Clinton W of 14th Aug 2014 WB	64	4.71	5.62	18.14	17	24	N	N
Clinton W of 14th Mar 2018 EB	5	1.34	7.58	10.23	11	19	N	N
Clinton W of 14th Mar 2018 WB	40	5.10	5.29	15.16	15	18	N	N
Clinton W of 14th May 2018 EB	366	48.90	3.25	14.32	14	17	N	N
Clinton W of 14th May 2018 WB	639	47.99	2.80	14.93	15	17	N	N
Clinton W of 14th Sep 2019 EB	793	73.01	3.05	13.74	14	17	N	N
Clinton W of 14th Sep 2019 WB	932	62.75	2.92	14.52	15	17	N	N



Clinton W of 25th Jun 2015 EB	756	41.31	3.39	11.40	11	14	Y	N
Clinton W of 25th Jun 2015 WB	951	41.08	3.11	15.81	16	18	Y	N
Clinton W of 25th Mar 2014 EB	18	1.81	6.80	18.49	20	25	Y	N
Clinton W of 25th Mar 2014 WB	16	1.46	5.98	19.53	20	25	Y	N
Clinton W of 30th Aug 2014 EB	37	3.60	8.76	16.81	19	24	N	N
Clinton W of 30th Aug 2014 WB	27	2.11	7.40	20.53	21	29	N	N
Clinton W of 30th Jun 2015 EB	821	46.98	3.06	11.74	11	14	N	N
Clinton W of 30th Jun 2015 WB	824	44.50	3.11	16.10	16	19	N	N
Harrison E of 25th Apr 2019 EB	62	7.80	4.74	11.93	12	17	N	N
Harrison E of 25th Feb 2017 EB	335	26.14	3.19	18.23	18	21	N	N
Harrison E of 25th Feb 2017 WB	340	38.81	4.70	13.37	13	19	N	N
Lincoln E of 30th Apr 2019 WB	87	9.23	3.77	15.47	15	20	N	N
Lincoln E of 30th Feb 2019 WB	201	23.50	4.15	14.04	13	19	N	N
Lincoln E of 45th Jul 2019 EB	412	62.66	3.03	13.87	14	17	N	N
Lincoln E of 45th Jul 2019 WB	107	24.37	3.27	16.90	17	19	N	N
Lincoln E of 45th Nov 2012 EB	7	1.28	8.14	21.00	23	27	N	N
Lincoln E of 45th Nov 2012 WB	4	0.54	7.68	26.25	26	33	N	N
Lincoln E of 48th Jan 2017 EB	47	6.04	4.57	12.93	13	15	N	N
Lincoln E of 48th Jan 2017 WB	140	17.39	3.63	17.65	18	21	N	N
Lincoln E of 48th Oct 2012 EB	36	5.67	8.27	22.04	23	30	N	N
Lincoln E of 48th Oct 2012 WB	91	12.56	4.67	18.71	19	22	N	N
Lincoln E of 50th Apr 2011 EB	50	3.53	7.38	18.93	20	26	N	N
Lincoln E of 50th Apr 2011 WB	34	1.98	8.34	17.68	19	25	N	N

Lincoln E of 50th Feb 2012 WB	49	3.55	4.76	20.41	21	24	N	N
Lincoln E of 50th Jun 2011 WB	30	2.29	5.36	18.04	18	22	N	N
Lincoln E of 50th Mar 2017 EB	254	16.09	2.89	11.51	11	14	N	N
Lincoln E of 50th Mar 2017 WB	443	34.92	3.93	16.33	16	20	N	N
Lincoln E of 50th May 2019 EB	345	55.72	2.81	11.54	11	14	N	N
Lincoln E of 50th May 2019 WB	280	32.45	3.27	18.30	18	22	N	N
Lincoln W of 41st Jan 2017 WB	120	11.32	3.27	15.54	16	18	N	N
Lincoln W of 41st Nov 2012 WB	11	1.28	7.39	17.36	19	22	N	N
Lincoln W of 57th Feb 2012 EB	18	1.47	10.02	17.59	18	28	Y	N
Lincoln W of 57th Feb 2012 WB	59	5.32	6.16	19.44	21	27	Y	N
Lincoln W of 57th Jan 2017 EB	135	12.67	4.86	12.99	12	18	Y	N
Lincoln W of 57th Jan 2017 WB	154	11.83	3.27	16.01	16	19	Y	N

\*Ped. Dist. = pedestrian district

**Table 2.6: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations with bicycle lanes.**

<b>Dataset</b>	<b>ADT</b>	<b>Traffic %</b>	<b>SD</b>	<b>Mean</b>	<b>50th</b>	<b>85th</b>	<b>Bus</b>	<b>Ped Dist.</b>
Division E of 116th Apr 2018 EB	339	2.56	8.04	29.97	31	36	Y	Y
Division E of 116th Apr 2018 WB	434	3.10	6.57	30.88	32	36	Y	Y
Division E of 116th Dec 2019 EB	303	2.77	6.22	29.84	31	34	Y	Y
Division E of 116th Feb 2017 EB	477	5.11	12.19	16.21	11	32	Y	Y
Division E of 116th Feb 2017 WB	400	2.90	6.95	31.73	33	37	Y	Y
Division E of 116th Feb 2017 WB b	366	2.47	6.96	31.73	33	37	Y	Y
Division E of 116th Oct 2019 WB	347	2.65	5.76	31.26	32	36	Y	Y
Holgate E of 111th Feb 2017 EB	247	4.07	4.36	15.17	15	18	Y	N

Holgate E of 111th Feb 2017 WB	48	0.68	6.48	12.56	12	19	Y	N
Holgate E of 111th Jun 2019 EB	99	1.50	8.47	13.34	11	22	Y	N
Holgate E of 111th Jun 2019 WB	51	0.55	8.25	21.40	21	31	Y	N
Willamette E of Chase Jul 2019 EB	349	4.04	8.77	20.62	17	34	Y	N
Willamette E of Chase Jun 2015 EB	655	7.41	8.21	18.23	16	23	Y	N
Williams N of Going Jan 2015 NB	43	0.83	6.97	25.56	27	31	Y	N
Williams N of Going Jul 2019 NB	909	14.53	4.15	13.87	13	17	Y	N
Williams N of Hancock Feb 2015 NB	27	0.36	8.91	28.30	29	36	Y	N
Williams N of Hancock Sep 2019 NB	1226	15.17	3.97	14.67	14	18	Y	N

\*Ped. Dist. = pedestrian district

**Table 2.7: Class one traffic volumes and speed statistics with pedestrian proxy measures for surveys performed at locations without explicit bicycle facilities.**

<b>Dataset</b>	<b>ADT</b>	<b>Traffic %</b>	<b>SD</b>	<b>Mean</b>	<b>50th</b>	<b>85th</b>	<b>Bus</b>	<b>Ped</b>
Alberta E of 14th Jul 2019 EB	112	2.65	6.10	16.15	15	22	Y	Y
Alberta E of 14th Jul 2019 WB	85	2.28	6.62	15.84	14	22	Y	Y
Alberta E of 14th Nov 2019 EB	20	0.50	7.19	15.95	14	22	Y	Y
Alberta E of 14th Nov 2019 WB	8	0.25	7.07	20.75	23	25	Y	Y
Alberta E of 28th Jul 2019 EB	83	2.82	7.12	12.77	12	21	Y	N
Alberta E of 28th Jul 2019 WB	128	4.71	7.01	12.48	11	21	Y	N
Alberta E of 28th Oct 2016 EB	7	0.25	5.50	11.00	9	12	Y	N
Alberta E of 28th Oct 2016 WB	2	0.07	11.31	14.00	14	20	Y	N
Alberta E of 28th Sep 2016 WB	144	5.27	6.95	12.25	11	20	Y	N

Alberta E of 28th Sep 2016 WB b	116	4.30	5.40	11.95	11	17	Y	N
Division E of 33rd Jul 2015 EB	122	2.33	6.57	14.40	13	21	Y	Y
Division E of 33rd Jul 2015 WB	209	3.51	7.05	14.37	13	21	Y	Y
Division E of 33rd Jul 2019 EB b	77	1.66	7.36	15.08	14	22	Y	Y
Division E of 33rd Jul 2019 WB	96	2.00	7.02	13.99	14	22	Y	Y
Fremont E of 46th Feb 2018 EB	165	3.45	4.37	11.74	11	14	Y	N
Fremont E of 46th Feb 2018 WB	47	1.02	7.79	12.60	10	23	Y	N
Fremont E of 46th Sep 2019 EB	147	2.94	5.66	11.49	10	16	Y	N
Fremont E of 46th Sep 2019 WB	77	1.59	5.82	11.66	10	18	Y	N
Fremont E of 48th Dec 2014 WB	49	1.05	5.12	11.10	10	12	Y	N
Fremont E of 48th Jul 2019 WB	42	0.80	8.23	15.50	18	24	Y	N

\*Ped. Dist. = pedestrian district

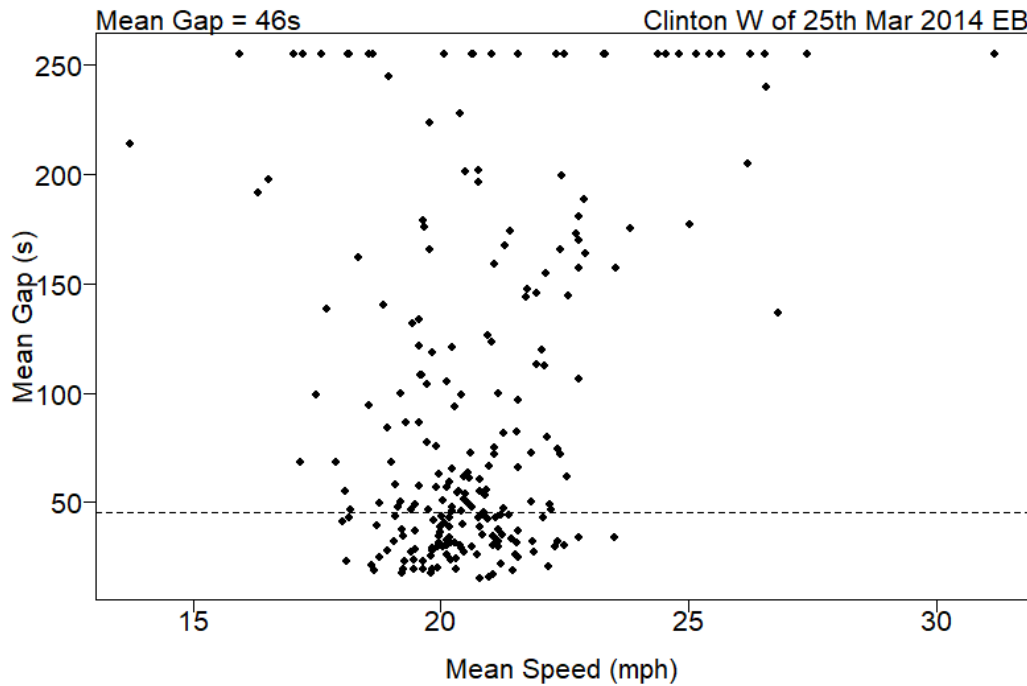
A high percentage of cyclists, more than 20% of traffic, is present on shared used roadways that are also neighborhood greenways such as SE Clinton, SE Harrison, and SE Lincoln. Only, Hence, in the analysis performed in later section roadways are classified as neighborhood and non-neighborhood greenways.

### 3.0 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 within the 15-minute bin. A difference between streets designated as neighborhood greenways and those without the designation was found.

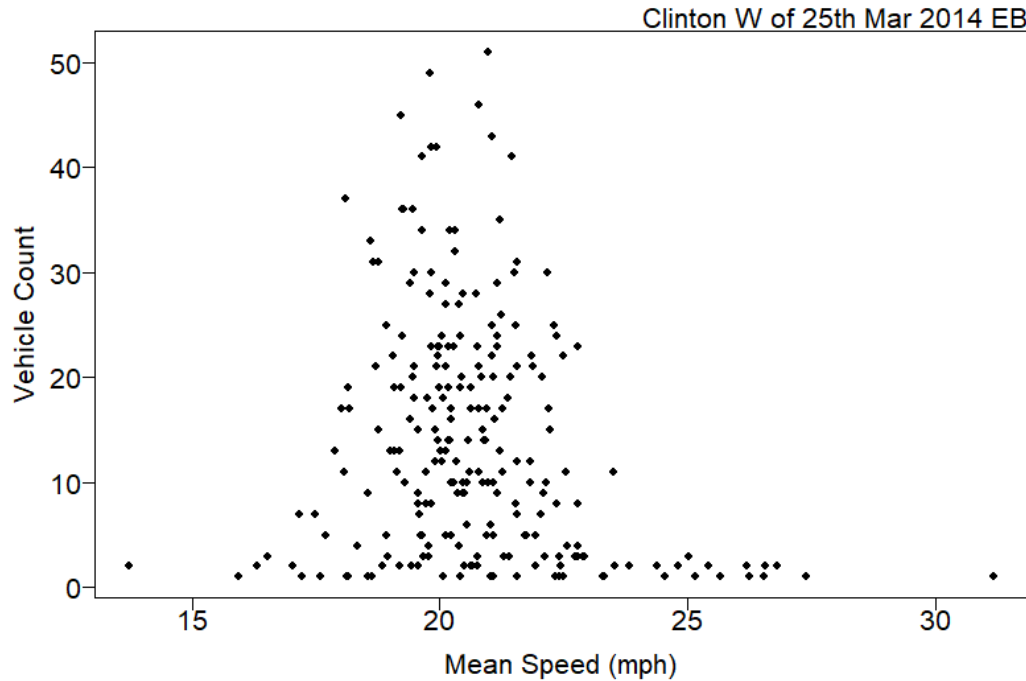
#### 3.1 NEIGHBORHOOD GREENWAYS

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 3.1 shows a typical scatterplot of mean speed vs. mean gap for a neighborhood greenway, eastbound Clinton west of 25<sup>th</sup> from a March 2014 survey. The dashed line shows the overall mean gap time for that survey.



**Figure 3.1: Typical example for a neighborhood greenway mean speed vs. mean gap scatterplot for the March 2014 eastbound Clinton west of 25<sup>th</sup> dataset.**

Similarly, Figure 3.2 shows the scatterplot of the mean speed vs. vehicle count for the March 2014 eastbound Clinton west of 25<sup>th</sup> dataset as a typical example along neighborhood greenways.



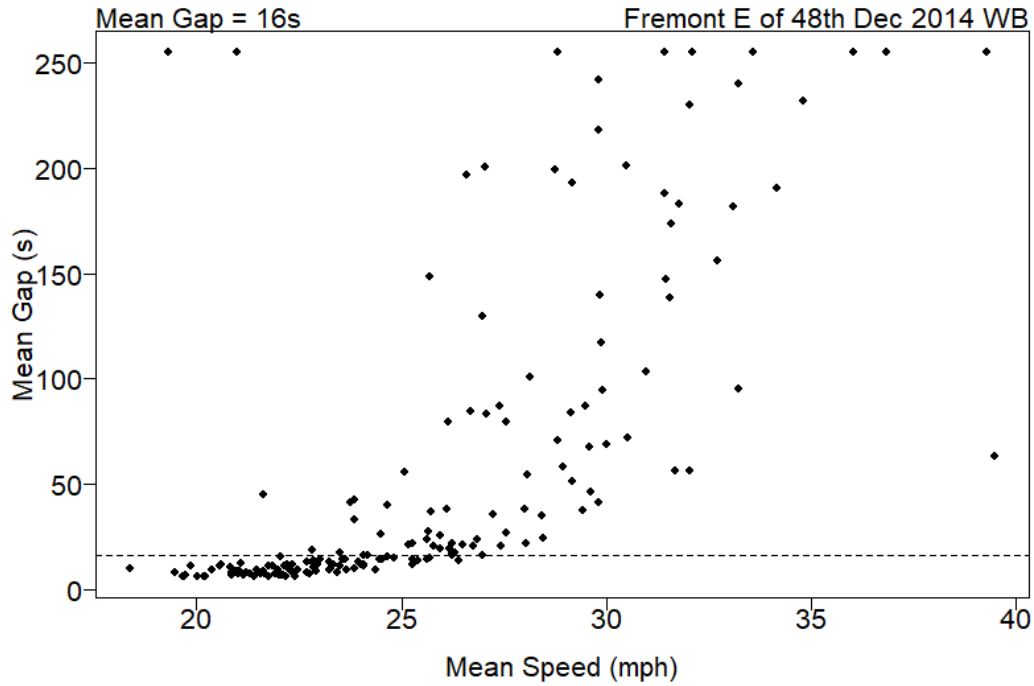
**Figure 3.2: Typical example for a neighborhood greenway mean speed vs. vehicle count scatterplot for the March 2014 eastbound Clinton west of 25th dataset.**

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 50<sup>th</sup>, 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.

