UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS

Task 6 Data Quality Analysis and Outlier Description

SPR 827

UPDATE TO METHODOLOGY FOR SETTING SPEED LIMITS IN URBAN AREAS

Task 6 Data Quality Analysis and Outlier Description

SPR 827

by

Miguel Figliozzi, 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

November 2019

Technical Report Documentation Page

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 6 Data Quality Analysis and Outlier Description		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 13th 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 13th 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 details an analysis of the quality and characteristics of the 305 unidirectional datasets from 126 unique sites available for analysis within the project. Collected site characteristics are listed and summaries are provided for functional classifications, bicycle routes and facilities, speed limits, transit service, traffic calming, parking facilities, pedestrian facilities, presence of school zones, and number of traveled ways. Speed-related or fatal crashes at locations within the study segments are listed. A general overview of the data quality is given. Data cleaning logic is discussed, and statistics and correlations related to data exclusions is given. Three outlying datasets are discussed and class one volume patterns at select locations are examined.

17. Key Words Speed limit, operating speed, speed compliance, active traveler, bicycle, pedestrian, data quality, speed distribution	18. Distribution Statement Copies available from NTIS, and online at http://www.oregon.gov/ODOT/TD/TP_RES/		
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

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

Λ

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

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This report serves to document a description of the study site characteristics and an analysis of the quality of the data collected and utilized within SPR 827.

A description of the data collection effort and results is given in Section 2. The site and traffic survey data collected is listed and defined. A summary of the site characteristic values and categories is given. Relevant speed-related and fatal crash data is provided. The general overview of the speed data and its quality are discussed. Sites which were subject to repeated traffic speed surveys and their general characteristics are presented.

Data cleaning logic is discussed in section three. Statistics related to the amount of data excluded by the data cleaning are provided. Section four inspects and documents correlations between outlying data. Section five reviews three datasets where a high percentage of outliers or other unusual characteristics were observed. Class one volume patterns are also discussed and one outlying site is noted. A summary is provided in section six.

2.0 GENERAL OVERVIEW OF DATA

The traffic speed data utilized in this project were collected by the Portland Bureau of Transportation (PBOT) using pairs of pneumatic tubes which are capable of counting vehicles, measuring vehicle speed, and classifying vehicles based on axle detection and spacing. Both archived data and newly collected data were received. New and archived data collection occurred along the following streets: N Vancouver Ave, N Willamette Blvd, N Williams Ave, NE Alberta St, NE Fremont St, NW 23rd Ave, SE 13th Ave, SE Clinton St, SE Division St, SE Harrison St, SE Hawthorne Blvd, SE Holgate Blvd, SE Lincoln St, and SE Woodstock Blvd. The dates of the data collection ranged from April 2011 to October 2019 with the majority collected during the spring or summer. A total of 305 unidirectional datasets were obtained from 126 locations, including 22 locations where repeated surveys were performed. Fourteen of the repeated locations had changes made to the posted speed limit (PSL) between surveys. A link for a Google map of the data collection locations is provided in the references at the end of this report *(Schaefer, 2019)*.

2.1 TRAFFIC SURVEY AND SITE CHARACTERISTICS COLLECTED

For each dataset, a number of variables related to the traffic survey and site were collected. Descriptions of these variables are provided in this section. Appendix A displays the values of select variables for each speed survey dataset.

2.1.1 Traffic Survey Data

- Location – describes the street name with the direction (from) and name of the nearest cross street of the data collection location.
- Counter ID – a numerical ID representing the survey equipment used. Numbers greater than 70 represent equipment with improved bicycle data collection abilities.
- Day of the week – indicates the day of the week the speed data collection began.
- Month – indicates the month in which the speed data collection occurred.
- Season – indicates the season in which the speed data collection occurred.
- Year – indicates the year in which the speed data collection occurred.
- Posted speed limit – the posted speed limit at the time of the speed data collection.
- Vehicle classification – the vehicle classification based on the FHWA Scheme F *(FHWA, 2016)*.
- Traffic volume – the estimated ADT, calculated as the total number of recorded observations divided by the number of 24-hour intervals over which the data was collected.

2.1.2 General Road Features

- Grade – the estimated average grade at the speed data location, calculated as the change in elevation between two adjacent contour lines within which the speed data location is situated, divided by the distance between the adjacent contour lines and multiplied by 100.
- Road classification – the traffic classification, sourced from the PBOT Transportation System Plan *(PBOT, 2018b)*. The classifications used in this data and their definitions are:
    - Local Service – intended to provide access to local residences and commercial uses and connect neighborhoods while often functioning as a through route for active travelers.
    - Neighborhood Collector – serve as distributors from district collectors to local service streets.
    - District Collector – intended to distribute traffic from higher classed streets and generally connect town centers, main streets, and other major destinations.
- Bicycle route classification – the bicycle route classification, sourced from the PBOT Transportation System Plan *(PBOT, 2018b)*. The classifications used in this data and their definitions are:
    - Major City Bikeway – intended to serve high volumes of bicycle traffic and provide direct, efficient travel across and between transportation districts.
    - City Bikeway – intended to provide direct and convenient bicycle access to significant destinations and Major City Bikeways.
    - Local Service Bikeway – intended to provide local circulation and access to adjacent properties for bicyclists.
    - Neighborhood Greenway – a low speed, low traffic volume street which is prioritized for bicycles and enhanced for pedestrians.
- Bus route – the number(s) of any TriMet bus routes that pass through the speed data collection location *(TriMet, 2019)*.
- Number of traveled ways – indicates if one-way or two-way traffic is allowed.
- Number of lanes – indicates the total number of through lanes in the specified direction of travel and whether auxiliary lanes are present.
- Segment length – the approximate number of feet between the centers of the intersections of the nearest traffic control devices that encompass the speed data collection location, including on-demand pedestrian signals.
- Distance to traffic control – the approximate number of feet from the center of the intersection nearest the speed data collection location to the center of the intersection of the nearest traffic control device in the specified direction of travel.

- Distance to traffic calming – if any, the approximate number of feet from the center of the intersection nearest the speed data collection location to the center of the nearest traffic calming measure in the specified direction of travel within the given road segment.
- Distance to crosswalk – if any, the approximate number of feet from the center of the intersection nearest the speed data collection location to the center of the nearest marked crosswalk in the specified direction of travel within the given road segment.
- Access density – the ratio between the total number of useable driveways on both sides of the street within one block in either direction of the speed data collection location and the approximate distance in feet between the centers of the respective intersections.

2.1.3 On-Road Features

- Bicycle facilities – if any, the type of bicycling facility present at the speed data collection location.
- Presence of bus stop – indicates the presence of a bus stop within one block in either direction of the intersection nearest the speed data collection location.
- Road width – the total width of the paved roadway at the speed data collection location.
- Parking allowance – if any, the type of parking allowed on the side of the street adjacent to the specified direction of travel.
- Traffic calming type – if any, indicates the type of the nearest traffic calming measure in the specified direction of travel within the given road segment.
- Road marking – describes the lane markings present and the presence of sharrows.

2.1.4 Roadside and Environment Features

- Sidewalk presence – indicates whether at least 75% of the length of the block within which the speed data was collected has a paved sidewalk.
- Pedestrian classification - the pedestrian network classification, sourced from the PBOT Transportation System Plan *(PBOT, 2018b)*. The classifications used in this data and their definitions are:
    - Pedestrian Districts – centers where high levels of pedestrian activity exist or is expected to exist in the future, including areas within one-quarter mile of major transit stations.
    - Major City Walkways – corridors where pedestrian destinations exist or are expected to exist in the future, frequent transit routes, and core downtown streets that serve a high number of pedestrians.
    - City Walkways – non-frequent transit routes where a moderate level of pedestrian activity is expected.
    - Neighborhood Walkways – designated Safe Routes to School and neighborhood greenways intended to serve neighborhood level demands.

- School zone – indicates if the speed data collection location is within a designated school zone.
- Land use – describes the primary type of land use surrounding the speed data collection location

2.1.5 Other Site-Specific Information

- Street view – presents a link to a representative street view at the data collection location in the specified direction of travel.
- Street view date – indicates the month and year the linked street view was captured.
- Bike counts – where available, the average estimated daily bike volume from the years 2016-2018 which were manually counted *(PBOT, 2018a)*.

2.2 SUMMARY OF SITE CHARACTERISTICS

The majority (> 90%) of the streets where data was collected are classified as either local service (LS) or neighborhood collector (NC), with the remaining locations classified as district collector (DC). The PSL at the time of data collection for all 305 datasets ranged from 20 mph to 35 mph with 81% of them posted at 20 or 25 mph.

Bicycle route classification was collected from Portland's Transportation System Plan (TSP) *(PBOT, 2018b)*. Nearly 57% of the datasets were located on major city bikeways and of those, 77% were on designated neighborhood greenways which have shared road bicycle facilities. Over 9% of datasets lacked bicycle facilities, almost 23% of datasets were collected from sites that had either standard or buffered bicycle lanes, and 24% had separated in road facilities.

Approximately 65% of the datasets were collected from locations served by one or more TriMet bus routes, and almost 43% of those datasets were collected from locations within approximately one block of a bus stop.

Almost 67% of the datasets were collected from locations within a road segment where one or more traffic calming measures were in place.

More than 95% of the datasets were collected from two-way streets with 82% of those having only one lane in the given direction of travel.

Less than 9% of the datasets were collected from locations with no parking available. The remainder had parallel parking available on the nearest side in the given direction of travel, or in the case of one-lane, one-way streets, on either side of the travel lane.

Nearly 10% of the datasets were from locations within designated school zones.

Over 92% of datasets were collected within blocks that had sidewalk completed on the near side for at least 75% of the block.

2.3 CRASH DATA

The PBOT Vision Zero crash map *(PBOT, 2019)* was referenced for information on crashes within the study site segments resulting in any injury in which speed was attributed as a causal factor and all fatal injuries by any cause. The data has been collected since 2007 through the time of writing this report, however, non-fatal injury crash data for 2018 and 2019 were not yet available so it is not included here. Tables 2-1 through 2-3 provide details on speed-related non-fatal crashes, speed-related fatal crashes, and unknown or non-speed-related fatal crashes, respectively. A total of 42 crashes producing 44 injury records occurred within the study site segments.

Table 2-1: Speed-related non-fatal injury crashes.