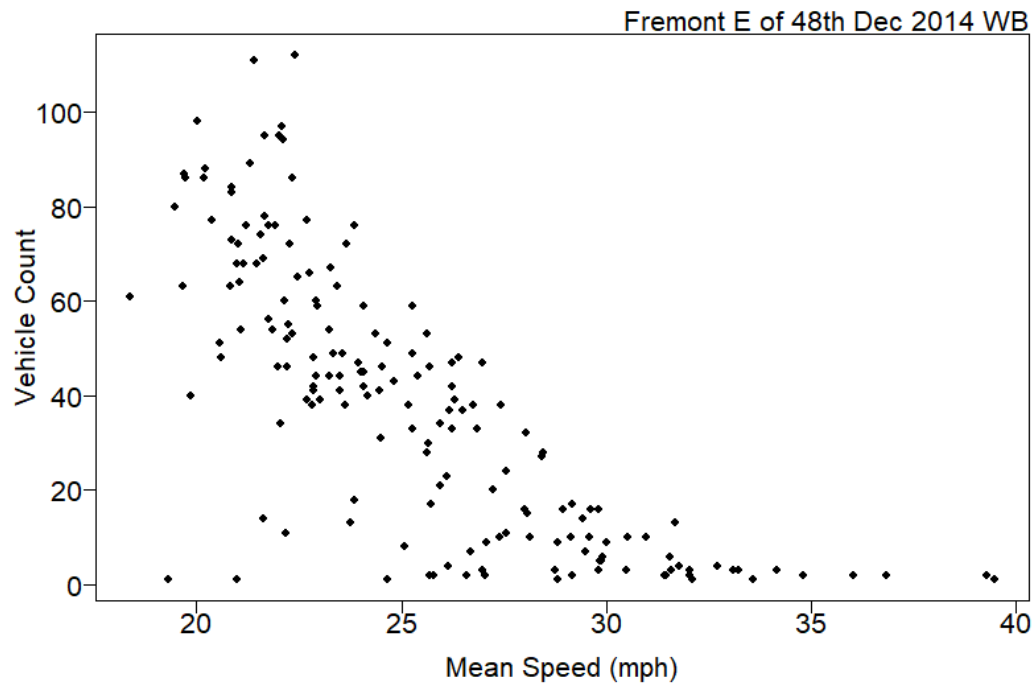
### 3.2 NON-NEIGHBORHOOD GREENWAY STREETS

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 correlation between mean speed and mean gap time was typically seen for datasets along such streets. In contrast, a negative correlation was generally found between mean speed and the 15-minute bin vehicle count. Figure 3.3 shows the scatterplot of mean speed vs. mean gap time for the 15-minute bins and overall class two average gap time for the December 2014 survey of westbound Fremont east of 48<sup>th</sup> as a typical example for non-neighborhood greenway streets. Figure 3.4 shows the scatterplot for the mean speed vs. vehicle count for the same 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.) were excluded and when observations with gap times of less than five seconds (used as a threshold for free-flow conditions) were excluded.



**Figure 3.3:** Typical example for a non-neighborhood greenway mean speed vs. mean gap scatterplot for the December 2014 westbound Fremont east of 48th dataset.



**Figure 3.4:** Typical example for a non-neighborhood greenway mean speed vs. vehicle count scatterplot for the December 2014 westbound Fremont east of 48th dataset.

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 111<sup>th</sup> for the June 2019 survey. The absence of the relationships between vehicle volume or mean gap time and mean speed is caused by the close proximity to the traffic control device to the east at 112<sup>th</sup> (less than 250 feet away) and a high volume of turning traffic at 112<sup>th</sup> which inhibits the speeds and affects the behavior of traffic at Holgate east of 111<sup>th</sup>. This location will be analyzed in more detail in Section 7.

### **3.3 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 (in Section 5) and those datasets displaying correlations between speed and gap or vehicle counts when observations are limited to free-flow conditions (in Section 6).



## 4.0 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 85<sup>th</sup> 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 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.

### 4.1 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 4.1 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 4.1.

Table 4.1 shows that the percent in the pace limits increased for each speed group. Table 4.1 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

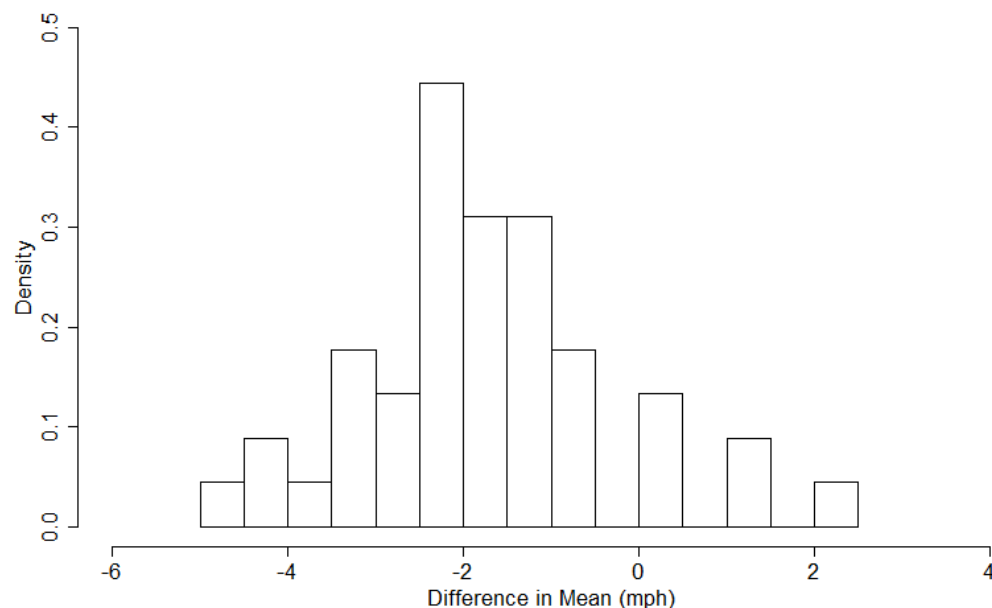
except percent in pace, but due to the low number of datasets to compare for each speed group, a broad conclusion could not be drawn by speed group.

**Table 4.1: 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
<i>Difference</i>		-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
<i>Difference</i>		-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
<i>Difference</i>		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
<i>Difference</i>		-1.78	-1.94	-20.10	-6.32	-0.53	-2.07	0.15

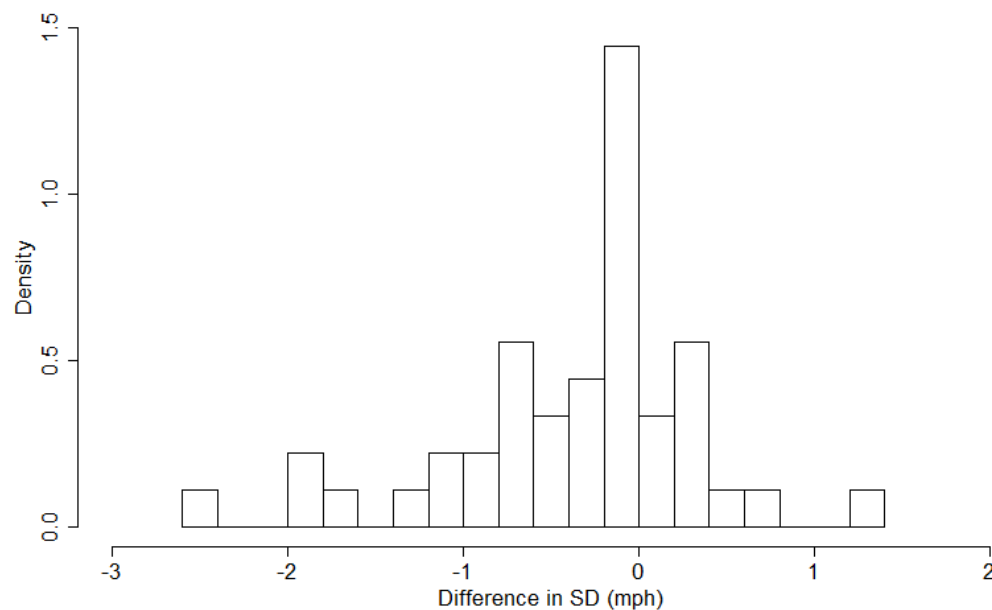
N = the number of datasets averaged

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 4.1 displays a histogram of the differences in the means for all treatment pairs. From Figure 4.1, 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.



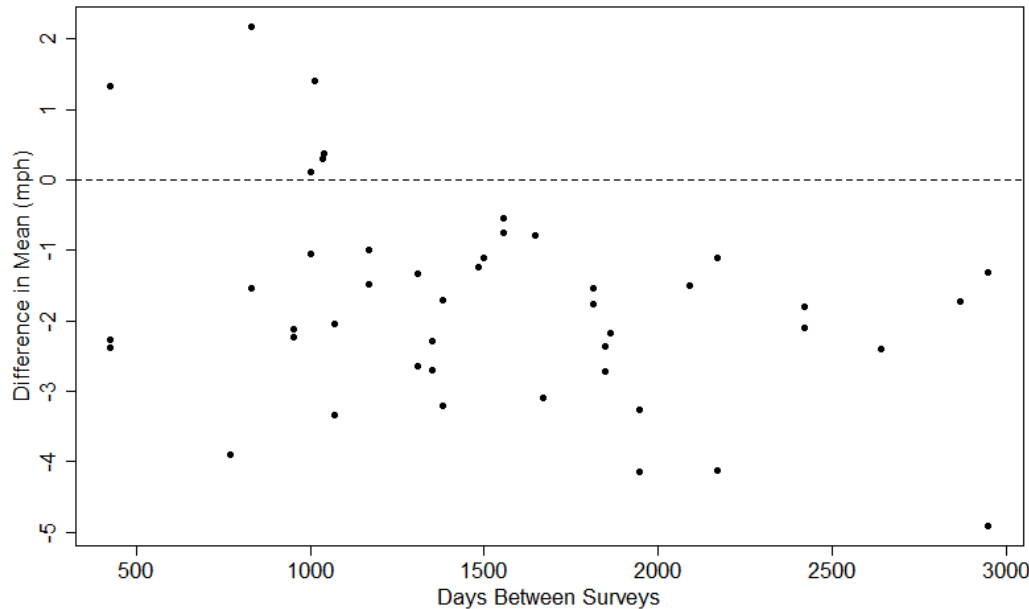
**Figure 4.1: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for all treatment pairs.**

Figure 4.2 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.



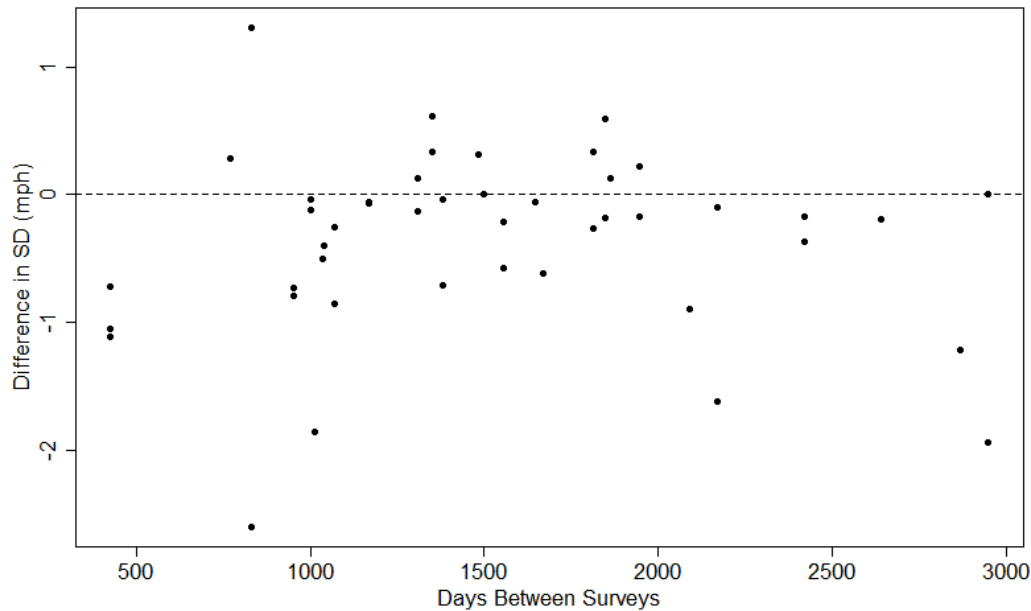
**Figure 4.2: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all treatment pairs.**

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 4.3 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 4.3, 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 4.3: 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 4.4. In contrast to Figure 4.3, there does not appear to be a significant correlation with time. Figure 4.4 provides a more detailed view of the data than Figure 4.2, showing the amount of change in the standard deviation for most sites was a decrease of zero to one mile per hour.



**Figure 4.4: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all treatment dataset pairs.**

## 4.2 CONTROL SITES

As with Table 4.1 for the treatment sites, Table 4.2 shows the control dataset pairs grouped by their speed limits and neighborhood greenway status. Average values for mean speed, 85<sup>th</sup> 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.

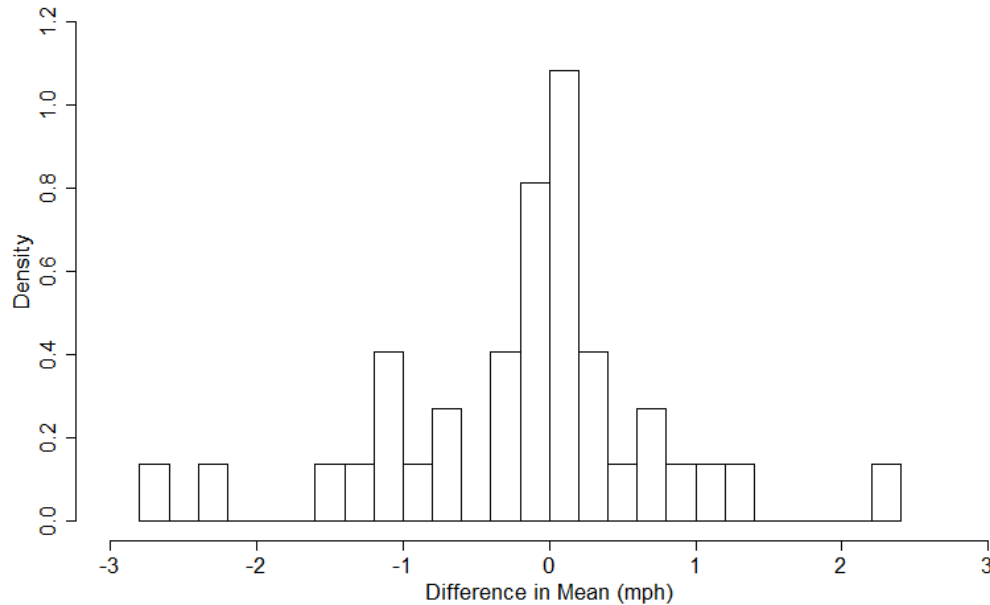
**Table 4.2: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for all datasets included in a control pair, grouped by PSL and greenway status.**

<b>Non-Neighborhood Greenways</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>% Exc. 45 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.11	-1.00	-0.89	-0.95	-0.45	0.00	-0.14
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		0.12	-0.50	0.99	-0.98	-0.66	0.00	2.87
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.41	-0.75	-1.45	-0.27	0.02	-0.75	1.42
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.45	-0.40	-3.54	-2.93	-1.04	-0.20	1.50
<b>Neighborhood Greenways</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		0.05	-0.21	-0.48	-0.04	-0.02	0.07	0.04
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.31	-0.57	-2.69	-0.97	-0.01	0.00	-0.62

N = the number of datasets averaged

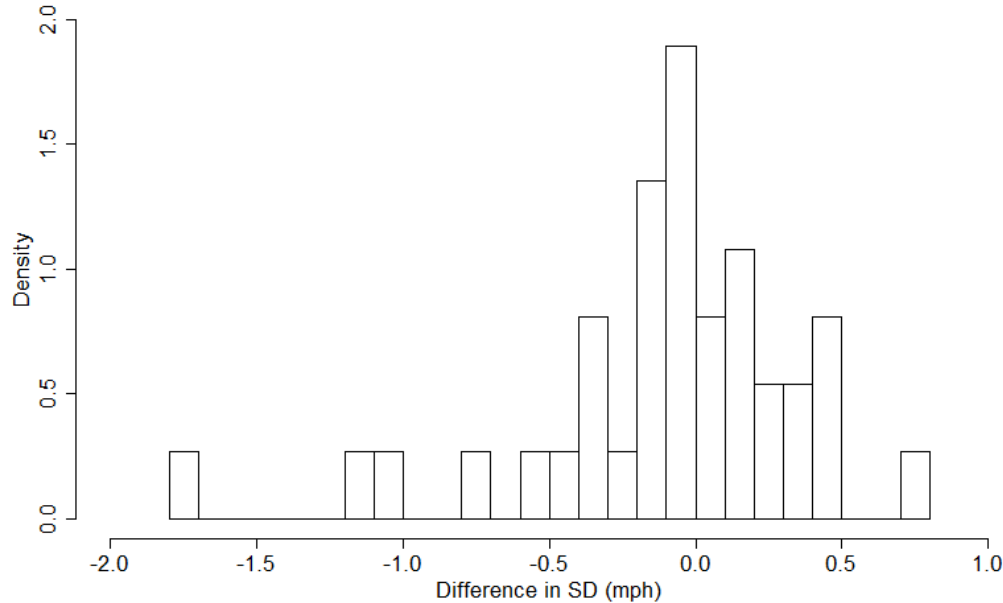
Differences in the mean speed and standard deviation were calculated for each control dataset pair ( $N = 37$ ), and histograms were constructed to show the distributions of the changes.

Figure 4.5 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 4.1 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 4.5: 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 4.6. As with Figure 4.5, 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.

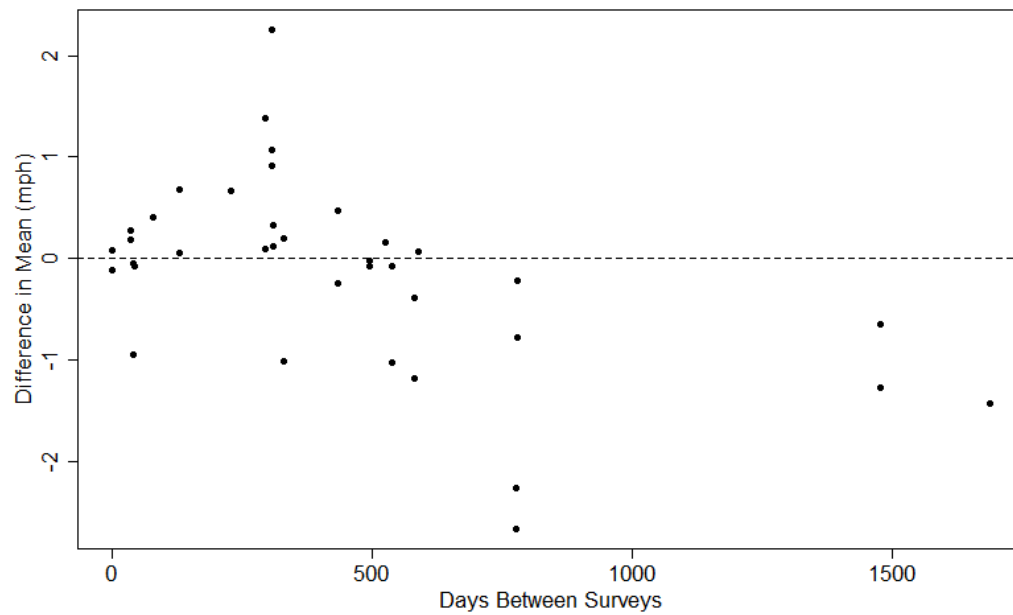


**Figure 4.6: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for all control pairs.**

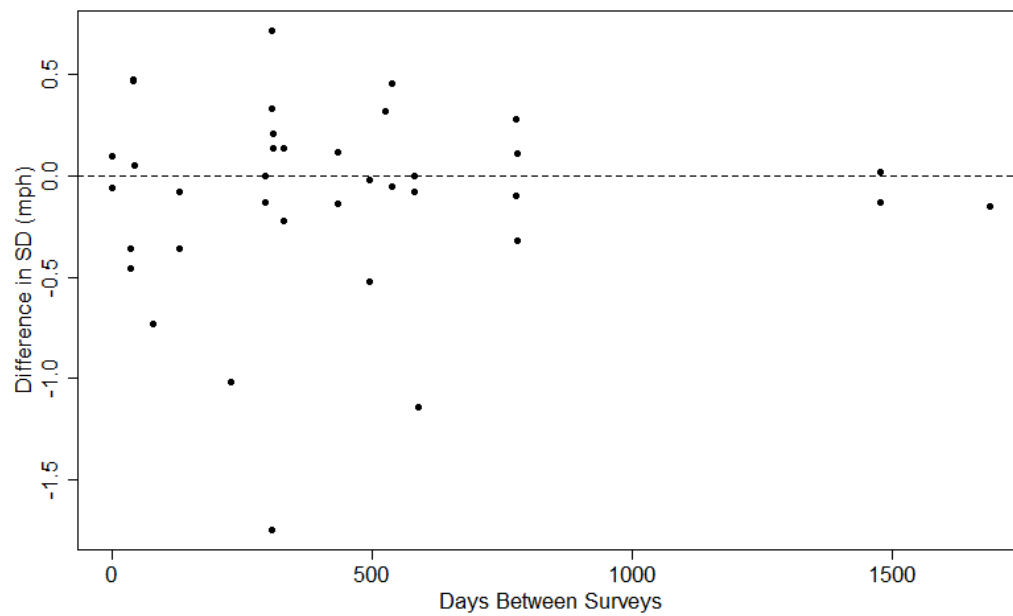
Looking at the magnitude of changes in the mean speed with respect to the time between subsequent surveys, Figure 4.7 indicates there may be a slight negative correlation with most surveys occurring more than 500 days after the initial survey showing decreases in mean speeds and those occurring within 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 4.4, Figure 4.8 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 4.7: Scatterplot of the difference in mean speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs.**



**Figure 4.8: Scatterplot of the difference in the standard deviation of speed vs. the number of days elapsed between subsequent surveys for all control dataset pairs.**

### 4.3 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 111<sup>th</sup> were not included as they involved datasets that did not demonstrate the relationship pattern, and the site was too close to a traffic signal as discussed later in Section 7. 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 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 85<sup>th</sup> percentile speeds (*Forbes et al, 2012; ODOT, 2014*).

Table 4.3 displays the average values for the mean and 85<sup>th</sup> 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.

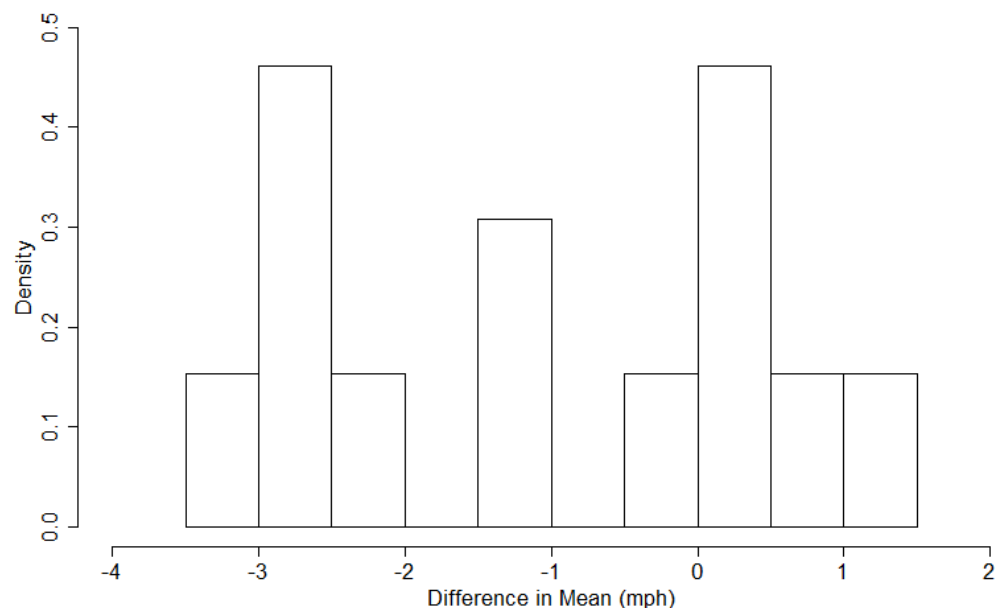
When the treatment datasets are limited to free-flow gap times, the magnitude and direction of changes in the performance measure averages are largely in agreeance with the results of the analysis when all observations for all treatment datasets are included. For the 35-30 mph free-flow treatment pairs, 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 111<sup>th</sup>.

**Table 4.3: 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.**

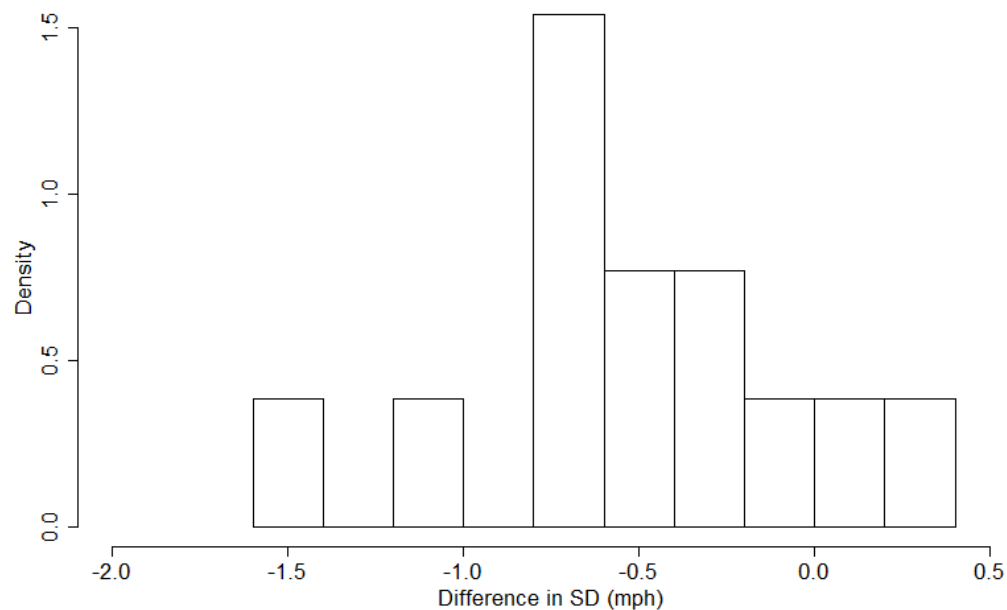
Treatment Datasets								
	PSL	Mean	85th	% Exc. 30 mph	% Exc. 35 mph	% Exc. 40 mph	Pace Min	% in Pace
Before (N=4)	35	36.26	41.25	87.59	60.60	20.39	32.50	70.62
After (N=5)	30	34.77	39.80	83.08	45.21	12.27	30.60	71.19
<i>Difference</i>		-1.49	-1.45	-4.51	-15.39	-8.12	-1.90	0.57
	PSL	Mean	85th	% Exc. 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
<i>Difference</i>		-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
<i>Difference</i>		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 4.9 (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 4.10 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 4.9: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow treatment pairs (N = 13).**

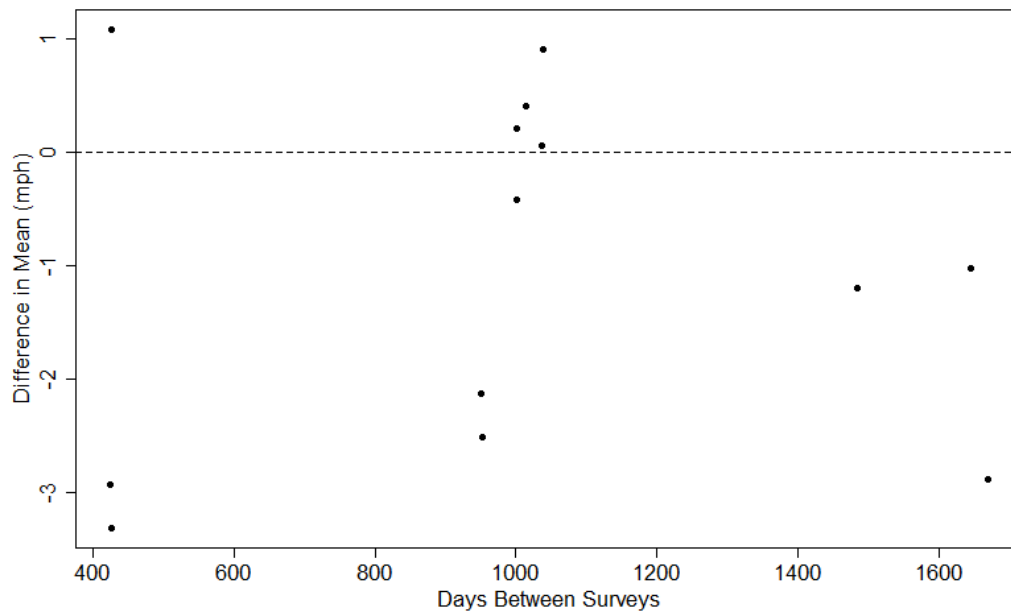


**Figure 4.10: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for the free-flow treatment pairs (N = 13).**

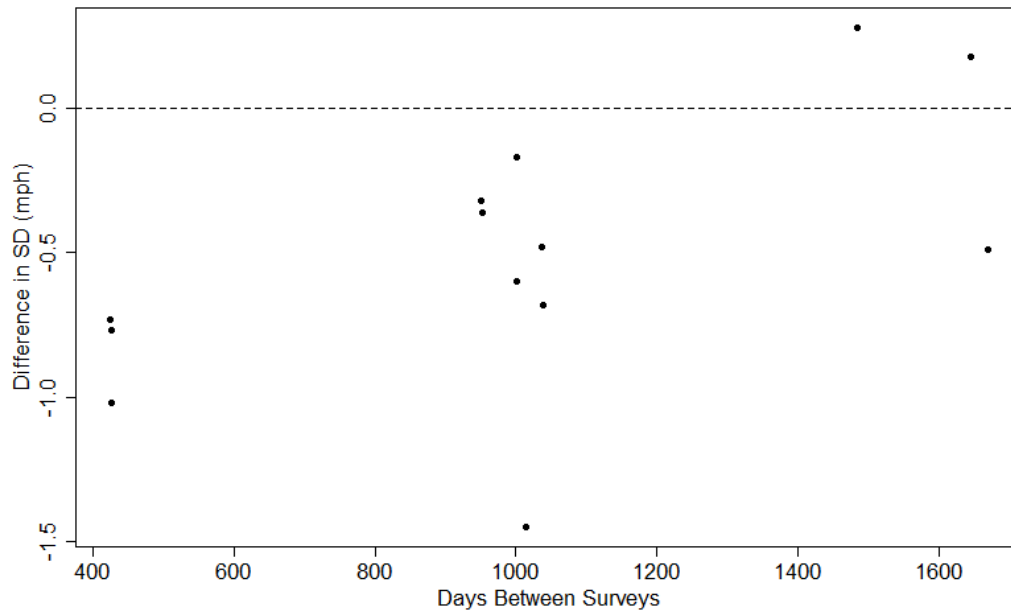
A scatterplot showing the differences in mean speed versus the number of days elapsed between surveys can be seen in Figure 4.11. The slight negative correlation observed when all

observations from all treatment pairs are included (Figure 4.3) does not appear in the plot of Figure 4.11. However, thirteen data points may not be enough to detect a clear trend.

In Figure 4.12, 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 4.12, 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 4.4.



**Figure 4.11: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for free-flow treatment dataset pairs.**



**Figure 4.12: Scatterplot of the difference in standard deviation vs. the number of days elapsed between surveys for the gap-limited treatment dataset pairs.**

Table 4.4 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, 85<sup>th</sup> 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, 85<sup>th</sup> percentile, and pace speeds were one to five miles per hour higher when only free-flow data were included.

Table 4.5 displays the same comparisons as Table 4.4 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 4.4: Comparison of all data and free-flow data from the before period for treatment datasets.**

<b>Treatment Datasets (Before)</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>5.09</i>	<i>4.42</i>	<i>25.53</i>	<i>27.71</i>	<i>12.53</i>	<i>5.33</i>	<i>4.93</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.86</i>	<i>2.00</i>	<i>13.42</i>	<i>16.23</i>	<i>4.46</i>	<i>2.00</i>	<i>-1.45</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.05</i>	<i>1.50</i>	<i>8.84</i>	<i>7.51</i>	<i>1.86</i>	<i>1.13</i>	<i>-4.28</i>

\*Free flow does not include Holgate sites.

**Table 4.5: Comparison of all data and free-flow data from the after period for treatment datasets.**

<b>Treatment Datasets (After)</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>3.92</i>	<i>3.80</i>	<i>22.42</i>	<i>22.79</i>	<i>8.17</i>	<i>3.46</i>	<i>1.86</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.85</i>	<i>2.00</i>	<i>18.14</i>	<i>12.07</i>	<i>2.68</i>	<i>2.00</i>	<i>-3.54</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.43</i>	<i>1.50</i>	<i>13.28</i>	<i>7.31</i>	<i>2.01</i>	<i>1.50</i>	<i>-0.30</i>

\*Free flow does not include Holgate sites.

## **4.4 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 85<sup>th</sup> 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 4.6. Minor to negligible reductions in the mean, 85<sup>th</sup> 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.