Street	Cross Street	Date	Day	Time	People Injured
N Williams Ave	Fargo St	11/15/2014	Saturday	21:00	In Vehicle
N Williams Ave	N of Shaver St	1/15/2013	Saturday	21:00	In Vehicle
NW 23rd Ave	S of Everett St	10/9/2013	Wednesday	16:00	Biking
SE Division St	E of 22nd Ave	8/11/2012	Saturday	12:00	Biking
SE Division St	E of 33rd Ave	9/30/2012	Sunday	22:00	In Vehicle
SE Division St	E of 67th	8/18/2014	Monday	15:00	In Vehicle
SE Division St	82nd Ave	8/29/2011	Monday	9:00	In Vehicle
SE Division St	82nd Ave	9/4/2014	Thursday	10:00	In Vehicle
SE Division St	W of I205 on-ramp	3/20/2015	Friday	1:00	In Vehicle
SE Division St	W of 96th Dr	11/25/2007	Sunday	1:00	In Vehicle
SE Division St	W of 101st Ave	1/11/2016	Monday	19:00	Walking
SE Division St	W of 101st Ave	2/7/2014	Friday	19:00	Walking
SE Division St	101st Ave	10/22/2009	Thursday	0:00	In Vehicle
SE Division St	106th Ave	8/30/2015	Sunday	7:00	In Vehicle
SE Division St	W of 109th Ave	5/18/2010	Tuesday	23:00	In Vehicle
SE Division St	W of 121st Ave	1/27/2015	Tuesday	18:00	In Vehicle
SE Division St	E of 121st Ave	9/182013	Wednesday	16:00	Walking
SE Hawthorne Blvd	33rd Ave	5/5/2007	Saturday	4:00	In Vehicle
SE Hawthorne Blvd	Cesar Chavez Blvd	1/2/2011	Sunday	0:00	In Vehicle
SE Holgate Blvd	67th Ave	9/13/2016	Tuesday	19:00	In Vehicle
SE Holgate Blvd	92nd Ave	4/22/2016	Friday	2:00	In Vehicle
SE Holgate Blvd	W of I205 path	3/21/2016	Monday	2:00	In Vehicle

SE Holgate Blvd	97th Ave	8/11/2016	Thursday	7:00	Biking
SE Holgate Blvd	103rd Ave	7/28/2016	Thursday	18:00	In Vehicle
SE Holgate Blvd	122nd Ave	4/22/2007	Sunday	19:00	Walking

Table 2-2: Speed-related fatal injury crashes.

Street	Cross Street	Date	Day	Time	People Injured
N Willamette Blvd	W of Burr Ave	11/15/2018	Thursday	23:00	Walking
N Willamette Blvd	W of Hodge Ave	11/4/2009	Wednesday	2:00	Biking
N Williams Ave	S of Graham St	3/29/2008	Saturday	20:00	In Vehicle
SE Division St	W of 42nd Ave	1/23/2013	Wednesday	1:00	In Vehicle
SE Division St	E of 67th	8/18/2014	Monday	15:00	Walking
SE Division St	112th Ave	8/12/2019	Monday	NA	In Vehicle
SE Hawthorne Blvd	16th Ave	12/6/2008	Saturday	1:00	Walking
SE Hawthorne Blvd	43rd Ave	8/19/2016	Friday	15:00	Walking
SE Holgate Blvd	92nd Ave	4/22/2016	Friday	2:00	In Vehicle
SE Holgate Blvd	E of 118th Ave	10/17/2016	Monday	0:00	In Vehicle

NA = Time unknown.

Table 2-3: Unknown or non-speed-related fatal injury crashes.

Street	Cross Street	Date	Day	Time	People Injured
N Williams Ave	Monroe St	8/9/2015	Sunday	2:00	In Vehicle
SE Division St	84th Ave	2/14/2014	Friday	11:00	Walking
SE Division St	87th Ave	12/7/2016	Wednesday	21:00	Walking
*SE Division St**	115th Ave	3/11/2018	Sunday	NA	Walking
*SE Division St**	122nd Ave	3/9/2019	Saturday	23:00	In Vehicle
SE Holgate Blvd	60th Ave	7/4/2015	Saturday	21:00	Walking
SE Holgate Blvd	W of 102nd Ave	6/1/2011	Wednesday	13:00	In Vehicle
*SE Holgate Blvd**	92nd Ave	3/1/2019	Friday	7:00	Walking
*SE Holgate Blvd**	E of 100th Ave	4/16/2019	Tuesday	3:00	In Vehicle

NA = Time unknown

* Indicates speed attribution is unknown.

From Tables 2-1 through 2-3, it can be seen that the majority of crashes that occurred on the street segments in this study took place along Division (20 crashes resulting in 21 injury records) and Holgate (11 crashes resulting in 12 injury records). Division and Holgate are among the top 30 high crash streets in Portland *(PBOT, 2019)* so it is not surprising that the majority of crashes included here occurred along them. Hawthorne is also one of Portland's high crash streets and is represented in Tables 2-1 and 2-2. While Fremont is named as a high crash street, no fatal or speed-related crashes were found for the segments studied in this project. Additional study site

segments that had no occurrences of speed-related or fatal injury crashes include 13th, Alberta, Clinton, Harrison, Lincoln, Vancouver, and Woodstock.

2.4 TRAFFIC SPEED DATA

Overall it was observed that the quality of the speed data collected is very high. Histograms of class two vehicles *(FHWA, 2016)* followed normal or near normal distributions in all but approximately 7% of the datasets. Most cases in which a non-normal distribution was observed were due to insufficient class two observations. An example of a typical class two dataset is shown in Figure 2-1.

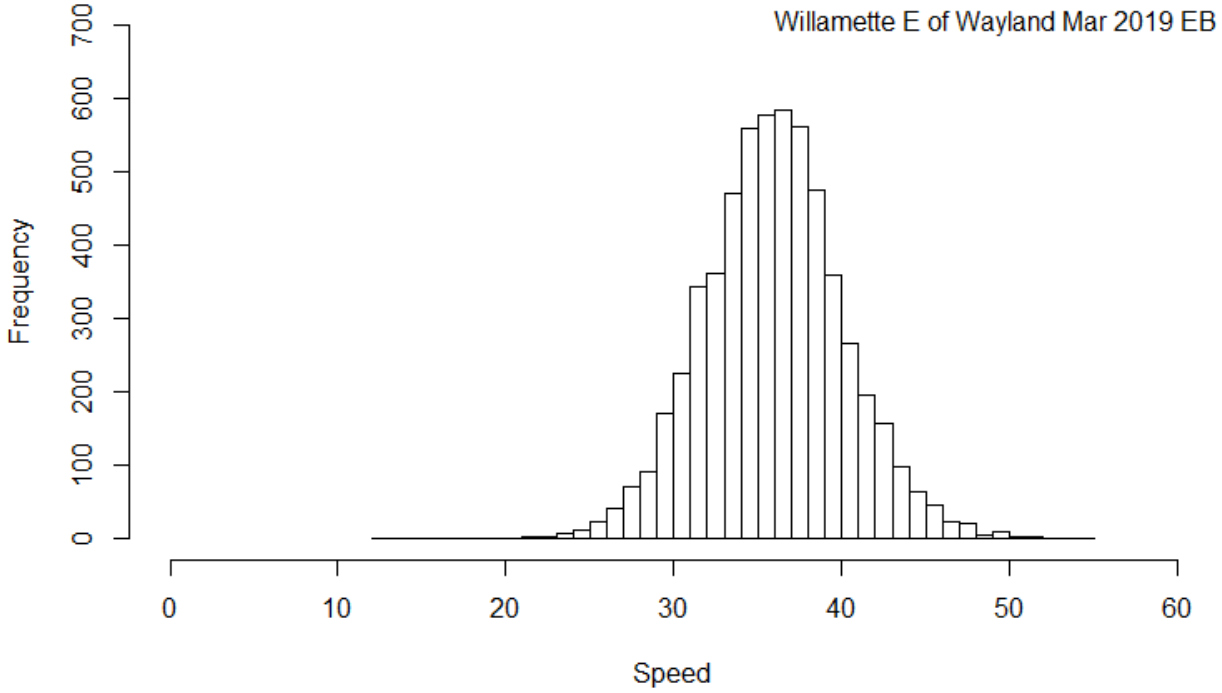

Figure 2-1: Typical example of a class two dataset speed distribution.

Active travelers are a key aspect of this research. As such, class one speed distributions for datasets from locations along neighborhood greenways where bicycles are expected to dominate the class were inspected. Datasets containing a sufficient number of observations were also generally found to have normal or near normal speed distributions. An example of a typical class one dataset can be seen in Figure 2-2

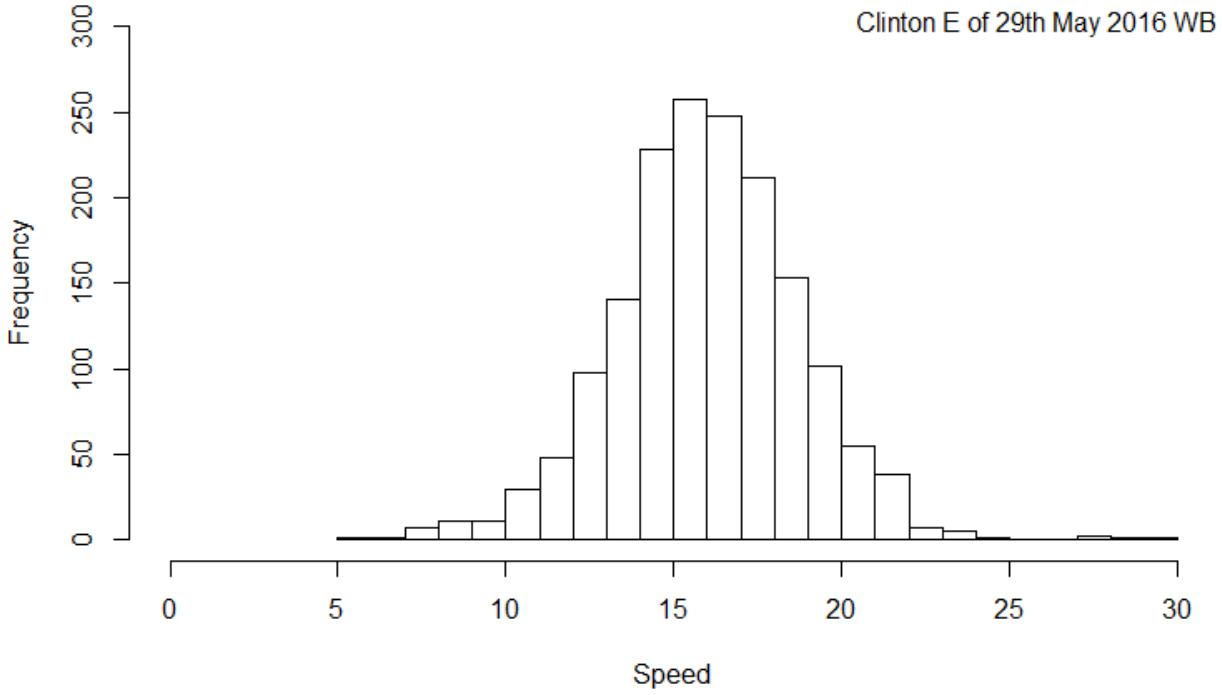

Figure 2-2: Typical example of a class one dataset speed distribution.

The specifics of the data cleaning and statistics related to it are discussed in section two. However, it is worth noting that after the data cleaning process was complete, the average amount of data that was excluded from all 305 datasets was less than 10%.

2.5 PRELIMINARY ANALYSIS DESCRIPTION

A preliminary analysis was performed to summarize traffic volumes as well as 50th and 85th percentile speeds throughout the corridors studied. The results can be seen in Table 2-5.

Table 2-4: Summary of preliminary data analysis results.

Corridor	Section	Dataset Count	Road Width	PSL	ADT	Class 1 ADT*	Pedestrian Activity	50th Per. Speed	85th Per. Speed
N Vancouver Ave	Tillamook-Holland	12	36-40	20-30	2,300-8,400	0-1,200	PD, MCW, CW	23-28	28-33
N Willamette Blvd	Rosa Parks-Richmond	21	36-40	30-35	3,800-8,800	0-700	PD, MCW, NW	28-36	32-40
N Williams Ave	Broadway-Rosa Parks	10	28-40	20-30	100-7,400	0-1,300	PD, MCW, NW	15-28	19-32
NE Alberta St	11th-29th	14	36-40	20-25	1,700-4,500	0-200	PD, MCW	17-25	22-30
NE Fremont St	41st-49th	11	36	20	3,700-5,900	0-200	MCW	19-23	24-28
NW 23rd Ave	Irving-Wilson	7	36-52	20	3,300-8,600	0-200	PD, MCW, CW	15-22	21-26
SE 13th Ave	Umatilla-Malden	18	36	20-25	1,700-4,300	0-100	PD, MCW	16-23	18-27
SE Clinton St	12th-39th	56	36	20-25	300-2,300	300-1100	NW	12-31	14-40
SE Division St	23rd-78th	23	36-44	25-30	4,600-10,100	0-300	PD, MCW	17-32	22-37
SE Division St	84th-117th	10	76	30-35	8,700-14,900	300-700	PD, MCW	32-37	37-41

SE Harrison St	Hemlock-30th	16	36	20-25	300-1,600	100-500	NW	11-24	20-28
SE Hawthorne Blvd	6th-46th	19	52	20-25	5,600-9,000	100-900	PD, MCW	20-31	26-36
SE Holgate Blvd	46th-78th	8	36	25-30	4,400-6,700	0-100	CW	24-31	30-35
SE Holgate Blvd	97th-130th	14	40-66	25-35	3,500-9,200	0-200	CW	20-35	28-39
SE Lincoln St	30th-60th	60	34-36	20-25	100-1,700	0-500	CW, NW	13-23	18-26
SE Woodstock	40th-48th	6	40-50	20-25	6,300-7,600	100-200	PD, MCW	21-24	25-28

*Includes traffic surveys from 2015-2019 only.
PD = Pedestrian District, MCW = Major City Walkway, CW = City Walkway, NW = Neighborhood Walkway.

2.6 REPEATED SITES DISCUSSION

Repeated traffic speed surveys were performed at 22 locations. At three locations, only one travel direction was repeated. Changes to the posted speed limit occurred at 14 of the 22 locations between repeated surveys. Characteristics of each location are provided in this section. Street views of each direction for which a site was repeated are available in Appendix B.

2.6.1 N Willamette Blvd

N Willamette Blvd east of Chase Ave is a two-way street which was surveyed in June 2015 in the eastbound direction and again in July 2019 in both directions. The speed limit was initially posted at 35 mph which was then lowered in August 2017 to 30 mph. At this location, N Willamette is classified as a neighborhood collector. There is one lane in each direction, separated by a double yellow line. Parking is not allowed. TriMet route 044 serves this location and a sidewalk is available adjacent to the westbound lane. A standard bike lane was present during the initial survey which was restriped to a buffered bike lane before the survey in July 2019. There is little to no grade at this location.

2.6.2 N Williams Ave

Surveys were performed in January 2015 and July 2019 at N Williams Ave north of Going St. The speed limit was posted at 30 mph in January 2015 and was lowered in 2016 to 25 mph, effective for the July 2019 survey. At this location, N Williams Ave is a one-way, neighborhood collector in the northbound direction with a left-side buffered bike lane. The estimated grade at this location is 1.4%. Manual bike counts have been performed at this location since 2012 and include bicyclists traveling through the intersection from and to any direction. The 2016-2018 average estimated daily bike volume at the intersection was 3,048 bicyclists. Sidewalks and parallel parking are present on both sides of the street. This location is served by TriMet route 044.

2.6.3 NE Alberta St

NE Alberta St east of 28th Ave is a two-way street with one lane in each direction separated by a broken yellow line. At this location, NE Alberta is classified as a neighborhood collector street and bicycle facilities are listed as “separated in-road.” Parallel parking and sidewalks are available on both sides. TriMet frequent service route 072 serves this location. The estimated grade at this location is less than 1%. Surveys were performed for both the eastbound and westbound directions in October 2016 and July 2019. An additional survey was performed in the westbound direction only during September 2016. The speed limit was posted at 25 mph during the September and October 2016 surveys. In August 2017 the speed limit was reduced to 20 mph, effective during the July 2019 survey.

2.6.4 NE Fremont St

Two locations along NE Fremont St were subject to repeated traffic speed surveys, east of 46th Ave and east of 48th Ave. At both locations, NE Fremont St is classified as a neighborhood collector and carries a speed limit of 20 mph which did not change over the course of the repeated surveys. The street is two-way with two lanes separated by a broken yellow line. The grade at both locations is zero. Bicycle facilities are listed as "separated in-road." Parallel parking and sidewalks are available on both sides of the street. TriMet route 024 passes both locations and bus stops for both travel directions are located just to the west of 48th Ave.

2.6.4.1 East of 46th Ave

Surveys were performed in both directions at NE Fremont St east of 46th in February 2018 and in September 2019. No additional defining characteristics were noted.

2.6.4.2 East of 48th Ave

For NE Fremont St east of 48th Ave, only the westbound direction was repeated. The first survey was performed in December 2014 and the second survey was performed in July 2019. A marked crosswalk is located west of the intersection with 48th Ave.

2.6.5 SE Clinton St

Seven locations along SE Clinton St were repeated in both the eastbound and westbound directions each time. These locations and their respective survey dates consist of the following:

- West of 13th Ave: July 2015, May 2016
- West of 14th Ave: August 2014, March 2018, May 2018, September 2019
- East of 17th Ave: August 2014, July 2015
- East of 23rd Ave: July 2015, May 2016, April 2019
- West of 25th Ave: March 2014, June 2015
- East of 29th Ave: April 2014, May 2016, July 2019
- West of 30th Ave: August 2014, June 2015

The section of SE Clinton St encompassing these locations is designated as a neighborhood greenway where sharrows on the roadway indicate shared lane bicycle facilities. At all locations, the traffic is two-way and there is one lane in each direction. Lane delineators are not present. Parallel parking and sidewalks are available on both sides of the street at all locations. Speed humps are present along this section with an average spacing of 668 ft.

SE Clinton is classified as a local service street as defined by the Portland Transportation System Plan *(PBOT, 2018)* at all repeated locations. During all surveys performed in 2014, 2015, and 2016, the posted speed limit (PSL) was 25 mph. The PSL was reduced to 20 mph prior to the

surveys performed in 2018 and 2019. TriMet route 010 serves the east of 23rd location and the west of 25th location. Transit service is not available at all other repeated locations.

2.6.5.1 West of 13th Ave

No changes in the 25-mph PSL occurred at this location between the July 2015 and May 2016 surveys. The estimated grade at this location is less than 1%. Manual bike counts have been performed at the intersection of SE Clinton St and 13th Ave since 2009. All bicyclists traveling through the intersection are counted, regardless of their direction of travel. The 2016-2018 average estimated daily bike volume was 2,730 bicyclists.

2.6.5.2 West of 14th Ave

The PSL during the first survey in August 2014 was 25 mph. During the following surveys performed in March 2018, May 2018, and September 2019, the PSL was 20 mph. The estimated grade at this location is less than 1%.

2.6.5.3 East of 17th Ave

The PSL during both the August 2014 and July 2015 surveys was 25 mph at this location. The grade was estimated to be less than 1%.

2.6.5.4 East of 23rd Ave

During the July 2015 and May 2016 speed surveys, the speed limit on SE Clinton St east of 23rd Ave was 25 mph. During the April 2019 survey, the speed limit was 20 mph. The estimated grade at this location is 3.6%, positive in the eastbound direction. Additionally, there is a minor traffic circle at the intersection of 23rd Ave. TriMet route 010 serves a bus stops west of 23rd Ave.

2.6.5.5 West of 25th Ave

Traffic speed surveys were performed on SE Clinton west of 25th Ave in March 2014 and June 2015. The PSL during both surveys was 25 mph. The estimated grade at this location is 1.5% and positive in the eastbound direction. TriMet route 010 passes this location and there are bus stops for both travel directions within one block of 25th Ave.

2.6.5.6 East of 29th Ave

The PSL during the April 2014 and May 2016 traffic surveys was 25 mph. Prior to the July 2019 survey, the speed limit had been lowered to 20 mph. The estimated grade at this location is 1%, positive in the eastbound direction.

2.6.5.7 West of 30th Ave

Surveys were performed at SE Clinton west of 30th Ave in August 2014 and June 2015. At both times the speed limit was posted at 25 mph. The estimated grade at this location is 1%, positive in the eastbound direction.

2.6.6 SE Division St

Repeated surveys were performed at two locations along SE Division St, east of 33rd Ave and east of 116th Ave. TriMet route 002 serves both locations. Other characteristics differ considerably between these locations.

2.6.6.1 East of 33rd Ave

SE Division St east of 33rd Ave is classified as a neighborhood collector and is listed to have separated in-road bicycle facilities. It is two-way with one lane in each direction. Parallel parking and sidewalks are available on both sides. Surveys were performed in both directions in July 2015, in the eastbound direction only in July 2019, and again later in July 2019 in both directions. The posted speed limit (PSL) at this location did not change throughout the course of the repeated surveys. This section of SE Division St is estimated to have little to no grade.

2.6.6.2 East of 116th Ave

East of 116th Ave, SE Division St has two travel lanes in each direction and a two-way left-turn lane. It is classified as a district collector. Bicycle lanes are provided on both sides. Parallel parking is allowed on both sides and a sidewalk is available adjacent to the eastbound travel lanes. A bus stop for the eastbound direction is located to the west of 116th Ave. Surveys at this location were performed in both directions in February 2017 and April 2018 and in the westbound direction only in October 2019. The speed limit at the time of the February 2017 survey was 35 mph. It was reduced to 30 mph in May 2017, effective for both the April 2018 and October 2019 surveys.