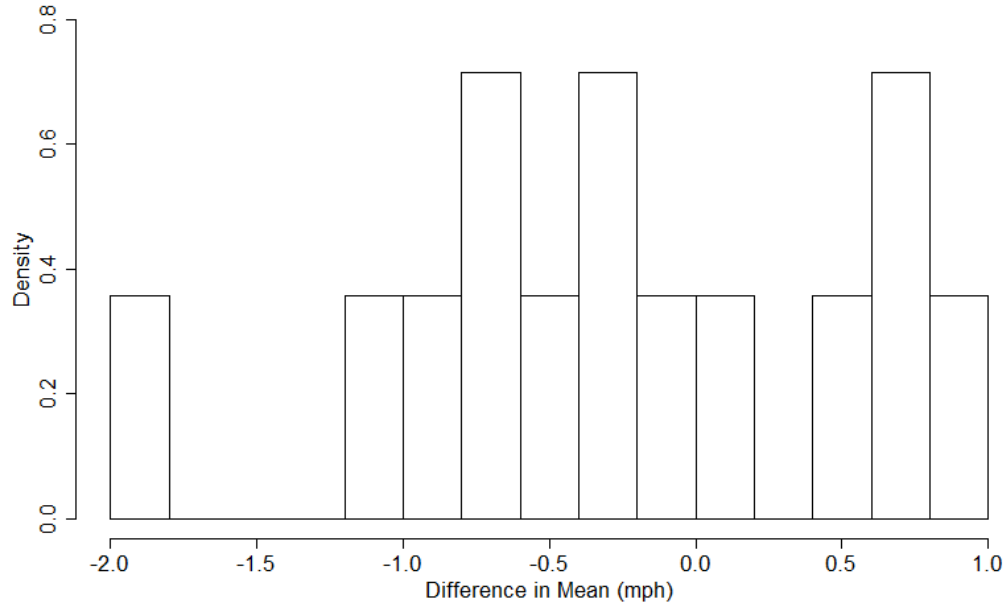
**Table 4.6: Averages for the mean and 85th percentile speeds and percent of observations exceeding the speed thresholds for control datasets limited to observations with gap times greater than or equal to the mean gap time.**

<b>Control Datasets</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>% Exc. 45 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.38	-1.00	-2.17	-2.12	-1.24	0.00	0.56
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		0.06	-0.50	0.31	1.14	-0.27	0.00	0.36
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.22	-0.40	-1.88	-0.58	-0.02	0.10	1.60
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		-0.59	-0.60	-4.20	-4.41	-2.36	-1.00	0.99

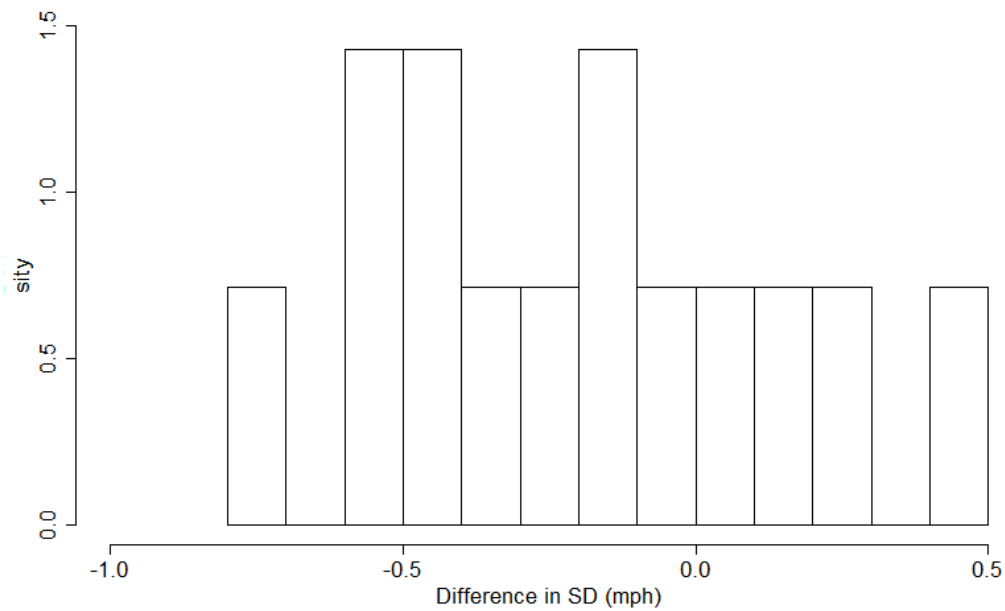
N = the number of datasets averaged

Differences in mean speed between individual dataset pairs are shown in the histogram in Figure 4.13 (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 4.14 (N = 14).



**Figure 4.13: Histogram of the differences in mean speed from the 'before' condition to the 'after' condition for the free-flow control pairs (N = 14).**

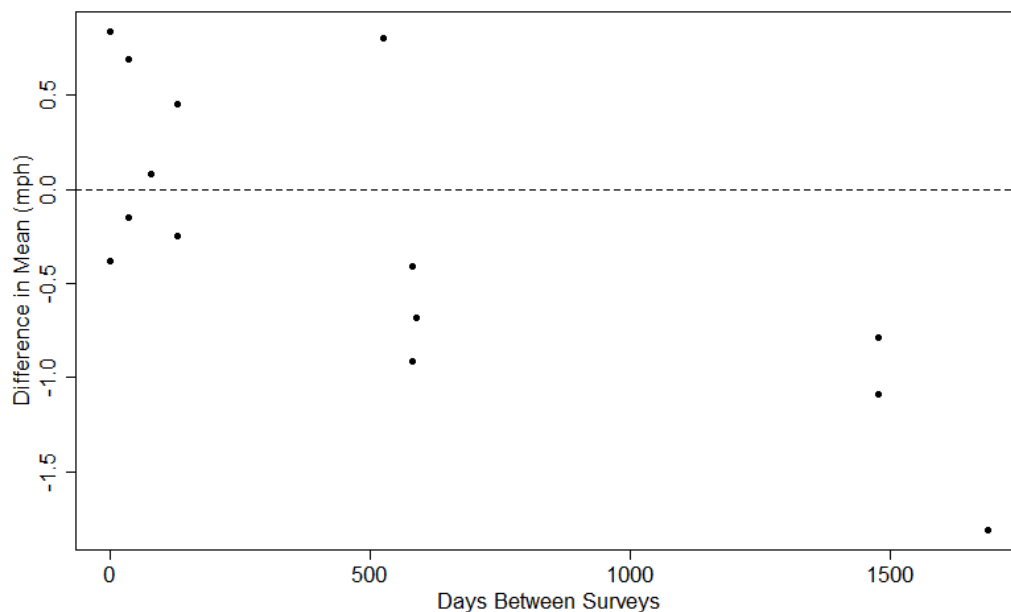


**Figure 4.14: Histogram of the differences in the standard deviation of speed from the 'before' condition to the 'after' condition for the free-flow control pairs (N = 14).**

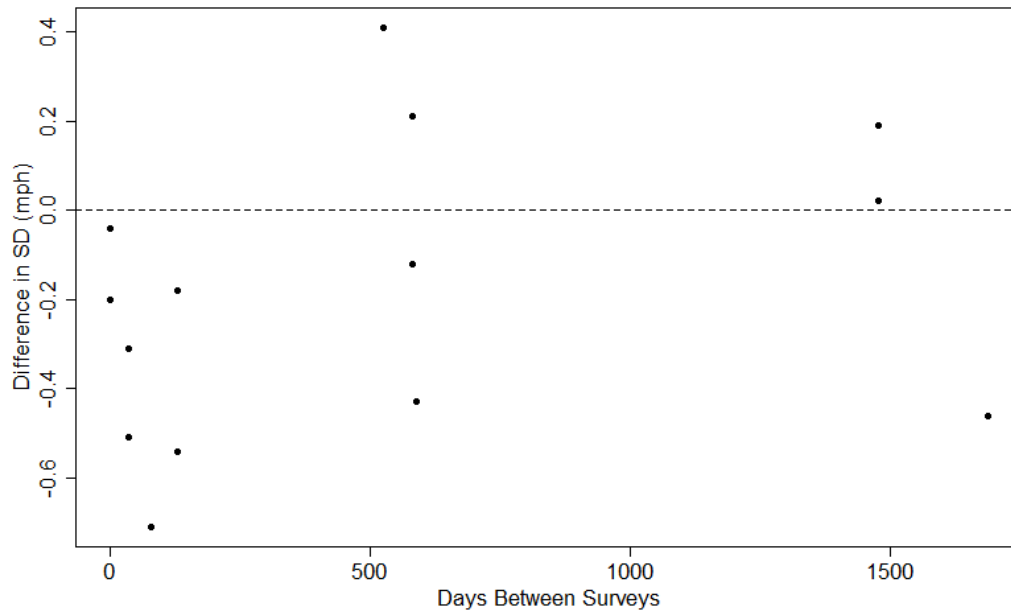
Similar to the scatterplot in Figure 4.7, including all control dataset pairs, the scatterplot in Figure 4.15 shows a negative trend between the change in mean speed and the amount of time

that occurred between repeated surveys. It bears reiterating that there are only 14 data points in the plot of Figure 4.15, 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 4.16. 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 4.16 as it did for the free-flow treatment pairs in Figure 4.14.



**Figure 4.15: Scatterplot of the difference in mean speed vs. the number of days elapsed between surveys for the free-flow control dataset pairs.**



**Figure 4.16: 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 4.7 for control datasets during the ‘before’ period. Similar to the comparisons for treatment datasets shown in Table 4.4, the mean, 85<sup>th</sup> 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 4.8 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, 85<sup>th</sup> percentile, and pace speeds were one to two miles per hour higher for free-flow datasets than when all non-neighborhood observations were included.

**Table 4.7: Comparison of all data and free-flow data from the before period for control datasets.**

<b>Control Datasets Before</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>% Exc. 45 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>2.06</i>	<i>2.00</i>	<i>16.96</i>	<i>13.19</i>	<i>3.81</i>	<i>2.00</i>	<i>-2.58</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.80</i>	<i>2.50</i>	<i>9.17</i>	<i>16.75</i>	<i>6.96</i>	<i>2.00</i>	<i>-4.43</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.46</i>	<i>1.40</i>	<i>6.99</i>	<i>1.68</i>	<i>0.27</i>	<i>1.15</i>	<i>-0.06</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.80</i>	<i>2.40</i>	<i>13.70</i>	<i>13.41</i>	<i>4.70</i>	<i>2.20</i>	<i>-2.65</i>

**Table 4.8: Comparison of all data and free-flow data from the after period for control datasets.**

<b>Control Datasets After</b>								
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>% Exc. 45 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.79</i>	<i>2.00</i>	<i>15.68</i>	<i>12.02</i>	<i>3.02</i>	<i>2.00</i>	<i>-1.88</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>% Exc. 40 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.74</i>	<i>2.50</i>	<i>8.49</i>	<i>18.87</i>	<i>7.34</i>	<i>2.00</i>	<i>-6.94</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>% Exc. 35 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.65</i>	<i>1.75</i>	<i>6.56</i>	<i>1.37</i>	<i>0.24</i>	<i>2.00</i>	<i>0.12</i>
	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. 20 mph</b>	<b>% Exc. 25 mph</b>	<b>% Exc. 30 mph</b>	<b>Pace Min</b>	<b>% in Pace</b>
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
<i>Difference</i>		<i>1.66</i>	<i>2.20</i>	<i>13.04</i>	<i>11.93</i>	<i>3.38</i>	<i>1.40</i>	<i>-3.16</i>

## 4.5 TRENDS IN MOTORIZED VEHICLE VOLUMES

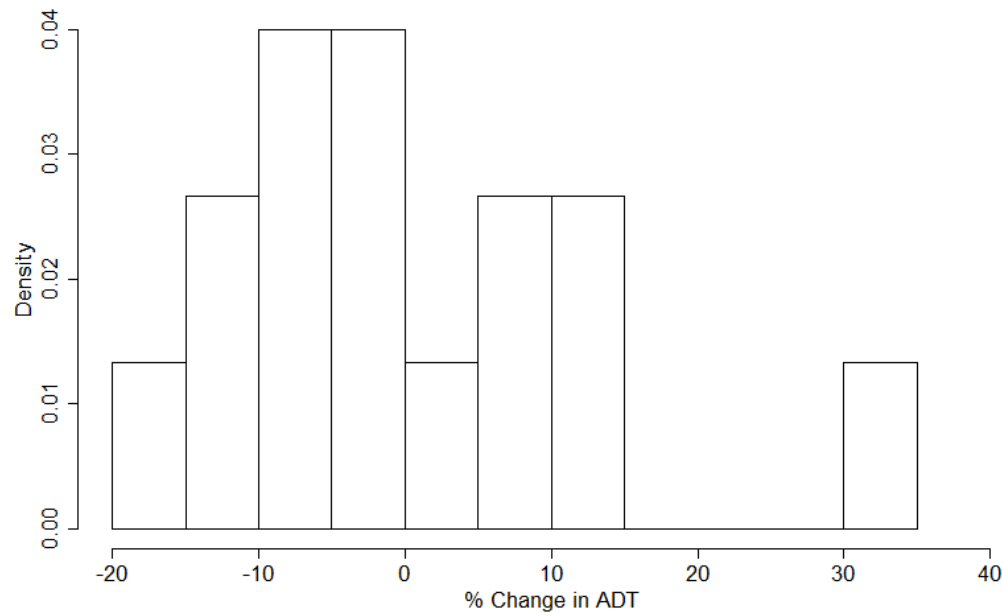
Changes in class two vehicle volumes for each ‘before’ and ‘after’ dataset pair were calculated and compared to changes in regional VMT throughout the time period of the data collection to assess whether traffic diversion was taking place at treatment sites. The change in volume was calculated as the 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 4.9-4.12 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 4.9 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 4.9: Change in class two vehicle volumes for non-neighborhood greenway treatment pairs.**

<b>Site</b>	<b>Before</b>	<b>After</b>	<b>PSL Before</b>	<b>PSL After</b>	<b>ADT Before</b>	<b>ADT After</b>	<b>% Change</b>
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

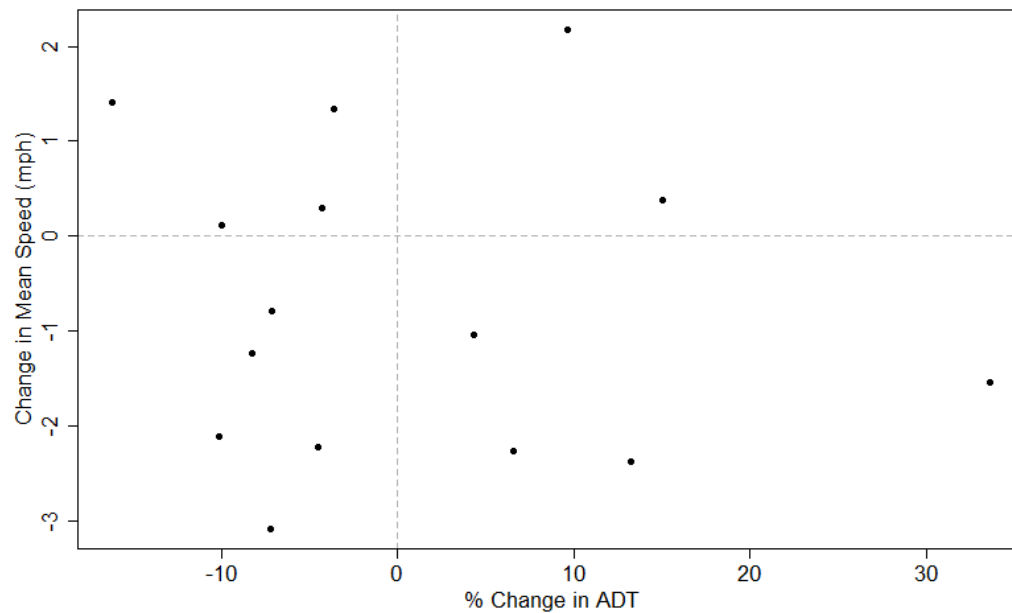
Figure 4.17 provides a visual representation of the changes in ADT occurring between the ‘before’ and ‘after’ conditions in the non-neighborhood treatment pairs. The histogram shows that the ADT decreased in more than half of the dataset pairs.



**Figure 4.17: 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 4.18. 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.