2.6.7 SE Harrison St

Two surveys were performed at SE Harrison St east of 25th Ave, the first during February 2017 and the second during April 2019. The initial PSL was 25 mph which was lowered to 20 mph in 2018, effective for the April 2019 survey. This segment of SE Harrison St is two-way with one lane in each direction. It is classified as a local service street and designated as a neighborhood greenway. Lane markings are not present, but sharrows indicate the shared road bicycle facilities. Parallel parking and sidewalks are available on both sides of the street. At this location, the grade is estimated as 3.3%, positive in the eastbound direction. An all-way stop is present at the intersection with 26th Ave.

2.6.8 SE Holgate Blvd

Two traffic speed surveys have been performed at SE Holgate Blvd east of 111th Ave. During the first survey in February 2017, the PSL was 35 mph. The second survey was performed in June 2019, after the PSL had been reduced to 30 mph in August of 2017. SE Holgate Blvd east of 111th Ave is a three-lane, two-way street with one through lane in each direction and a left turn lane for the westbound direction. It is classified as a neighborhood collector. A double yellow line separates opposing traffic lanes. The grade is estimated to be less than 1%. Parallel parking is present on both sides of the street, but sidewalks are incomplete on both sides. A traffic signal is present at the intersection with 112th Ave. TriMet route 017 serves this location and a bus stop is located west of 112th Ave for the eastbound direction. Buffered bike lanes are present on both sides of the street and manual bike counts have been performed at the intersection with 112th Ave since 2009. The 2016-2018 average estimated daily bike count was 127 and includes bicycles traveling from and to any direction through the intersection.

2.6.9 SE Lincoln St

Six locations along SE Lincoln St were subject to repeated traffic speed surveys. These locations and their respective survey dates consist of the following:

- East of 30th Ave: February 2019, April 2019
- West of 41st Ave: November 2012, January 2017
- East of 45th Ave: November 2012, July 2019
- East of 48th Ave: October 2012, January 2017
- East of 50th Ave: April 2011, June 2011 (westbound), February 2012 (westbound), March 2017, May 2019
- West of 57th Ave: February 2012, January 2017

The segment of SE Lincoln St that includes all of the repeated locations is classified as a local service street with two-way traffic and one lane in each direction. Lane delineators are generally absent along SE Lincoln St except for sections immediately adjacent to traffic control devices or minor traffic circles. This segment is designated as a neighborhood greenway and sharrows are present indicating the shared road bicycle facilities. Parallel parking and sidewalks are available on both sides of the street. Speed humps are present along this segment of SE Lincoln St at an average spacing of 636 feet. During all surveys performed in 2011 and 2012, the PSL was 25 mph. The speed limit was reduced to 20 mph prior to the surveys performed in 2017 and was in effect during the surveys performed in 2019 as well.

2.6.9.1 East of 30th Ave

Surveys were performed at SE Lincoln east of 30th Ave in February 2019 and again in April 2019. During both surveys, the PSL was 20 mph. There is no grade at this location. An all-way

stop is present at the intersection of 30th Ave. Double yellow lines were present for approximately 75 feet east of the intersection.

2.6.9.2 West of 41st Ave

SE Lincoln St west of 41st Ave was surveyed in both directions in November 2012 and again in January 2017. During the initial survey, the PSL was 25 mph which was reduced to 20 mph prior to the subsequent survey in 2017. There is little to no grade at this location. Manual bike counts have been performed at the intersection of 41st Ave consistently since 2006. The 2016-2018 average estimated daily bike count was 1,930 and includes bikes traveling from and to any direction through the intersection.

2.6.9.3 East of 45th Ave

Two traffic speed surveys were performed at SE Lincoln St east of 45th Ave. The PSL was 25 mph during the November 2012 survey and was 20 mph during the July 2019 survey. At this location, there is little to no grade.

2.6.9.4 East of 48th Ave

Traffic speed surveys were performed at SE Lincoln St east of 48th Ave in October 2012 while the speed limit was posted at 25 mph and again in January 2017 when the speed limit was posted at 20 mph. Little to no grade exists at this location.

2.6.9.5 East of 50th Ave

Three bidirectional and two additional westbound only surveys were performed at SE Lincoln St east of 50th Ave. The first bidirectional survey was performed in April 2011, which was followed by the two westbound only surveys in June 2011 and February 2012. The PSL was 25 mph during these initial surveys. Bidirectional surveys were again performed in March 2017 and May 2019 when the PSL was 20 mph. The estimated grade at this location is 3%, positive in the eastbound direction. This location is positioned between a traffic signal at 50th Ave and a minor traffic circle at 51st Ave and double yellow lines are present. Additionally, there is a speed hump approximately mid-block.

2.6.9.6 West of 57th Ave

SE Lincoln St west of 57th Ave was surveyed in February 2012 while the PSL was 25 mph and again in January 2017 when the PSL was 20 mph. The estimated grade at this location is less than 1%. TriMet route 71 serves this location and bus stops for both eastbound and westbound directions are located immediately west of the intersection with 57th Ave. A marked crosswalk is present to the east of the intersection.

2.6.10 Summary of Repeated Sites

A selection of the primary site characteristics for the repeated locations are displayed in Table 2-4. The pedestrian network classification of each site was used as a proxy for expected pedestrian activity. The hierarchy of levels can be seen in Figure 2-1. The ADT range was estimated from the data received and covers all allowed travel directions at that location.

Figure 2-3: Hierarchy of pedestrian network classifications (reproduced from *PBOT, 2018a*).

Table 2-5: Summary of active travel and related characteristics for repeated sites.

Location	PSL		Bike Facility	Daily Bike Volume	Bus Route	Ped Activity	Grade %	ADT
	Before	After						
N Willamette E of Chase	**35**	**30**	**Buffered Bike Lane**		**044**	**MCW**	**0.6**	**7,700-8,800**
N Williams N of Going	**30**	**25**	**Buffered Bike Lane**	**3,048 at Going**	**044**	**MCW**	**1.4**	**5,200-6,300**
NE Alberta E of 28th	**25**	**20**	**Separated In-Road**		**072***	**MCW**	**0.7**	**2,700-2,900**
NE Fremont E of 46th	20	20	Separated In-Road		024	MCW	0	4,600-5,000
NE Fremont E of 48th	20	20	Separated In-Road		024	MCW	0	4,600-5,300
SE Clinton W of 13th	25	25	Neighborhood Greenway	2,730 at 13th		NW	0.7	800-1,600
SE Clinton W of 14th	**25**	**20**	**Neighborhood Greenway**	**2,730 at 13th**		**NW**	**0.7**	**700-1,500**
SE Clinton E of 17th	25	25	Neighborhood Greenway			NW	0.7	800-1,300
SE Clinton E of 23rd	**25**	**20**	**Neighborhood Greenway**		**010**	**NW**	**3.6**	**900-2,000**
SE Clinton W of 25th	25	25	Neighborhood Greenway		010	NW	1.5	1,000-2,300
SE Clinton E of 29th	**25**	**20**	**Neighborhood Greenway**			**NW**	**1**	**900-1,400**
SE Clinton W of 30th	25	25	Neighborhood Greenway	2,830 at 34th		NW	1.1	1,000-1,900

SE Division E of 33rd	25	25	Separated In-Road		002*	PD, MCW	0.6	4,600-6,000
SE Division E of 116th	**35**	**30**	**Bike Lane**		**002***	**PD, MCW**	**0**	**9,300-14,800**
SE Harrison E of 25th	**25**	**20**	**Neighborhood Greenway**			**NW**	**3.3**	**300-1,400**
SE Holgate E of 111th	**35**	**30**	**Buffered Bike Lane**	**127 at 112th**	**017**	**CW**	**0.7**	**6,100-9,200**
SE Lincoln E of 30th	20	20	Neighborhood Greenway			NW	0	300-900
SE Lincoln W of 41st	**25**	**20**	**Neighborhood Greenway**	**1930 at 41st**		**NW**	**0.6**	**100-1,000**
SE Lincoln E of 45th	**25**	**20**	**Neighborhood Greenway**			**NW**	**0.7**	**400-700**
SE Lincoln E of 48th	**25**	**20**	**Neighborhood Greenway**			**NW**	**0.7**	**600-800**
SE Lincoln E of 50th	**25**	**20**	**Neighborhood Greenway**	**1,315 at 52nd**		**NW**	**3**	**600-1,700**
SE Lincoln W of 57th	**25**	**20**	**Neighborhood Greenway**		**071**	**CW**	**1.2**	**1,100-1,300**

*Indicates frequent service route.

PD = Pedestrian District, MCW = Major City Walkway, CW = City Walkway, NW = Neighborhood Walkway.

ADT is given as the range for the repeated surveys for all travel directions.

3.0 DATA CLEANING

Although the average counting error of pneumatic road tube counters is often claimed to be quite low, a study in Montana proposed the absolute error of these devices may be closer to ten percent over a 15-minute interval and that the low average error is a result of the positive and negative counting errors canceling each other out over longer monitoring periods *(McGowen & Sanderson, 2011)*. The study mentions that the possibility of erroneous data recording increases when vehicles are traveling very close together because the tubes may record two vehicles as one. Higher instances of error may also occur if the same pair of tubes is used for bidirectional collection since the quality of axle contact pattern matching may be reduced when two vehicles traveling in opposite directions cross the tubes simultaneously. In another study regarding the accuracy of pneumatic tubes to count bicycles, researchers found that all tested models led to undercounting although the degree of which varied from 10% to 73% according to the type of equipment and the software used *(Nordback et al, 2016)*. Although not discussed in either of the aforementioned studies, it is intuitive that a vehicle parked or stopped on a tube may also cause errors in data recording due to the nature of the operation of the pneumatic tubes.

For this research, speed data was considered erroneous and rejected if the vehicle classification was recorded as '14,' which is undefined by the FHWA vehicle classification scheme *(FHWA, 2016)*, or if the recorded speed was equal to zero. Either of these instances seem to indicate a failure of the pneumatic tubes to properly capture speed or analyze the axle contact pattern.

As noted previously, vehicles traveling very close together increase the possibility of error so observations with a gap time equal to zero were also eliminated.

Finally, the recorded vehicle speeds were inspected. An observation was considered an outlier if the recorded speed was greater than 25 mph above the posted speed limit at the time of the data collection. This speed threshold was chosen based on the maximum difference between the posted speed limit (PSL) and the 99^{th} percentile speed of all but one of the raw datasets, excluding all observations when speed was recorded as zero.

Table 3-1 provides summary statistics of the percentage of speed data that corresponds to each of these data cleaning rules for the 305 datasets provided. It should be noted that some observations may have been subject to more than one cleaning rule category so the addition of the individual categories will not equal the total eliminated in each dataset.

Table 3-1: Summary statistics of the percent of speed data eliminated by each cleaning rule.