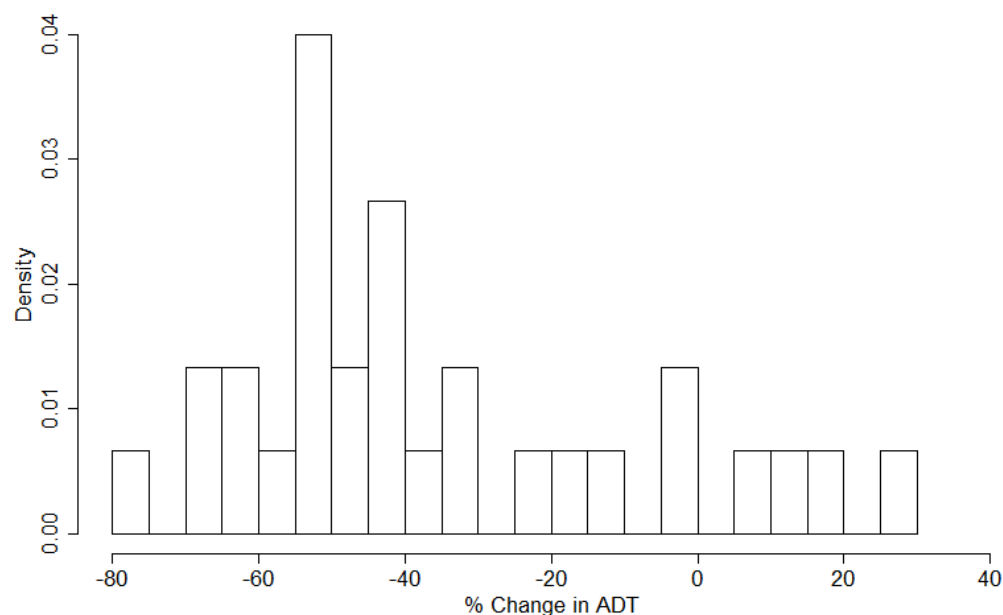
**Figure 4.18: Change in ADT vs. change in mean speed for non-neighborhood greenway treatment pairs.**

For the neighborhood greenway treatment pairs, Table 4.10 and the histogram in Figure 4.19 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 4.10: Change in class two vehicle volumes for neighborhood greenway treatment pairs.**

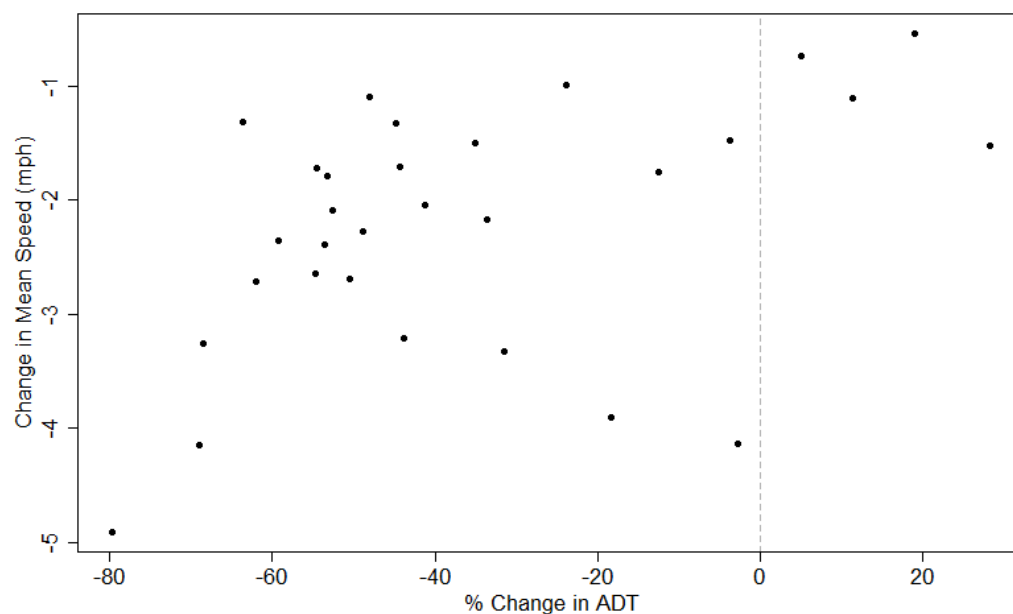
Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Clinton E of 23rd EB	Jul 2015	Apr 2019	25	20	693	385	-44.4
Clinton E of 23rd WB	Jul 2015	Apr 2019	25	20	873	491	-43.7
Clinton E of 23rd EB	May 2016	Apr 2019	25	20	655	385	-41.2
Clinton E of 23rd WB	May 2016	Apr 2019	25	20	716	491	-31.4
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
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 4.19: Histogram of ADT changes for neighborhood greenway treatment pairs.**

The scatterplot of Figure 4.20 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.

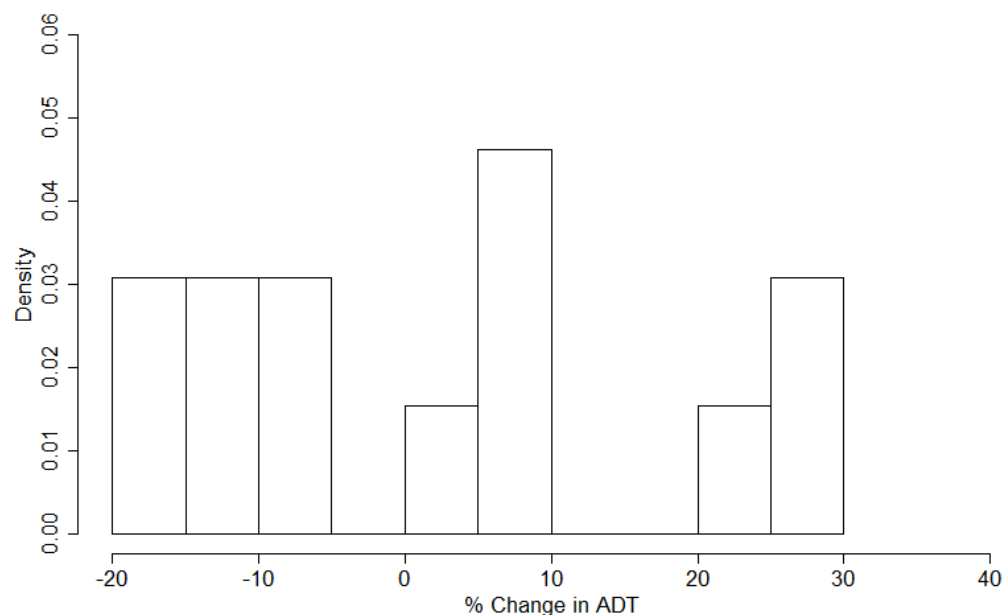


**Figure 4.20: Change in ADT vs. change in mean speed for neighborhood greenway treatment pairs.**

Non-neighborhood greenway control pairs displayed changes in ADT that ranged from a decrease of nearly 17% to an increase of about 28% (Table 4.11). The histogram in Figure 4.21 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%.

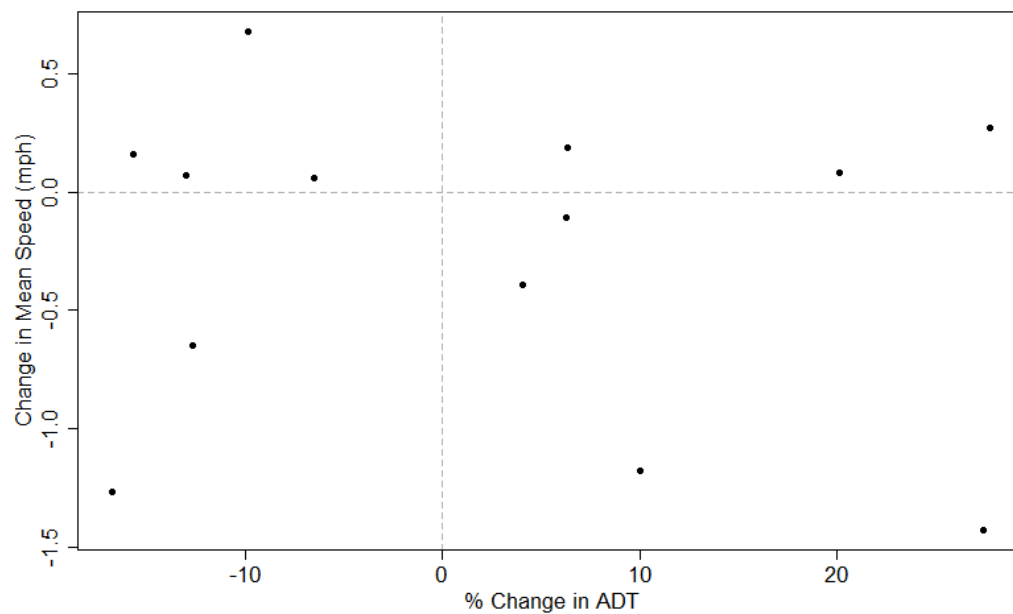
**Table 4.11: Change in class two vehicle volumes for non-neighborhood greenway control pairs.**

<b>Site</b>	<b>Before</b>	<b>After</b>	<b>PSL Before</b>	<b>PSL After</b>	<b>ADT Before</b>	<b>ADT After</b>	<b>% Change</b>
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 4.21: Histogram of ADT changes for non-neighborhood greenway control pairs.**

Similar to the scatterplot in Figure 4.18 for the non-neighborhood greenway treatment pairs, the scatterplot in Figure 4.22 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.



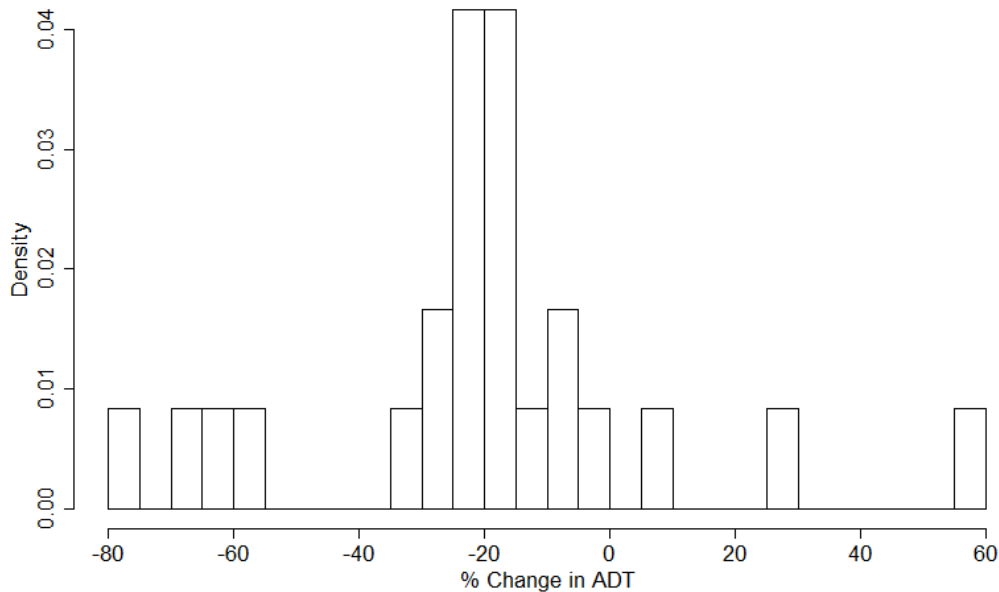
**Figure 4.22: Change in ADT vs. change in mean speed for non-neighborhood greenway control pairs.**

Changes in ADT for neighborhood greenway control pairs, shown in Table 4.12 and the histogram of Figure 4.23, 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 4.12: Change in class two vehicle volumes for neighborhood greenway control pairs.**

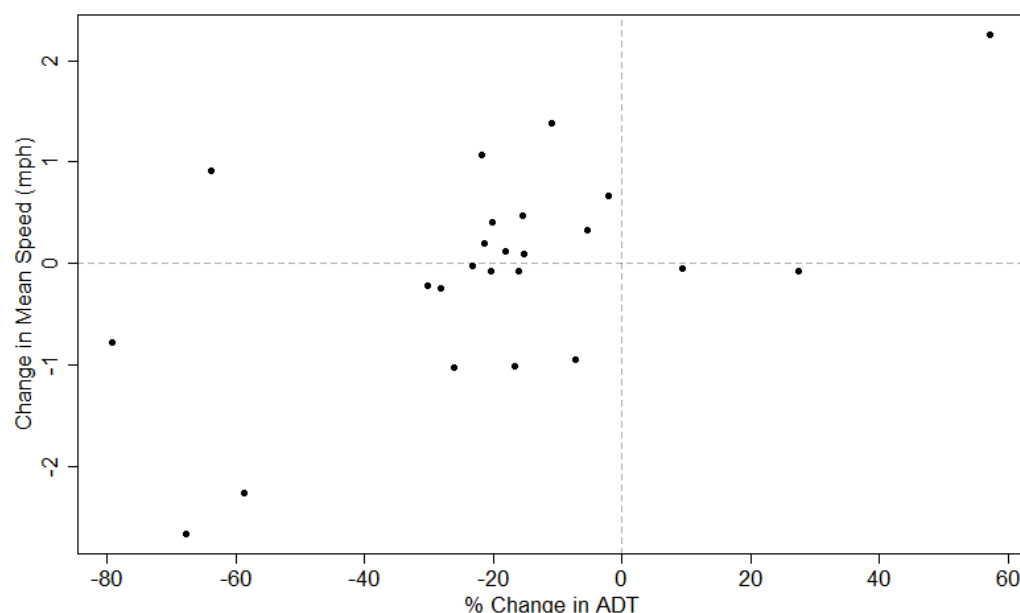
Site	Before	After	PSL Before	PSL After	ADT Before	ADT After	% Change
Clinton E of 17th EB	Aug 2014	Jul 2015	25	25	682	569	-16.5
Clinton E of 17th WB	Aug 2014	Jul 2015	25	25	924	725	-21.4
Clinton E of 23rd EB	Jul 2015	May 2016	25	25	693	655	-5.4
Clinton E of 23rd WB	Jul 2015	May 2016	25	25	873	716	-18.0
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
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 4.23: 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 4.24. 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 4.20).



**Figure 4.24: 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 (Section 2.2).

## 4.6 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 85<sup>th</sup> 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, 85<sup>th</sup> 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.

## 5.0 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 free-flow data.

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 85<sup>th</sup> 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  $\chi^2$  (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 2.1, 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 included the eastbound Holgate east of 111<sup>th</sup> survey performed in June 2019 and the westbound Holgate east of 111<sup>th</sup> survey performed in February 2017. Both datasets contained in excess of 5,000 observations, however, thereby allowing the testing of most hypotheses without violating fundamental prerequisites. Results from these datasets are identified with an asterisk (\*) in the tables within Section 5. The non-normal speed distributions observed at Holgate east of 111<sup>th</sup> are due to the location’s proximity to a traffic signal. Further details regarding this location are discussed in Section 7. Results of the hypothesis testing for all datasets can be found in Appendix B.

### 5.1 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. Similar speed differences between the ‘before’ and ‘after’ periods were also observed at treatment sites analyzed in Section 4.1.

### 5.1.1 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 5.1. 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 5.1: Hypothesis test for equality of mean speeds significant results for treatment dataset pairs.**

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

Facility: NN = non-neighborhood greenway

\*Normal-mixture distribution

From Table 5.1, it can be seen that two of the significant results were from the westbound Alberta east of 28<sup>th</sup> 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 5.1 also shows that two of the significant results were found at the eastbound Division east of 116<sup>th</sup> 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 5.2. 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 50<sup>th</sup> site. Three traffic studies were conducted at this site between 2011 and 2012 and from Table 5.2, it appears as though the mean speed increased with each of these successive surveys.

**Table 5.2: Hypothesis test for equality of mean speeds significant results for control dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\mu_B$	$\mu_A$	$p$ -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

### 5.1.2 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 5.3 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 23<sup>rd</sup> 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 14<sup>th</sup> compared to one ‘before’ survey and decreased in two ‘after’ periods in the westbound direction at the same location.

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

**Table 5.3: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for treatment dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\mu_B$	$\mu_A$	<i>p</i> -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
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 50<sup>th</sup>, 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 50<sup>th</sup> 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 5.4. Both directions at Clinton east of 29<sup>th</sup> experienced reduced mean speeds of more than 1.25 mph. The westbound direction at Fremont east of 48<sup>th</sup>, a two-lane neighborhood collector without bicycle facilities, also showed a decrease in mean speed of more than 1.25 mph.

**Table 5.4: Hypothesis test for decrease of mean speeds by 1.25 mph significant results for control dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\mu_B$	$\mu_A$	$p$ -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

## 5.2 85<sup>TH</sup> PERCENTILE SPEEDS

The 85<sup>th</sup> percentile operating speed has traditionally been used as an important input when setting speed limits, thus, the magnitude or direction of change in the 85<sup>th</sup> percentile speed is of interest to this study. A modified  $t$ -test was used to determine the significance of differences in the 85<sup>th</sup> 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 85<sup>th</sup> percentile speed in the ‘before’ condition is equal to the 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds were higher in the ‘after’ period.

The second null hypothesis tested states that the 85<sup>th</sup> percentile speed in the ‘before’ condition is equal to 1.25 mph greater than the 85<sup>th</sup> percentile speed in the ‘after’ condition,  $H_0: \zeta_{85,B} - \zeta_{85,A} = 1.25$ . The alternative hypothesis states that the 85<sup>th</sup> percentile speed of the ‘before’ condition is more than 1.25 mph greater than the 85<sup>th</sup> 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 85<sup>th</sup> 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.