	Class = 14	Speed = 0	Gap = 0	Speed > PSL + 25	Total Eliminated
Average	7.61	6.04	4.77	0.04	9.49
St. Dev.	7.36	6.45	4.71	0.38	8.11
Median	5.38	4.09	3.2	0	7.21
Minimum	0.1	0.09	0	0	0.2
Maximum	53.6	49.62	24.57	6.68	54.73

From Table 3-1, it can be seen that the class 14 and zero speed rules accounted for most of the data eliminated. Conversely, the speed threshold rule typically excluded very little data with the exception of the westbound direction at Clinton west of 22nd dataset which had 6.68% of its observations in excess of the speed threshold. Discounting that dataset, the maximum percentage of data eliminated due to the speed threshold was only 0.62%.

Table 3-1 also shows that the average amount of data that was excluded from all 305 datasets was less than 10% and the median was just over 7%. The 85th percentile of the amount of data eliminated was 16.5% and is shown in the plot of Figure 3-1.

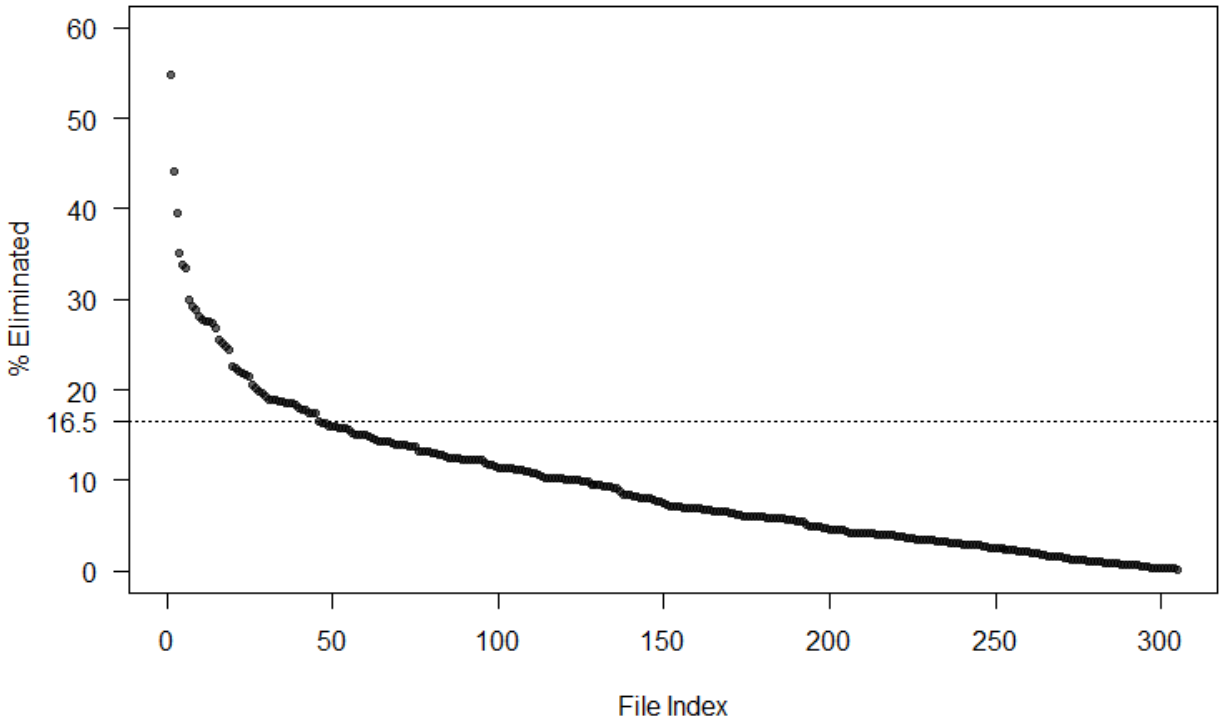

Figure 3-1: Percent of data eliminated in each dataset and the 85th percentile percentage.

4.0 ERROR CORRELATION

To further investigate the collected speed data and its associated errors or outliers, a correlation matrix between the percent of data corresponding to the error categories and the variables of PSL, grade, and road classification was calculated. The grade was estimated based on a 10-foot contour map *(Metro & USGS, 2011)*. The results can be seen in Table 4-1. Functional classification was defined categorically as local = 1, urban collector = 2, minor arterial = 3, and principal arterial = 4.

Table 4-1: Correlation matrix for error categories and select location variables.

	PSL	**Gap=0**	**Class 14**	**Speed=0**	**Speed > Limit+25**	**Grade**	**Functional Class**
PSL	1	-0.18	-0.46	-0.44	-0.07	0.01	0.31
Gap=0		1	0.54	0.56	0.14	-0.02	0.21
Class 14			1	0.96	0.09	-0.03	-0.27
Speed=0				1	0.08	-0.06	-0.24
Speed> Limit+25					1	-0.1	0.05
Grade						1	-0.01
FC							1

From Table 4-1, it can be seen that there is a very high correlation between the percentage of speed data recorded as class 14 and data recorded with speed equal to zero (r = 0.96). Checking individual datasets confirms that in all but two datasets, all observations with a recorded speed of zero were labeled as class 14, although not all records of class 14 had a speed of zero. A plot of the percent of class 14 data versus the percent of data with zero speed (Figure 4-1) provides a visual confirmation of the high level of correlation.

Moderate correlations can also be seen between the percent of class 14 data and the percent of zero gap data (r = 0.54) and the percent of zero speed data and the percent of zero gap data (r = 0.56). Figures 4-2 and 4-3 provide visuals of these correlations.

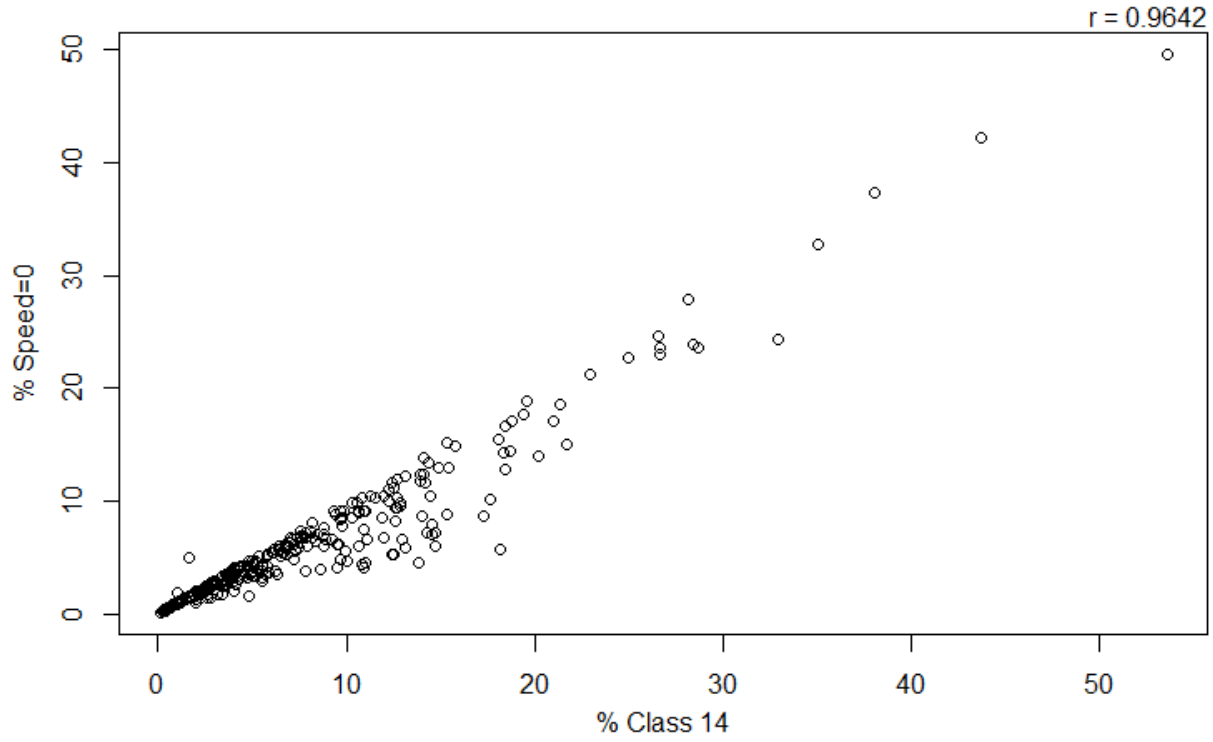

Figure 4-1: Percent of speed data recorded as class 14 vs percent recorded with zero speed.

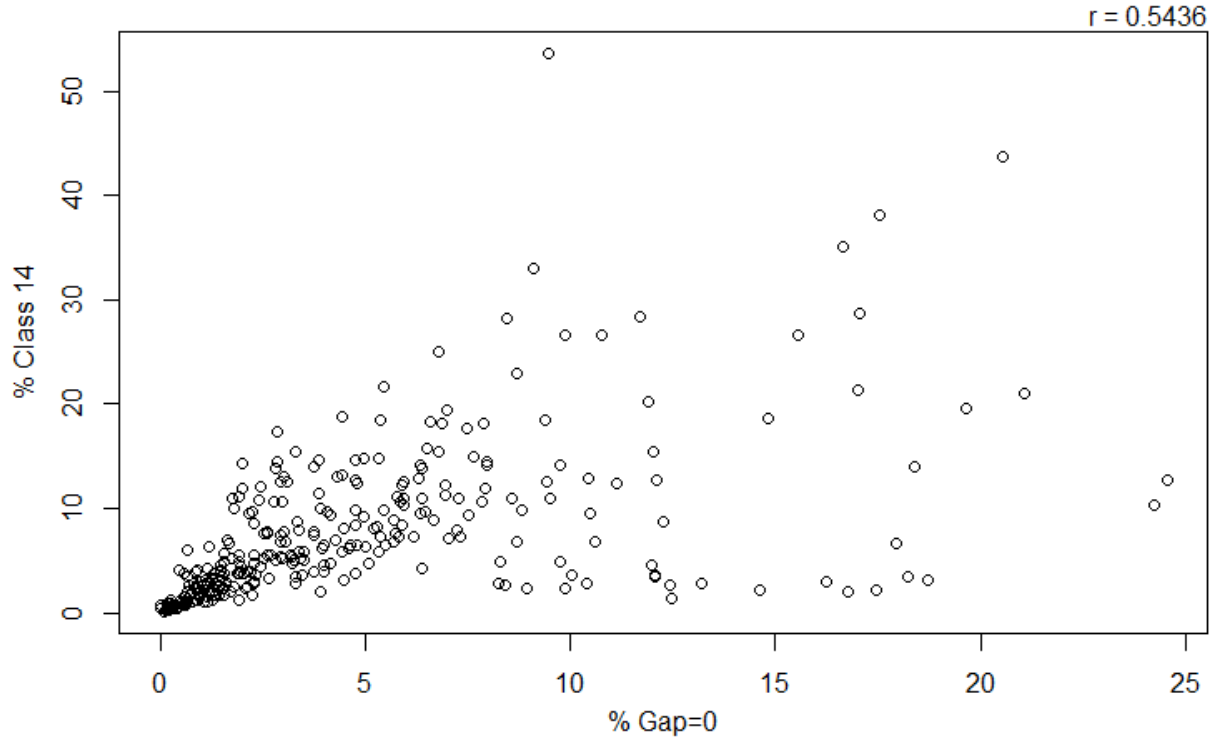

Figure 4-2: Percent of zero gap data vs percent of class 14 data.