### 5.2.1 Hypothesis Test for Equality of 85<sup>th</sup> Percentile Speeds

Only two of the 45 treatment pairs (4.4%) showed statistically significant increases in the 85<sup>th</sup> percentile speeds, rejecting the null hypothesis that the ‘before’ and ‘after’ 85<sup>th</sup> percentile speeds were equal. Their results are shown in Table 5.5. Both dataset pairs also rejected the first null hypothesis for mean speeds,  $H_0: \mu_B - \mu_A = 0$  (see Section 5.1.1). For the eastbound Division east of 116<sup>th</sup> site, an increase of one mile per hour was observed, and at the eastbound Holgate east of 111<sup>th</sup> site, the data indicate the 85<sup>th</sup> 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 111<sup>th</sup> was one of two datasets displaying a normal-mixture distribution.



**Table 5.5: Hypothesis test for equality of 85<sup>th</sup> percentile speeds significant results for treatment dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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 85<sup>th</sup> percentile speeds, three of which are designated as neighborhood greenways (Table 5.6). All four of these control pairs also produced significant results for the first null hypothesis for mean speeds (refer to Section 5.1.1). Increases in 85<sup>th</sup> 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 13<sup>th</sup> site between July 2015 and May 2016.

**Table 5.6: Hypothesis test for equality of 85<sup>th</sup> percentile speeds significant results for control dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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

## 5.2.2 Hypothesis Test for Decrease of 85<sup>th</sup> Percentile Speeds by 1.25 mph

The second null hypothesis for 85<sup>th</sup> percentile speeds states that the 85<sup>th</sup> percentile speed ‘before’ is 1.25 mph higher than the 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds in the ‘after’ condition were reduced by more than 1.25 mph. Table 5.7 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 5.1.2). For the 85<sup>th</sup> percentile speeds, all combinations of the three ‘before’ datasets for westbound Lincoln east of 50<sup>th</sup> 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 85<sup>th</sup> percentile speed of more than 1.25 mph were observed include Clinton east of 23<sup>rd</sup>, Clinton west of 14<sup>th</sup>, and westbound Division east of 116<sup>th</sup>.

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

**Table 5.7: Hypothesis test for decrease of 85<sup>th</sup> percentile speeds by 1.25 mph significant results for treatment dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> - 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
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 85<sup>th</sup> percentile speeds, shown in Table 5.8. Statistically significant decreases in mean speed of more than 1.25 mph were also found in three of these control pairs (refer to Section 5.1.2). Decreases in 85<sup>th</sup> percentile speeds of two to three miles per hour were observed.

**Table 5.8: Hypothesis test for decrease of 85<sup>th</sup> percentile speeds by 1.25 mph significant results for control dataset pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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

### 5.3 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 5.9. Of these 21 treatment pairs, ten were collected from non-neighborhood greenways. Thirteen of the treatment pairs in Table 5.9 also displayed significantly reduced mean speeds by more than 1.25 mph, notably at westbound Division east of 116<sup>th</sup> (refer to Section 5.1.2). Four of the treatment pairs found in Table 5.9 – two at westbound Alberta east of 28<sup>th</sup> and two at eastbound Division east of 116<sup>th</sup> – also experienced significantly increased mean speeds (refer to Section 5.1.1).

**Table 5.9: 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 116 <sup>th</sup> 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 =  $\sigma_B^2 / \sigma_A^2$

\*Normal-mixture distribution

Table 5.10 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 111<sup>th</sup>, also experienced a significant increase in mean speed (Section 5.1.1) while the six neighborhood greenway treatment pairs in Table 5.10 were found to have significantly decreased mean speeds in the ‘after’ period (Section 5.1.2).

**Table 5.10: 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 =  $\sigma_B^2 / \sigma_A^2$

\*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 5.11. One of these control pairs (westbound Fremont east of 48<sup>th</sup>) also experienced a significant reduction in mean speed by more than 1.25 mph (see Section 5.1.2). Three pairs – all at westbound Lincoln east of 50<sup>th</sup>, also showed that mean speeds significantly increased from the ‘before’ period to the ‘after’ period (see Section 5.1.1).

**Table 5.11: Control pairs indicating a significant decrease in standard deviation during the ‘after’ period.**

Site	Before	After	SD Before	SD After	Ratio	<i>p</i> -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 =  $\sigma_B^2 / \sigma_A^2$

Table 5.12 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 5.1.1) while one control pair experienced a decrease in mean speed in the ‘after’ period (refer to Section 5.1.2).

**Table 5.12: Control pairs indicating a significant increase in the standard deviation during the ‘after’ period.**

Site	Before	After	SD Before	SD After	Ratio	<i>p</i> -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 =  $\sigma_B^2 / \sigma_A^2$

## 5.4 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 5.13). Four of these pairs were from the

westbound Division east of 116<sup>th</sup> 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 5.13: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 30 mph.**

<b>30 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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 5.14. 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 5.15). 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<sup>th</sup>. In total, 39 of 45 treatment pairs (86.7%) exhibited a 4% to 58% (average 25%) reduction of vehicles exceeding the speed threshold.



**Table 5.14: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 25 mph.**

<b>25 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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 5.15: Treatment pairs with a significant reduction in the proportion of vehicles exceeding 20 mph.**

<b>20 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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
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 116<sup>th</sup> and one at eastbound Holgate east of 111<sup>th</sup>. Increases ranged from 7% to 16%. All three dataset pairs had a 30-mph speed threshold and are displayed in Table 5.16.

**Table 5.16: Treatment pairs with a significant increase in the proportion of vehicles exceeding 30 mph.**

<b>30 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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 5.17 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 33<sup>rd</sup>, a two-lane urban collector without bicycle facilities.

**Table 5.17: Control pairs with a significant decrease in the proportion of vehicles exceeding 25 mph.**

<b>25 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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 5.18 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 5.18: Control pairs with a significant decrease in the proportion of vehicles exceeding 20 mph.**

<b>20 mph Threshold</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>	<b>Facility</b>
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 5.19-5.21 for the 30 mph, 25 mph, and 20 mph thresholds, respectively. Increases of 1% to 8% were observed.

**Table 5.19: Control pair with a significant increase in the proportion of vehicles exceeding 30 mph.**

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

Facility: NN = non-neighborhood greenway

**Table 5.20: 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	<i>p</i> -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 5.21: 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	<i>p</i> -value	Facility
Alberta E of 14th WB	Jul 2019	Nov 2019	0.54	0.62	0.000	NN

Facility: NN = non-neighborhood greenway

## 5.5 SUMMARY OF HYPOTHESIS TESTING FULL DATASETS

A summary of the hypothesis testing results is given in Table 5.22. 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 5.22: Summary of treatment and control dataset pairs producing statistically significant results for the hypothesis tests.**

Hypothesis Test:	Treatment Pairs						Control Pairs					
	G (of 30)		NN (of 15)		Total (of 45)		G (of 24)		NN (of 13)		Total (of 37)	
	N	%	N	%	N	%	N	%	N	%	N	%
<b>H<sub>0</sub>: <math>\mu_B - \mu_A = 0</math> H<sub>A</sub>: <math>\mu_B - \mu_A &lt; 0</math></b>	0	0.0	5	33.3	5	11.1	9	37.5	2	15.4	11	29.7
<b>H<sub>0</sub>: <math>\mu_B - \mu_A = 1.25</math> H<sub>A</sub>: <math>\mu_B - \mu_A &gt; 1.25</math></b>	22	73.3	6	40.0	28	62.2	2	8.3	1	7.7	3	8.1
<b>H<sub>0</sub>: <math>\zeta_{85,B} - \zeta_{85,A} = 0</math> H<sub>A</sub>: <math>\zeta_{85,B} - \zeta_{85,A} &lt; 0</math></b>	0	0.0	2	13.3	2	4.4	3	12.5	1	7.7	4	10.8
<b>H<sub>0</sub>: <math>\zeta_{85,B} - \zeta_{85,A} = 1.25</math> H<sub>A</sub>: <math>\zeta_{85,B} - \zeta_{85,A} &gt; 1.25</math></b>	22	73.3	6	40.0	28	62.2	3	12.5	2	15.4	5	13.5
<b>H<sub>0</sub>: <math>\sigma_B^2 = \sigma_A^2</math> H<sub>A</sub>: <math>\sigma_B^2 &gt; \sigma_A^2</math></b>	11	36.7	10	66.7	21	46.7	6	25.0	6	46.2	12	32.4
<b>H<sub>0</sub>: <math>\sigma_B^2 = \sigma_A^2</math> H<sub>A</sub>: <math>\sigma_B^2 &lt; \sigma_A^2</math></b>	6	20.0	2	13.3	8	17.8	8	33.3	1	7.7	9	24.3
<b>H<sub>0</sub>: <math>P_B - P_A = 0</math> H<sub>A</sub>: <math>P_B - P_A &gt; 0</math></b>	30	100.0	9	60.0	39	86.7	7	29.2	5	38.5	12	32.4
<b>H<sub>0</sub>: <math>P_B - P_A = 0</math> H<sub>A</sub>: <math>P_B - P_A &lt; 0</math></b>	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 5.23 presents the same information shown in Table 5.22 but compares treatment and control results without including the number of sites.

**Table 5.23: 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.
<b>H<sub>0</sub>: <math>\mu_B - \mu_A = 0</math></b> <b>H<sub>A</sub>: <math>\mu_B - \mu_A &lt; 0</math></b>	37.5	0.0	15.4	33.3	29.7	11.1
<b>H<sub>0</sub>: <math>\mu_B - \mu_A = 1.25</math></b> <b>H<sub>A</sub>: <math>\mu_B - \mu_A &gt; 1.25</math></b>	8.3	73.3	7.7	40.0	8.1	62.2
<b>H<sub>0</sub>: <math>\zeta_{85,B} - \zeta_{85,A} = 0</math></b> <b>H<sub>A</sub>: <math>\zeta_{85,B} - \zeta_{85,A} &lt; 0</math></b>	12.5	0.0	7.7	13.3	10.8	4.4
<b>H<sub>0</sub>: <math>\zeta_{85,B} - \zeta_{85,A} = 1.25</math></b> <b>H<sub>A</sub>: <math>\zeta_{85,B} - \zeta_{85,A} &gt; 1.25</math></b>	12.5	73.3	15.4	40.0	13.5	62.2
<b>H<sub>0</sub>: <math>\sigma_B^2 = \sigma_A^2</math></b> <b>H<sub>A</sub>: <math>\sigma_B^2 &gt; \sigma_A^2</math></b>	25.0	36.7	46.2	66.7	32.4	46.7
<b>H<sub>0</sub>: <math>\sigma_B^2 = \sigma_A^2</math></b> <b>H<sub>A</sub>: <math>\sigma_B^2 &lt; \sigma_A^2</math></b>	33.3	20.0	7.7	13.3	24.3	17.8
<b>H<sub>0</sub>: <math>P_B - P_A = 0</math></b> <b>H<sub>A</sub>: <math>P_B - P_A &gt; 0</math></b>	29.2	100.0	38.5	60.0	32.4	86.7
<b>H<sub>0</sub>: <math>P_B - P_A = 0</math></b> <b>H<sub>A</sub>: <math>P_B - P_A &lt; 0</math></b>	20.8	0.0	15.4	20.0	18.9	6.7

Cont. = control group, Treat. = treatment group

The results of the hypothesis tests for mean speed are generally in agreement with those for the 85<sup>th</sup> percentile speed across the treatment and control dataset pairs. More than 62% of the 45 treatment pairs showed statistically significant reductions in mean and 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds, respectively. Furthermore, the number of dataset pairs exhibiting any increase in mean or 85<sup>th</sup> percentile speeds was lower for the treatment group than the control 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 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds (nine of eleven pairs for mean speed and three of four pairs for the 85<sup>th</sup> 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<sup>th</sup> 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.



## 6.0 HYPOTHESIS TESTING (FREE-FLOW DATA)

The analysis in Section 3 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. This section presents a second set of hypothesis tests focusing on these treatment and control pairs. Datasets were limited to observations with gap times greater than or equal to the mean gap time for the dataset to ensure free-flow conditions. A total of 13 treatment and 14 control pairs were tested.

As in Section 5, when all datasets with all class two observations were included, mean and 85<sup>th</sup> 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. As in Section 5, all differences are calculated as ‘before’ minus ‘after’.

### 6.1 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.

#### 6.1.1 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 6.1. All three treatment pairs also produced significant results when all observations were considered in Section 5.1.1. Mean speeds at westbound Alberta east of 28<sup>th</sup> and eastbound Division east of 116<sup>th</sup> 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 6.2. The westbound Alberta east of 14<sup>th</sup> and westbound Division east of 116<sup>th</sup> dataset pairs also rejected

the null hypothesis when all observations were included (Section 5.1.1). The other two control pairs were located at westbound Alberta east of 28<sup>th</sup> and involved the same ‘before’ dataset as in the treatment pair in Table 6.1. Increases in mean speeds for the control pairs were less than one mile per hour.

**Table 6.1: Hypothesis test for equality of mean speeds significant results for free-flow treatment pairs.**

Site	Before	After	PSL Before	PSL After	$\mu_B$	$\mu_A$	<i>p</i> -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 6.2: Hypothesis test for equality of mean speeds significant results for free-flow control pairs.**

Site	Before	After	PSL Before	PSL After	$\mu_B$	$\mu_A$	<i>p</i> -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

### 6.1.2 Hypothesis Test for Decrease of Mean Speeds by 1.25 mph

For the second null hypothesis for mean speeds ( $H_0: \mu_B - \mu_A = 1.25$ ;  $H_A: \mu_B - \mu_A > 1.25$ ), 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 6.3 and 6.4, 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 in Section 5.1.2.

**Table 6.3: 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	$\mu_B$	$\mu_A$	$p$ -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 6.4: 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	$\mu_B$	$\mu_A$	$p$ -value
Fremont E of 48th WB	Dec 2014	Jul 2019	20	20	25.21	23.40	0.000

## 6.2 85<sup>TH</sup> PERCENTILE SPEEDS

The modified  $t$ -tests from Section 5.2 were also used to compare 85<sup>th</sup> percentile speeds for the free-flow dataset pairs. The first null hypothesis says that the 85<sup>th</sup> percentile speed in the ‘before’ condition is equal to the 85<sup>th</sup> percentile speed of the ‘after’ condition,  $H_0: \zeta_{85,B} - \zeta_{85,A} = 0$ . The alternative hypothesis is that the difference in the 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds increased in the ‘after’ period.

The second null hypothesis tested states that the difference in 85<sup>th</sup> 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 85<sup>th</sup> 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 85<sup>th</sup> percentile speeds decreased by more than one-quarter of the amount of the PSL reduction for treatment pairs.

### 6.2.1 Hypothesis Test for Equality of 85<sup>th</sup> Percentile Speeds

One of the free-flow treatment pairs (7.7%), at eastbound Division east of 116<sup>th</sup>, displayed a significant increase of one mile per hour in the 85<sup>th</sup> percentile speed (Table 6.5). This dataset pair also displayed a significant increase when all observations were included (refer to Section 5.2.1).

**Table 6.5: Hypothesis test for equality of 85<sup>th</sup> percentile speeds significant result for free-flow treatment pairs.**

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

Table 6.6 exhibits the three free-flow control pairs (of 14, or 21.4%) that reject the first null hypothesis for 85<sup>th</sup> percentile speeds. The 85<sup>th</sup> percentile speeds increased by one mile per hour in all three control pairs.

**Table 6.6: Hypothesis test for equality of 85<sup>th</sup> percentile speeds significant result for free-flow control pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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

### 6.2.2 Hypothesis Test for Decrease of 85<sup>th</sup> Percentile Speeds by 1.25 mph

Six of the 13 free-flow treatment pairs (46.2%) rejected the second null hypothesis for 85<sup>th</sup> percentile speeds,  $H_0: \zeta_{85,B} - \zeta_{85,A} = 1.25$ , and can be seen in Table 6.7. 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 85<sup>th</sup> percentile speeds when all observations were analyzed in Section 5.2.2.

**Table 6.7: Hypothesis test for decrease of 85<sup>th</sup> percentile speeds by 1.25 mph significant result for free-flow treatment pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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 85<sup>th</sup> percentile speeds, seen in Table 6.8. Speeds appear to have decreased two to three miles per hour between subsequent surveys. The westbound Fremont east of 48<sup>th</sup> dataset pair also produced significant results when all gap times were included in Section 5.2.2.

**Table 6.8: Hypothesis test for decrease of 85<sup>th</sup> percentile speeds by 1.25 mph significant result for free-flow control pairs.**

Site	Before	After	PSL Before	PSL After	$\zeta_{85,B}$	$\zeta_{85,A}$	<i>p</i> -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

### 6.3 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,  $\sigma$ ) decreased significantly between subsequent traffic surveys for 10 of the 13 treatment pairs (76.9%), shown in Table 6.9. Three of these six treatment pairs also had significantly increased mean speeds

when observations were limited to larger gap times (refer to Section 6.1.1), while five pairs experienced significantly reduced mean speeds (refer to Section 6.1.2). Nine of the ten free-flow treatment pairs in Table 6.9 also resulted in a rejection of the null hypothesis for variance when all observations were included in Section 5.3.