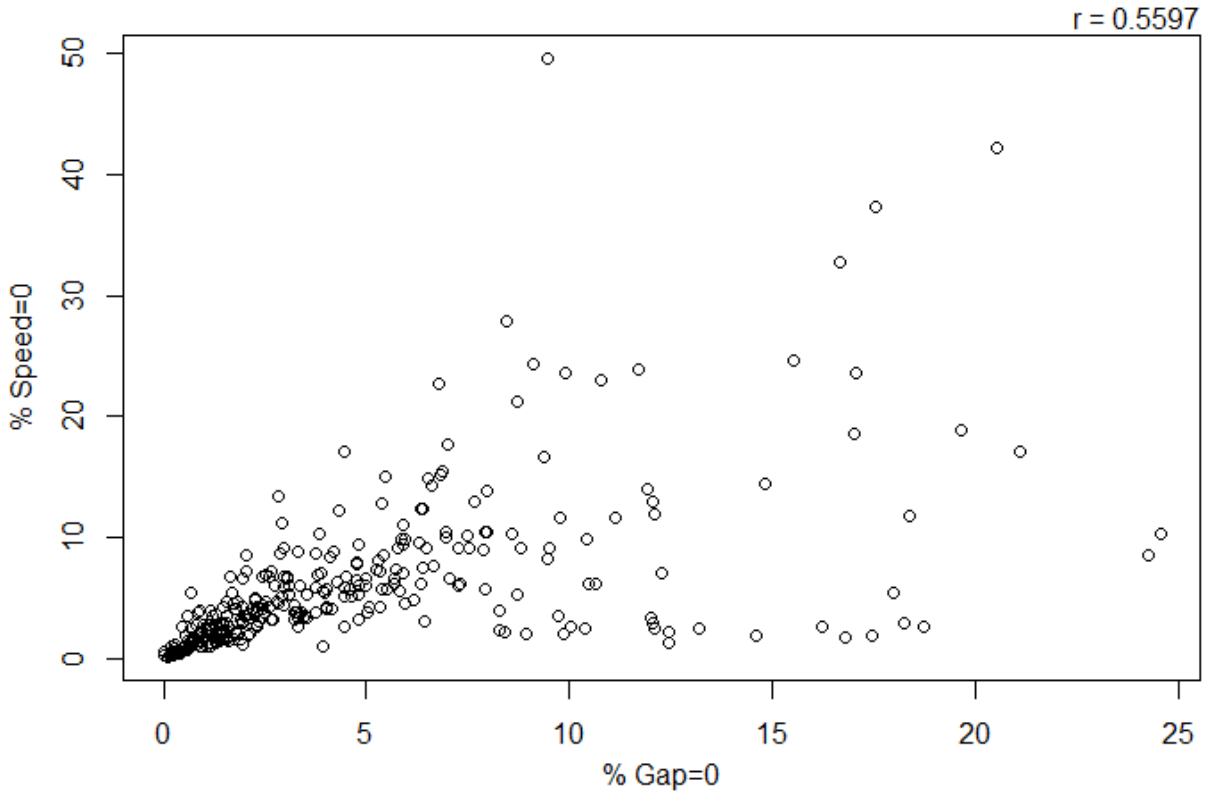

Figure 4-3: Percent of zero gap data vs percent of zero speed data.

A moderate correlation can be seen between the posted speed limit (PSL) and functional class (r = 0.31), and negative correlations are seen between the percent of class 14 or zero speed data and the functional class (r = -0.27 and r = -0.24, respectively). Additionally, moderate negative correlations between the percent of class 14 or zero speed data and the PSL are present (r = -0.46 and r = -0.44, respectively). A positive correlation between PSL and functional class is to be expected with higher classed roads having higher speed limits. The negative correlations between the percent of class 14 or zero speed observations and road class or PSL indicate that lower classed roads or those with lower speed limits have higher rates of recorded errors.

5.0 INSPECTION OF DATASETS WITH HIGH ERROR RATES

Reviewing and inspecting the provided speed data revealed that overall the quality seems quite good with an average exclusion rate of less than 10%. However, several of the datasets had much higher percentages of data eliminated by the data cleaning rules or speed threshold. The following subsections will explore some of these in more detail.

Datasets that had a high percentage of excluded data were found primarily along Clinton and Lincoln. The class 14 and zero speed cleaning rules were responsible for most of the exclusions, followed by the zero gap rule. The 10 datasets with the highest percent of total exclusions and the percent of zero gap, zero speed, and class 14 data within each is provided in Table 5-1. Again, note that some of the observations were subject to more than one cleaning rule so the total eliminated is less than the sum of the individual categories.

Table 5-1: Summary of the ten datasets with the highest percent of total excluded data.

Location	PSL	Functional Class	Gap = 0	Class 14	Speed = 0	Total Eliminated
Lincoln E of 30th Feb 2019 EB	20	Local	9.47	53.60	49.62	54.73
Clinton W of 14th Mar 2018 EB	20	Local	20.54	43.67	42.17	44.07
Clinton E of 15th Jun 2019 WB	20	Local	17.55	38.05	37.42	39.57
Clinton E of 23rd Apr 2019 WB	20	Local	16.65	35.08	32.77	35.12
Clinton W of 22nd May 2019 WB	20	Local	14.83	18.68	14.47	33.78
Clinton W of 14th May 2018 EB	20	Local	9.09	32.94	24.34	33.46
Clinton W of 20th May 2016 WB	25	Local	24.57	12.72	10.33	30.00
Clinton E of 23rd Apr 2019 EB	20	Local	17.07	28.70	23.64	29.20
Lincoln E of 45th Jul 2019 EB	20	Local	11.70	28.44	23.89	28.76
Lincoln E of 35th Jul 2019 WB	20	Local	8.45	28.17	27.84	28.17

Within the individual data cleaning categories of zero speed and class 14, most of the same datasets encompassed the top ten rankings for highest percent eliminated. For the zero gap category, four of the top ten datasets were from locations along Division where the road consisted of two lanes in each direction. No obvious characteristics stood out when inspecting the top ten datasets in the speed threshold category.

5.1 LINCOLN EAST OF 30TH EASTBOUND DATASET DISCUSSION

SE Lincoln St. is classified as a local service street carrying a speed limit of 20 mph and a neighborhood greenway designation. An all-way stop is present at the intersection of 30th Ave.

As seen from Table 5-1, the eastbound direction of the February 2019 Lincoln east of 30th dataset had the highest percentage of total data excluded, equal to nearly 55%, which included one observation recorded with a speed of 128 mph. This dataset also had the highest percentages of class 14 and zero speed observations of all the datasets analyzed. This dataset had a total of only 528 observations during the 66 hours of the data collection.

A time series plot of the class 14 occurrences is shown in Figure 5-1. From the figure it can be seen that the number of class 14 occurrences increased during the peak traffic hours, especially during the evening peak hours and follows the general traffic volume pattern of all classes combined. The time series plot for the zero speed occurrences also appeared to follow the same pattern.

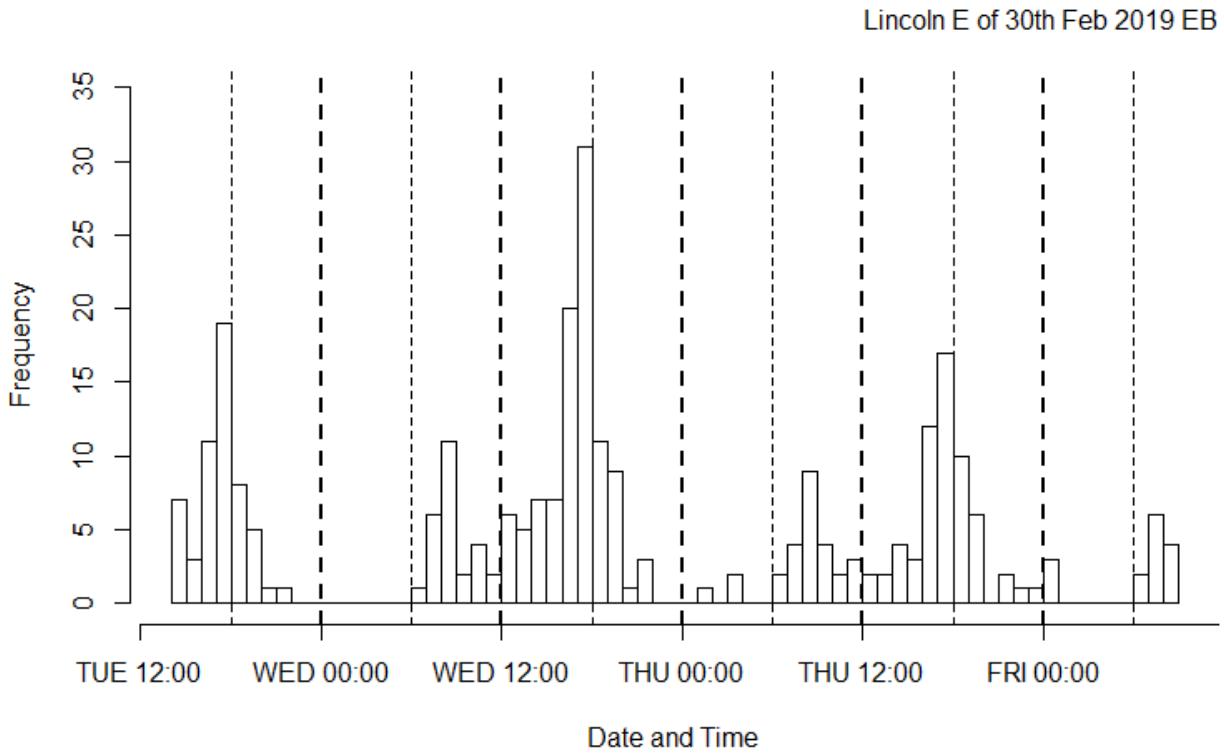

Figure 5-1: Class 14 observations over the duration of the data collection for the February 2019 eastbound Lincoln east of 30th dataset.