**Table 6.9: Free-flow treatment pairs indicating a significant reduction in the standard deviation.**

Site	Before	After	SD Before	SD After	Ratio	<i>p</i> -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

$$\text{Ratio} = \sigma_B^2 / \sigma_A^2$$

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 6.10: Free-flow treatment pairs with significant increases in the standard deviation.**

Site	Before	After	SD Before	SD After	Ratio	<i>p</i> -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

$$\text{Ratio} = \sigma_B^2 / \sigma_A^2$$

Table 6.11 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 6.1.1), and one control pair experienced a decrease in mean speed of more than 1.25 mph (refer to Section 6.1.2). All control pairs in Table 6.11 also produced significant results for the F-tests in Section 5.3 when all observations were analyzed.

**Table 6.11: 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

$$\text{Ratio} = \sigma_B^2 / \sigma_A^2$$

The standard deviation was significantly greater in the ‘after’ period for two of the 14 free-flow control pairs (14.3%). Table 6.12 displays their results. The westbound Division east of 116<sup>th</sup> control pair also experienced significant increases in mean and 85<sup>th</sup> percentile speeds (refer to Sections 6.1.1 and 6.2.1).

**Table 6.12: 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

$$\text{Ratio} = \sigma_B^2 / \sigma_A^2$$

## 6.4 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  $p < 0.05$ . As before in Section 5.4, 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 6.31 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 6.13 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 (refer to Section 5.4).

**Table 6.13: Free-flow treatment pairs that reject the null hypothesis for the proportions test.**

<b>Decrease</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Threshold</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>
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
<b>Increase</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Threshold</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>
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 6.14. All control pairs in Table 6.14 also had significant reductions in the proportion of vehicles exceeding the speed threshold when all observations were included (refer to Section 5.4).



**Table 6.14: Free-flow control datasets that reject the null hypothesis for the proportions test.**

<b>Decrease</b>						
<b>Site</b>	<b>Before</b>	<b>After</b>	<b>Threshold</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b><i>p</i>-value</b>
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

## 6.5 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.

Table 6.15 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. However, if just the results for the non-neighborhood greenway pairs for the treatment and control groups from Section 5 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<sup>th</sup> 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.

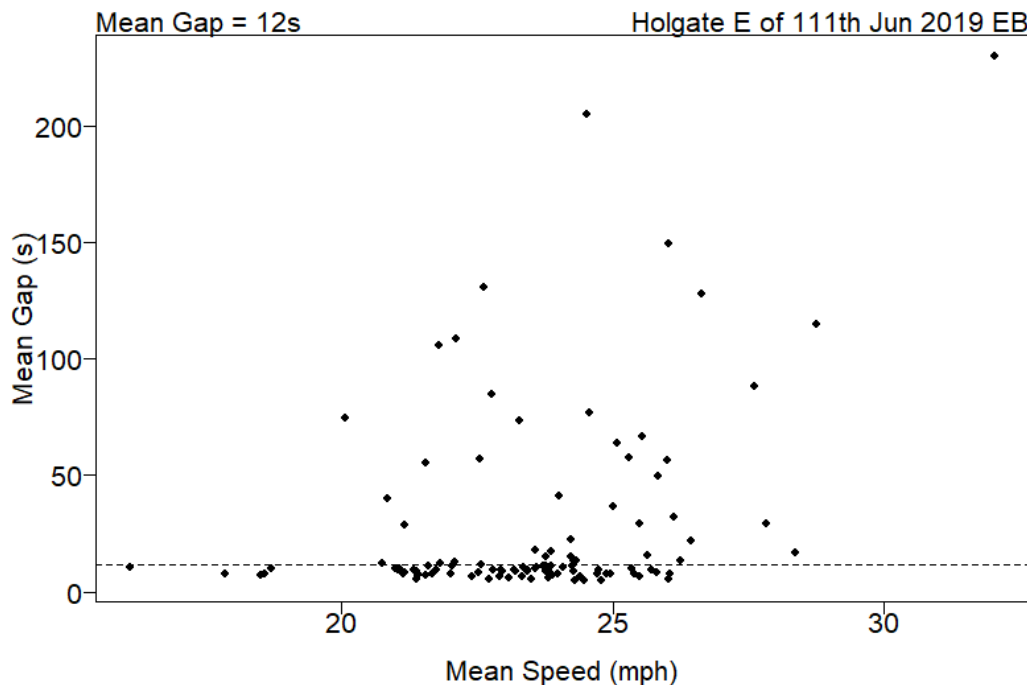
**Table 6.15: Summary of free-flow dataset pairs producing significant results for the hypothesis tests.**

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

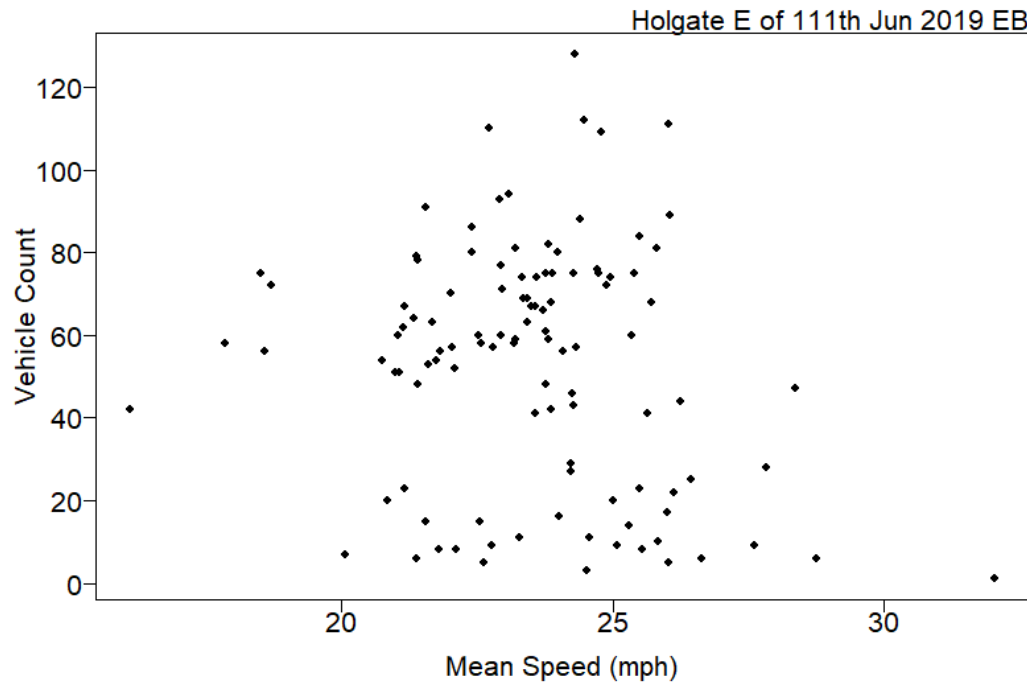
N = number of dataset pairs, % = percent of dataset pairs

## 7.0 DATA COLLECTION RECOMMENDATIONS

One of the interesting discoveries made during the data analysis was that two of the datasets from the Holgate east of 111<sup>th</sup> 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 Section 3.2, neither direction of the June 2019 survey at Holgate east of 111<sup>th</sup> followed the trends observed at other non-neighborhood greenway sites where speeds seemed to be affected by gap times and vehicle volumes. Figures 7.1 and 7.2 show the mean speed versus mean gap and mean speed versus vehicle count for the eastbound direction of the June 2019 Holgate east of 111<sup>th</sup> survey. Compared to the plots provided in Section 3.2, these more closely resemble the plots from the neighborhood greenway sites.

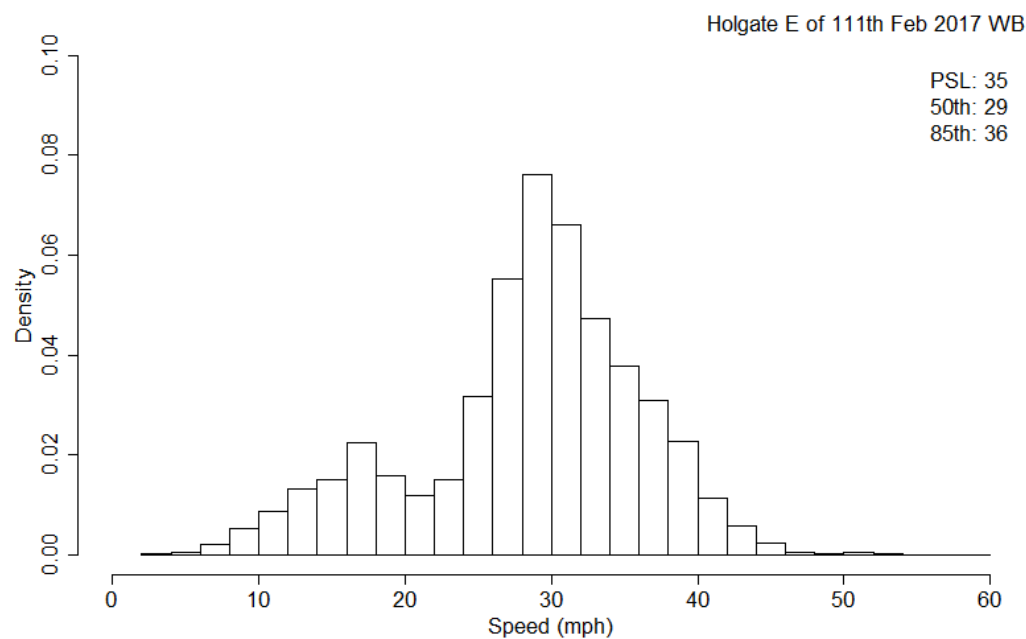


**Figure 7.1: Mean speed vs. mean gap for eastbound Holgate east of 111th with data binned in 15-minute intervals.**

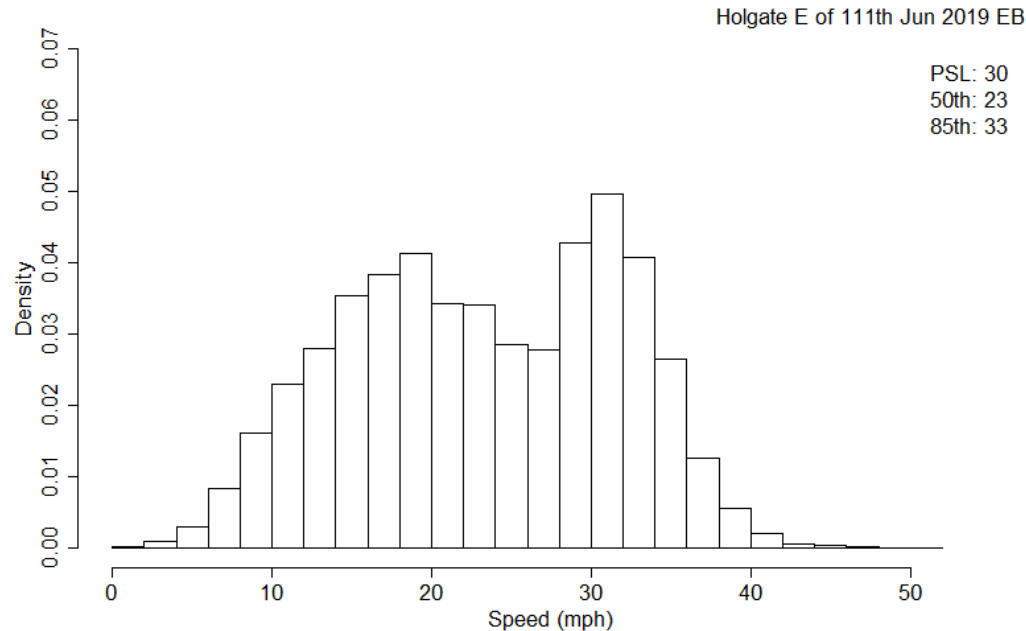


**Figure 7.2: Mean speed vs. vehicle count for eastbound Holgate east of 111th with data binned in 15-minute intervals.**

In addition to the deviation from the correlation patterns found at other non-neighborhood sites, two datasets from the Holgate east of 111<sup>th</sup> 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 7.3 and 7.4. The posted speed limit (PSL) and the 50<sup>th</sup> and 85<sup>th</sup> percentiles for the entire dataset are shown in the figures. It is evident that the 50<sup>th</sup> and 85<sup>th</sup> percentiles would be much higher for the eastbound dataset if only the group of observations on the right were considered. The 50<sup>th</sup> percentile of the right-hand group of observations in Figure 7.4 is estimated by visual inspection to be about 32 mph, significantly higher than the value of 23 mph calculated for the whole dataset.



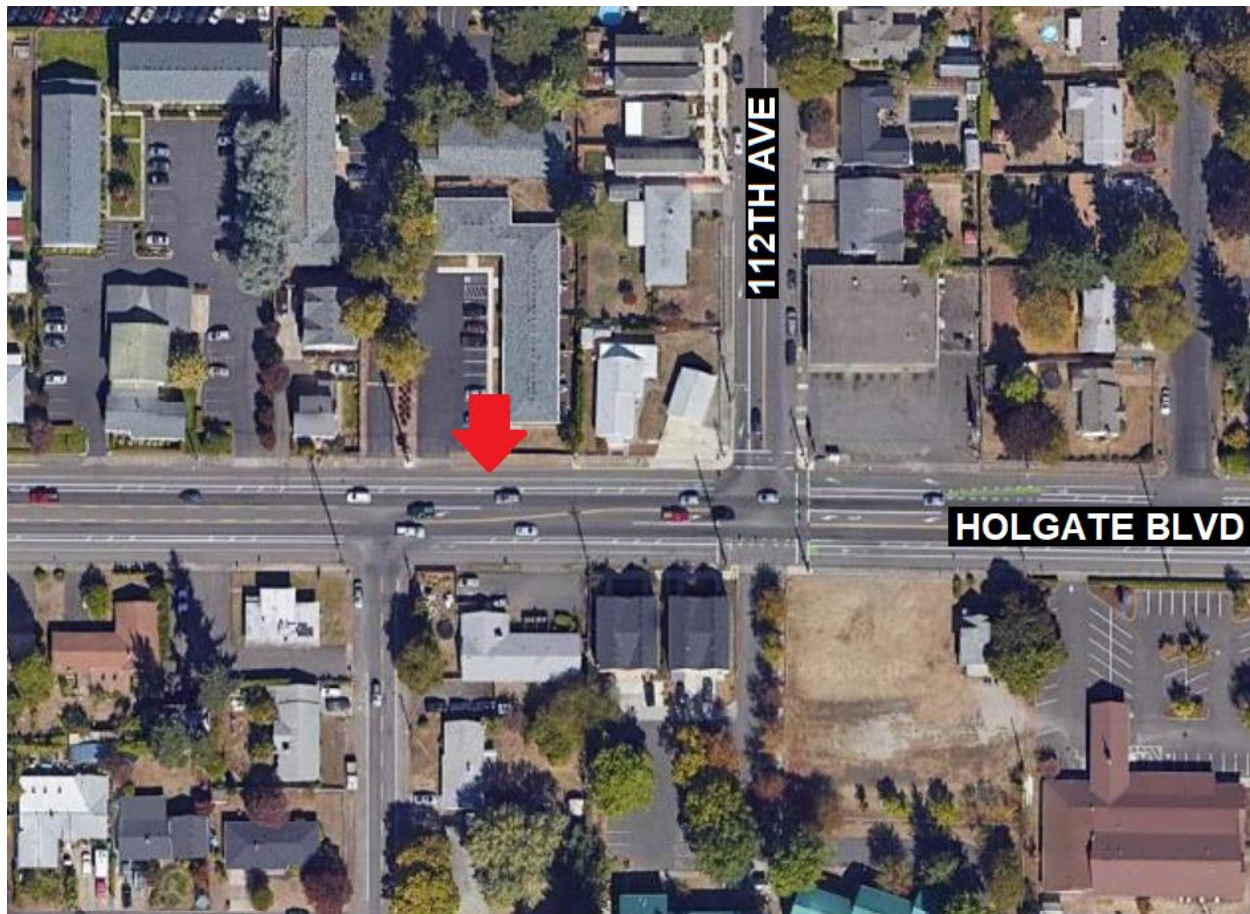
**Figure 7.3: Class two speed histogram for the February 2017 westbound Holgate east of 111th dataset.**



**Figure 7.4: 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 112<sup>th</sup> (250 ft. east) and a high volume of traffic turning from 112<sup>th</sup> affects vehicle speeds at the Holgate east of 111<sup>th</sup> location.

An overview of the area is provided in Figure 7.5, with a red arrow indicating the approximate location of the data collection. The smaller group on the left in the histogram of Figure 7.3 may be representing vehicles that were accelerating from the signal or had made a right turn onto Holgate from 112<sup>th</sup> 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 7.4 likely captured vehicles slowing for the signal or for left turns at 112<sup>th</sup>. The groups on the right of Figures 7.3 and 7.4 are expected to be more representative of the uninhibited free-flow speeds at this location.



**Figure 7.5: Location of data collection at Holgate east of 111th. (Google Maps, 2020)**

The speed characteristics at Holgate east of 111<sup>th</sup> 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).

Data collected along Holgate at nearby locations further from the traffic signal at 112<sup>th</sup> show higher mean and 85<sup>th</sup> percentile speeds than those from data collected at 111<sup>th</sup>. Mean speeds on Holgate east of 113<sup>th</sup> are approximately 33 mph and 85<sup>th</sup> percentile speeds are 37 mph. Data from Holgate east of 116<sup>th</sup> also provide evidence of higher speeds as the distance from the traffic signal increases. Mean speeds at 116<sup>th</sup> are approximately 33 mph to 35 mph and 85<sup>th</sup> percentile speeds are 37 mph to 39 mph. These speeds are generally much higher than mean and 85<sup>th</sup> percentile speeds for data collected east of 111<sup>th</sup> (refer to Table 2.3). The effect of right-turning

traffic from 112<sup>th</sup> is also apparent by looking at the ADT for westbound traffic at 111<sup>th</sup> and 113<sup>th</sup>. Data at these locations were collected concurrently in June 2019. The westbound ADT increased by about 1,000 vehicles, from 7,978 at 113<sup>th</sup> to 8,994 at 111<sup>th</sup>.

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 85<sup>th</sup> percentile speeds and the percent of vehicles exceeding the PSL were examined. These results are shown in Table 7.1, 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 85<sup>th</sup> 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 7.1: Basic speed statistics for sites within 500 ft. of a traffic control device compared to a nearby location on the segment.**

<b>Sites</b>	<b>PSL</b>	<b>Mean</b>	<b>85th</b>	<b>% Exc. PSL</b>	<b>Distance (ft.)</b>
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
<i>Difference</i>		<i>2.13</i>	<i>2</i>	<i>11.04</i>	
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
<i>Difference</i>		<i>4.32</i>	<i>4</i>	<i>53.71</i>	
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
<i>Difference</i>		<i>3.93</i>	<i>4</i>	<i>48.94</i>	
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
<i>Difference</i>		<i>4.76</i>	<i>6</i>	<i>21.17</i>	
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
<i>Difference</i>		<i>4.45</i>	<i>5</i>	<i>24.38</i>	
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
<i>Difference</i>		<i>1.10</i>	<i>3</i>	<i>15.99</i>	
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
<i>Difference</i>		<i>5.53</i>	<i>6</i>	<i>41.07</i>	
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
<i>Difference</i>		<i>11.32</i>	<i>6</i>	<i>61.02</i>	
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
<i>Difference</i>		<i>6.28</i>	<i>5</i>	<i>53.65</i>	

Distance = distance to the nearest traffic control device



## 8.0 SUMMARY AND DISCUSSION

This task 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.

### 8.1 SUMMARY

A high percentage of cyclists, more than 20% of traffic, is present on shared used 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 85<sup>th</sup> 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 correlations between mean speed and mean gap time and negative correlations 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 correlation patterns were absent in nearly all of the neighborhood greenway datasets. This discovery guided the decision to perform separate analyses on datasets displaying the correlation 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, 85<sup>th</sup> 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 Section 3 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 85<sup>th</sup> 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 85<sup>th</sup> 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 85<sup>th</sup> 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 85<sup>th</sup> 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.

## **8.2 DISCUSSION**

In terms of data collection, it is recommended that data collected to analyze speed characteristics is not obtained from locations near traffic control devices. 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 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.

Based on the results observed, 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.

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 85<sup>th</sup> 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 85<sup>th</sup> 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 85<sup>th</sup> speed distributions of at least 1.25 mph. The different performance of

neighborhood greenways may be linked to factors such as percentage of cyclists, initial PSL value, or motorized ADT values as detailed in Section 2.

PSL reductions of 5 mph are likely to reduce speed characteristics such as mean or 85<sup>th</sup> 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<sup>th</sup> 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, 85<sup>th</sup> 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 85<sup>th</sup> 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.

## 9.0 REFERENCES

- Altman, D. G., & Bland, J. M. (1995). Statistics notes: the normal distribution. *Bmj*, 310(6975), 298.
- Bassani, M., Catani, L., Cirillo, C., & Mutani, G. (2016). Night-time and daytime operating speed distribution in urban arterials. *Transportation Research Part F*, 42, 56-69.
- Bassani, M., Dalmazzo, D., Marinelli, G., & Cirillo, C. (2014). The effects of road geometrics and traffic regulations on driver-preferred speeds in northern Italy. An exploratory analysis. *Transportation Research Part F*, 25, 10-26.
- City of Portland. (2016). *Vision Zero Action Plan*. Portland, OR: City of Portland – Bureau of Transportation.
- City of Portland. (2019). *Portland Bicycle Plan for 2030, 2019 Progress Report* [draft]. Portland, OR: City of Portland – Bureau of Transportation.
- City of Portland. (2020a). *Portland 2035 Transportation System Plan*. Portland, OR: City of Portland – Bureau of Transportation.
- City of Portland. (2020b). *What is a Neighborhood Greenway?* [online] Available at: <https://www.portlandoregon.gov/transportation/article/348902> [Accessed 22 Apr. 2020].
- Dinh, D. D. & Kubota, H. (2013). Profile-speed data-based models to estimate operating speeds for urban residential street with a 30km/h speed limit, *IATSS Research*, 36, 115-122.
- Elvik, R. (2012). Speed limits, enforcement, and health consequences. *Annual review of public health*, 33, 225-238.
- FHWA. (2016). *Traffic Monitoring Guide*. Washington DC, US Department of Transportation, p. C-1.
- Fitzpatrick, K., Carlson, P., Brewer, M., & Wooldridge, M. (2001). Design factors that affect driver speed on suburban streets. (Paper No. 01-2163). *Transportation Research Record*, 1751.
- Forbes, G. J., Gardner, T., McGee, H., & Srinivasan, R. (2012). *Methods and Practices for Setting Speed Limits: An Informational Report*. (Report No. FHWA-SA-12-004). Washington, DC: U.S. Department of Transportation.
- Gargoum, S. A. & El-Basyouny, K. (2016). Exploring the association between speed and safety: A path analysis approach. *Accident Analysis & Prevention*, 93, 32-40.

Gargoum, S. A., El-Basyouny, K., & Kim, A. (2016). Towards setting credible speed limits: Identifying factors that affect driver compliance on urban roads. (2016). *Accident Analysis & Prevention*, 95, 138-148.

Google Maps. (2019). *Google Street View, 3226 SE Division St.* [online] Available at: <https://goo.gl/maps/fh9zFCGPZ2eXTPcN8> [Accessed 15 Apr. 2020].

Google Maps. (2020). *SE Holgate Blvd. and SE 111<sup>th</sup> Ave.* [online] Available at: <https://www.google.com/maps/place/SE+Holgate+Blvd+%26+SE+111th+Ave,+Portland,+OR+97266/@45.4898629,-122.5482167,242m/data=!3m1!1e3!4m5!3m4!1s0x5495a1d387dd38b7:0xeea1ea83b068832f!8m2!3d45.4897595!4d-122.5490455> [Accessed 6 Jun. 2020].

Hou, Y., Sun, C., & Edara, P. (2012). Statistical test for 85th and 15th percentile speeds with asymptotic distribution of sample quantiles. *Transportation Research Record*, 2279(1), 47-53.

Hummer, J. E., Rouphail, N. M., Toole, J. L., Patten, R. S., Schneider, R. J., Green, J. S., ... & Fain, S. J. (2006). *Evaluation of safety, design, and operation of shared-use paths—Final report* (No. FHWA-HRT-05-137).

*Interactive map: Portland-area density.* The Oregonian (2020). [online] Available at: <https://projects.oregonlive.com/maps/density/> [Accessed 21 Apr. 2020].

Islam, M. T., El-Basyouny, K., & Ibrahim, S. E. (2014). The impact of lowered residential speed limits on vehicle speed behavior. *Safety Science*, 62, 483-494.

Oregon Department of Transportation. (2020). *Data and Maps: Traffic Counting.* [online] Available at: <https://www.oregon.gov/odot/Data/Pages/Traffic-Counting.aspx>

Oregon Department of Transportation Traffic-Roadway Section. (2014). *Speed Zone Manual.* Salem, OR: Oregon Department of Transportation.

Organisation for Economic Co-operation and Development. (2006). *Speed Management.* Paris, France: European Conference of Ministers of Transport.

Schrank, D., Eisele, B., & Lomax, T. (2019). *2019 Urban Mobility Report.* [online]. Available: <https://mobility.tamu.edu/umr/report/>

Tapp, A., Nancarrow, C., & Davis, A. (2015). Support and compliance with 20mph speed limits in Great Britain. *Transportation Research Part F*, 31, 36-53.

Tapp, A., Nancarrow, C., Davis, A., & Jones, S. (2016). Vicious or virtuous circles? Exploring the vulnerability of drivers to break low urban speed limits. *Transportation Research Part A*, 91, 195-212.

Toy, S., Tapp, A., Musselwhite, C., & Davis, A. (2014). Can social marketing make 20mph the new norm? *Journal of Transport & Health, 1*, 165-173.

## 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
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
<i>Harrison E of 25th WB</i>	<i>Feb 2017</i>	<i>Apr 2019</i>	<i>447</i>	<i>9</i>	<i>19.12</i>	<i>19.00</i>	<i>3.36</i>	<i>6.68</i>	<i>23</i>	<i>24.8</i>	<i>35.45</i>	<i>41.18</i>	<i>1.64</i>	<i>17.65</i>	<i>0.00</i>	<i>5.88</i>
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
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
<i>Lincoln W of 41st EB</i>	<i>Nov 2012</i>	<i>Jan 2017</i>	<i>13</i>	<i>16</i>	<i>17.75</i>	<i>19.38</i>	<i>5.59</i>	<i>3.67</i>	<i>24.35</i>	<i>23.25</i>	<i>25.00</i>	<i>31.25</i>	<i>8.33</i>	<i>6.25</i>	<i>0.00</i>	<i>0.00</i>
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
<i>Division E of 33rd EB</i>	<i>Jul 2015</i>	<i>Jul 2019</i>	<i>4127</i>	<i>3922</i>	<i>19.30</i>	<i>17.30</i>	<i>5.34</i>	<i>5.05</i>	<i>25</i>	<i>22</i>	<i>10.96</i>	<i>5.38</i>	<i>1.78</i>	<i>0.70</i>	<i>0.22</i>	<i>0.09</i>
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
<i>Division E of 33rd EB</i>	<i>Jul 2019</i>	<i>Jul 2019 b</i>	<i>3922</i>	<i>3603</i>	<i>17.30</i>	<i>18.65</i>	<i>5.05</i>	<i>5.21</i>	<i>22</i>	<i>24</i>	<i>5.38</i>	<i>9.12</i>	<i>0.70</i>	<i>1.49</i>	<i>0.09</i>	<i>0.14</i>

*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
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
<i>Lincoln E of 30th EB</i>	<i>Feb 2019</i>	<i>Apr 2019</i>	<i>13</i>	<i>16</i>	<i>23.66</i>	<i>17.76</i>	<i>9.75</i>	<i>4.51</i>	<i>33.8</i>	<i>21.6</i>	<i>57.14</i>	<i>29.41</i>	<i>34.29</i>	<i>0.00</i>	<i>20.00</i>	<i>0.00</i>
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
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
<i>Harrison E of 25th WB</i>	<i>Feb 2017</i>	<i>Apr 2019</i>	<i>447</i>	<i>9</i>	<i>19.12</i>	<i>19.00</i>	<i>3.36</i>	<i>6.68</i>	<i>23</i>	<i>24.8</i>	<i>35.45</i>	<i>41.18</i>	<i>15</i>	<i>14</i>	<i>89.20</i>	<i>64.71</i>
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
<i>Lincoln W of 41st EB</i>	<i>Nov 2012</i>	<i>Jan 2017</i>	<i>13</i>	<i>16</i>	<i>17.75</i>	<i>19.38</i>	<i>5.59</i>	<i>3.67</i>	<i>24.35</i>	<i>23.25</i>	<i>25.00</i>	<i>31.25</i>	<i>13</i>	<i>17</i>	<i>66.67</i>	<i>87.50</i>
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
<i>Division E of 33rd EB</i>	<i>Jul 2015</i>	<i>Jul 2019</i>	<i>4127</i>	<i>3922</i>	<i>19.30</i>	<i>17.30</i>	<i>5.34</i>	<i>5.05</i>	<i>25</i>	<i>22</i>	<i>10.96</i>	<i>5.38</i>	<i>15</i>	<i>12</i>	<i>66.13</i>	<i>68.36</i>
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
<i>Division E of 33rd EB</i>	<i>Jul 2019</i>	<i>Jul 2019 b</i>	<i>3922</i>	<i>3603</i>	<i>17.30</i>	<i>18.65</i>	<i>5.05</i>	<i>5.21</i>	<i>22</i>	<i>24</i>	<i>5.38</i>	<i>9.12</i>	<i>12</i>	<i>14</i>	<i>68.36</i>	<i>67.14</i>

*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
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
<i>Lincoln E of 30th EB</i>	<i>Feb 2019</i>	<i>Apr 2019</i>	<i>13</i>	<i>16</i>	<i>23.66</i>	<i>17.76</i>	<i>9.75</i>	<i>4.51</i>	<i>33.8</i>	<i>21.6</i>	<i>57.14</i>	<i>29.41</i>	<i>16</i>	<i>16</i>	<i>73.98</i>	<i>90.82</i>
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:

$\mu$  = mean speed

$\zeta_{85}$  = 85<sup>th</sup> 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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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.**

<b>Site</b>	<b>Before</b>	<b>After</b>	<b><math>\mu_B</math></b>	<b><math>\mu_A</math></b>	<b><math>\zeta_{85,B}</math></b>	<b><math>\zeta_{85,A}</math></b>	<b>SD Before</b>	<b>SD After</b>	<b>Prop. Exc. Before</b>	<b>Prop. Exc. After</b>	<b>p-val. Hyp1</b>	<b>p-val. Hyp2</b>	<b>p-val. Hyp3</b>	<b>p-val. Hyp4</b>	<b>p-val. Hyp5</b>	<b>p-val. Hyp6</b>
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

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
<i>Harrison E of 25th WB</i>	<i>Feb 2017</i>	<i>Apr 2019</i>	<i>19.12</i>	<i>19.00</i>	<i>23</i>	<i>24.8</i>	<i>3.36</i>	<i>6.68</i>	<i>0.35</i>	<i>0.41</i>	<i>0.528</i>	<i>0.752</i>	<i>0.235</i>	<i>0.890</i>	<i>1.000</i>	<i>0.629</i>
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
<i>Lincoln W of 41st EB</i>	<i>Nov 2012</i>	<i>Jan 2017</i>	<i>17.75</i>	<i>19.38</i>	<i>24.35</i>	<i>23.25</i>	<i>5.59</i>	<i>3.67</i>	<i>0.25</i>	<i>0.31</i>	<i>0.197</i>	<i>0.930</i>	<i>0.651</i>	<i>0.521</i>	<i>0.065</i>	<i>0.717</i>
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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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
<i>Division E of 33rd EB</i>	<i>Jul 2015</i>	<i>Jul 2019</i>	<i>19.30</i>	<i>17.30</i>	<i>25</i>	<i>22</i>	<i>5.34</i>	<i>5.05</i>	<i>0.11</i>	<i>0.05</i>	<i>1.000</i>	<i>0.000</i>	<i>1.000</i>	<i>0.000</i>	<i>0.000</i>	<i>0.000</i>
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
<i>Division E of 33rd EB</i>	<i>Jul 2019</i>	<i>Jul 2019 b</i>	<i>17.30</i>	<i>18.65</i>	<i>22</i>	<i>24</i>	<i>5.05</i>	<i>5.21</i>	<i>0.05</i>	<i>0.09</i>	<i>0.000</i>	<i>1.000</i>	<i>0.000</i>	<i>1.000</i>	<i>0.998</i>	<i>0.000</i>

*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 gateway control pairs.**

Site	Before	After	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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 gateway control pairs.**

Site	Before	After	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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
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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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
<i>Lincoln E of 30th EB</i>	<i>Feb 2019</i>	<i>Apr 2019</i>	<i>23.66</i>	<i>17.76</i>	<i>33.8</i>	<i>21.6</i>	<i>9.75</i>	<i>4.51</i>	<i>0.57</i>	<i>0.29</i>	<i>0.998</i>	<i>0.012</i>	<i>1.000</i>	<i>0.000</i>	<i>0.001</i>	<i>0.060</i>
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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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	$\mu_B$	$\mu_A$	$\zeta_{85,B}$	$\zeta_{85,A}$	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