5.2 CLINTON WEST OF 22ND WESTBOUND DATASET DISCUSSION

The amount of data excluded by the overall speed threshold ranged from 0% to 0.62% for 304 of the 305 datasets analyzed. The westbound direction of the May 2019 Clinton west of 22nd dataset

had 6.68% of its data subject to elimination from this threshold, however. Clinton is classified as a local street, has a 20-mph speed limit, and is a designated neighborhood greenway. In total, almost 34% of this dataset was excluded from analysis by the data cleaning rules. Figure 5-2 shows a histogram of the raw speed data for all vehicle classes. The histogram clearly shows a bimodal distribution as well as a large number of observations of zero speed. Figure 5-2 also shows a significant number of observations exceeding the speed threshold. Upon closer inspection of those high-speed observations, it was found that over 45% of them were recorded as class four vehicles (buses) while class four comprised only 8% of the overall raw data. Trimet bus line 10 does travel along Clinton between 21st and 26th and has a stop at 21st for the westbound direction. Many of the timestamps of the high-speed class four observations appeared to match scheduled stops at that bus stop. The remainder of the high-speed observations consisted of approximately 31% class two vehicles (passenger cars) and nearly 22% class five vehicles (two-axle, six tire single unit trucks).

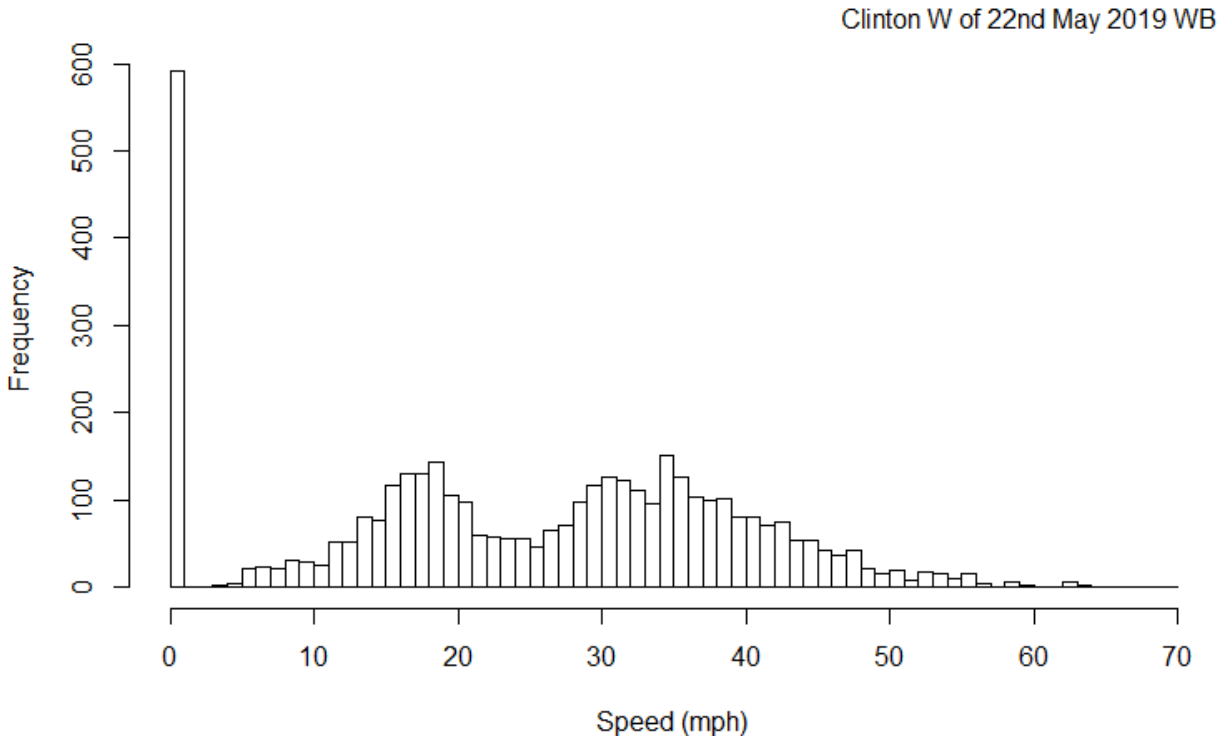

Figure 5-2: Speed histogram for the raw May 2019 Clinton west of 22nd westbound dataset.

The westbound May 2019 Clinton west of 22nd westbound dataset also contained a large amount class one data with speeds higher than would be expected typical for a bicycle. The characteristics and designations of this street do not seem to warrant significant numbers of higher-speed class one traffic such as motorcycles. After removing data outliers resulting from all data cleaning rules and the speed threshold, kernel density functions for class one and class two vehicles were plotted to compare speed distributions (Figure 5-3). If the class two distribution were to correspond with the higher-speed class one data, it could be assumed those

higher class one speeds were due to motorcycle traffic. However, Figure 5-3 shows bimodal distributions for both classes with the class two kernel density plot similarly shaped as the class one and shifted to the right.

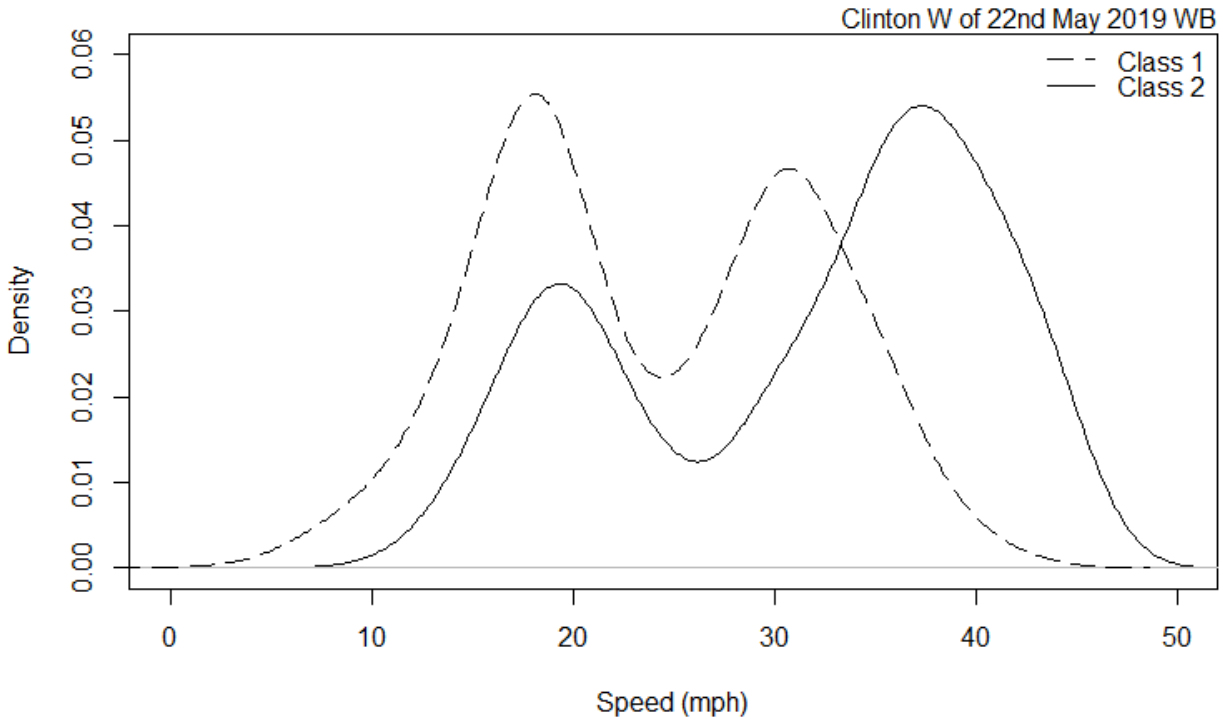

Figure 5-3: Kernel density plot of class 1 and class 2 vehicles for the May 2019 Clinton west of 22nd westbound dataset.

To further investigate the unexpected results from the kernel density plots, class one and class two speeds were plotted with respect to their recorded timestamps (Figure 5-4). From Figure 5-4, it appears that speeds suddenly increased at around 14:00 on Wednesday and remained high through the duration of the traffic survey.

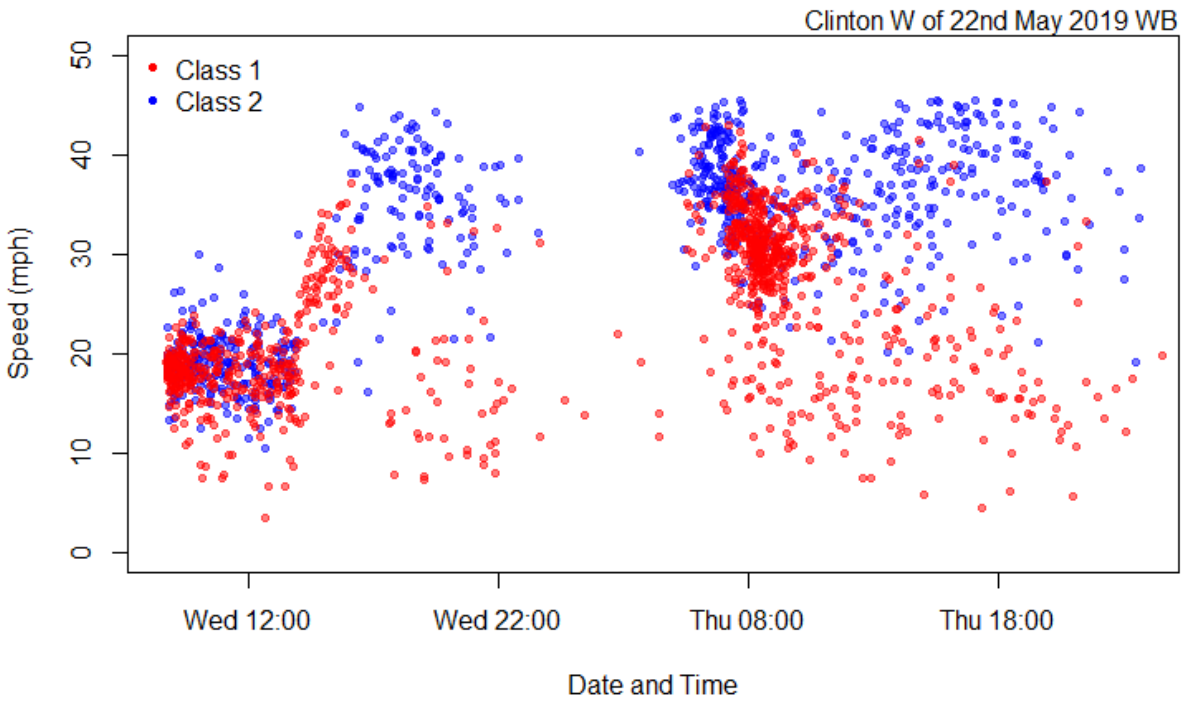

Figure 5-4: Class one and class two vehicle speeds vs date and time for the May 2019 Clinton west of 22nd westbound dataset.

5.3 CLINTON EAST OF 23RD EASTBOUND DATASET DISCUSSION

While both directions of the survey performed in April 2019 on SE Clinton east of 23rd were found to be in the top 10 for the total percent of data excluded from analysis, the eastbound direction dataset had an interesting characteristic. Between 18:01 and 19:47 Tuesday, all 262 recorded observations were classified as class 14 with both gap times and speeds equal to zero. Prior to and after that period, time series plots of gap (Figure 5-5) and speed appear to follow expected patterns.

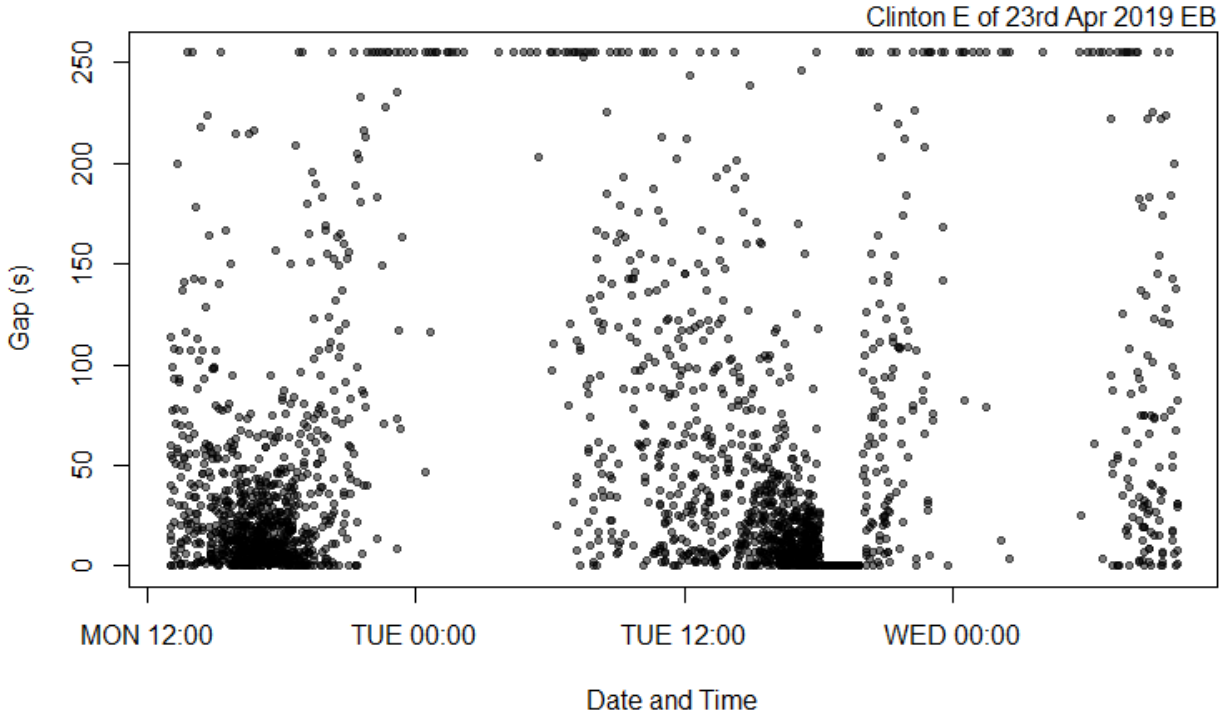

Figure 5-5: April 2019 Clinton east of 23rd eastbound gap vs time plot.

5.4 DETECTION OF CLASS ONE VEHICLES

In the research by *Nordback et al (2016)*, three types of off-the-shelf pneumatic tube counters were tested for accuracy in detecting bicycles in both a controlled environment and in mixed-traffic. Two bicycle-specific counters, three motor vehicle classification counters, and one volume-only motor vehicle counter were tested. The results generally showed all tested equipment undercounted bicyclists with a mean percent error (MPE) of 10% to 73%. Of the classification counters in mixed traffic, the TRAX Cycles Plus model seemed to present a lower overall error than the other two models when using the manufacturer supplied software (13% to 23% MPE vs 32% to 73% MPE).

Nearly all of the raw data files contained a one to three-digit numeric site code representing the ID of the equipment used to collect the survey data. ID numbers greater than 70 represented a TRAX Cycles Plus model. When comparing the class one volume patterns among repeated survey locations along designated neighborhood greenways where higher concentrations of bicycles are likely to be seen, it was observed that datasets collected with a Cycles Plus model seemed to have significantly higher class one volumes per hour compared to datasets collected from the same locations on different dates with an equipment model number less than 70. This observation may help confirm the superiority of Cycles Plus counters in detecting bicycles.

For example, a significant increase in class one observations was noticed between surveys conducted in August 2014 and July 2015 at the Clinton east of 17th location for both eastbound and westbound directions. The site code for the August 2014 data file did not correspond to a Cycles Plus model while the site code for the July 2015 data file did. Table 5-2 gives the start days and dates of the traffic surveys, the duration of the traffic surveys in hours, the total, class one and class two observations, and the average hourly class one and class two vehicle volumes for the Clinton east of 17th location.

Table 5-2: Class one volume comparison for Clinton east of 17th between 2014 and 2015.

Direction	Start Day	Start Date	Hours	Total	Class 1	Class 2	Class 1/ hour	Class 2/ hour
EB	Thu	8/19/14	23	2461	53	1992	2.3	86.6
	Wed	7/16/15	93	3985	1495	2205	16.1	23.7
WB	Thu	8/19/14	23	3302	148	2697	6.4	117.3
	Wed	7/16/15	93	4490	1576	2528	16.9	27.2

In general, it appears as though the Cycles Plus model began being implemented for data collection beginning in 2015 and has been the primary model used since. This is evidenced by the generally significantly smaller portion of class one observations in datasets prior to 2015 relative to data collected in 2015 or later at the same or nearby locations.

6.0 SUMMARY

This report provided definitions of the site and traffic data collected, a summary of the site characteristics, relevant crash statistics, and an analysis of the speed data quality. The 22 locations where repeated surveys were performed, of which 14 underwent changes to the posted speed limit between survey periods, were reviewed. The data cleaning logic and statistics and correlations regarding eliminated data for the 305 unidirectional datasets from 126 unique locations were given. Datasets with a high rate of excluded data were listed and three sites displaying unique traffic characteristics were examined.

The majority of the datasets analyzed were collected from sites with two-way traffic, local or urban collector functional classifications, 20 or 25 mph posted speed limits, complete sidewalks, parallel parking, traffic calming measures, and TriMet bus service. Estimates of grade, segment length, driveway density, and distances to the nearest traffic calming measure, traffic control device, and crosswalk were collected. Road width, bicycle route classification and facility, and manual bicycle count for select locations were among the additional variables collected.

All speed-related crashes within the study segments from 2007 through the date of this report and all fatal crashes from 2007 to 2017 were listed. A total of 42 crashes resulting in 44 injury records were found. The majority (74%) of those crashes occurred along two of Portland's high crash streets, SE Division and SE Holgate.

The quality of the data received for analysis from the Portland Bureau of Transportation was reviewed and discussed. Overall, the data was found to be of high quality, displaying normal or nearly normal speed distributions for class one and class two vehicles for the majority of datasets. The average amount of data excluded from analysis was less than 10%. Three datasets displaying various exceptions were examined and included the February 2019 Lincoln east of 30th eastbound dataset, the May 2019 Clinton west of 22nd westbound dataset, and the April 2019 Clinton east of 23rd eastbound dataset.

Site characteristics of the 22 repeated traffic survey sites, including 14 which experienced a reduction in the posted speed limit between survey periods were given and a summary of active travel characteristics was provided.

The data cleaning rules were provided and statistics about the amount of data excluded by each was given. Data recorded as class 14 was the largest source of exclusion and the February 2019 Lincoln east of 30th eastbound dataset had the highest percentage of class 14 data at 53.6%. The speed threshold excluded very little data in all except one dataset, the May 2019 westbound Clinton west of 22nd dataset which had 6.68% of observations exceeding the threshold of 25 mph over the posted speed limit. The shape of the speed distribution appeared to be highly bimodal and a sudden increase in speeds early in the survey was found when examining a time series plot

of that dataset. The ten datasets with the highest total percentages of data eliminated by the cleaning rules were listed.

Correlations between the amount of data excluded by the cleaning rules found that observations recorded as class 14 and observations with a speed of zero mph were highly positively correlated. Other significant positive correlations were seen between data recorded with a gap time of zero seconds and speed of zero mph or a gap time of zero and recorded as class 14.

Finally, a change in the average hourly volume of class one vehicles was observed in some datasets from repeated sites along neighborhood greenways. In some of the original data files, a "WITH BIKES" comment was present. Data files containing the comment were found to have higher class one average hourly volumes than those files without. An exception was noted for the Clinton east of 17th site where a significant increase in class one average hourly volume was seen between the August 2014 and July 2015 surveys despite an absence of a "WITH BIKES" comment in both original data files.

7.0 REFERENCES

FHWA. (2016). Appendix C of *Traffic Monitoring Guide*. Washington DC: USDOT.

Forbes, G. (1999). Urban Roadway Classification: Before the Design Begins. *Urban Street Symposium Conference Proceedings, TRB Circular E-C019*.

McGowen, P. & Sanderson, M. (2011). Accuracy of Pneumatic Road Tube Counters. *Proceedings of the Institute of Transportation Engineers 2011 Western District Annual Meeting*, Anchorage, AK.

Metro & USGS. (2011). 10 foot contours of the Portland, OR metro area. Retrieved from https://databasin.org/datasets/e5f48e27860046c6b4bc14d64adf1ceb

Nordback, K., Kothuri, S., Phillips, T., Gorecki, C., & Figliozzi, M. (2016). Accuracy of Bicycle Counting with Pneumatic Tubes in Oregon. *Transportation Research Record, 2593*(1), 8-17.

ODOT. (2012). *Oregon Transportation Map: Portland, Portland – Gladstone, Portland – Mount Tabor*. Retrieved from https://www.oregon.gov/odot/data/pages/maps.aspx

PBOT. (2018a). *Portland Bike Counts*. Retrieved from https://docs.google.com/spreadsheets/d/1urP-ZA0Pd25_JZZ18hkGPlDEUQusBp49XmLzwpZ-2ag/edit#gid=0

PBOT. (2018b). *Transportation System Plan*. Portland: PBOT.

PBOT. (2019). *Vision Zero crash map*. Retrieved from https://arcg.is/1fT4W4

Schaefer, J. (2019). *SPR Data Collection Locations*. Retrieved from https://drive.google.com/open?id=1Atxw_H36352EWOXU5wQtnxxmRZ5tjrm6&usp=sharing

Trimet. (2019). *Bus System*. Retrieved from https://trimet.org/bus/index.htm