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Heavy Vehicle Classification Analysis Using Length-Based Vehicle Count and Speed Data

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Heavy Vehicle Classification Analysis Using Length-Based Vehicle Count and Speed Data

by

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A thesis submitted in partial fulfillment
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DEDICATION

I dedicate my thesis to my beloved family. My father, Ismet Yuksel, who taught me to be honest, hardworking, and struggle. My mother, Leman Yuksel, who filled my life with her care and love. Also, my sisters, Irem, Ecem Nur, Burcu Sera, who have always been with my side with their cheerfulness.

I would like to dedicate my thesis to my uncles, Hacı Musa Unal and Levent Unal, who trusted and encouraged me for my academic career in the United States of America.

Finally, I would also dedicate my thesis to my country and my people. I would not have gained master's degree from the USA if the Republic of Turkey - Ministry of Education had not supported me.

To all whom martyr for homeland and on the path of education for the Republic of Turkey.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

There is an increasing demand for application of Intelligent Transportation Systems (ITS) in order to make highways safer and sustainable. Collecting and analyzing traffic stream data are the most important parameters in transportation engineering in enhancing our understanding of traffic congestion and mobility. Classification of the vehicles using traffic data is one of the most essential parameters for traffic management. Of particular interest are heavy vehicles which impact traffic mobility due to their lack of maneuverability and slower speeds. The impact of heavy vehicles on the traffic stream results in congestion and reduction of road efficiency. In this paper, length-based vehicle count and speed data were analyzed and interpreted using one week's data from Interstate 5 (I-5) in the Portland, Oregon (OR) region of the United States (US). I-5 was chosen due to its prominent role in promoting North-South freight movement between Canada and Mexico and its vicinity to the Port of Portland. The objective of this analysis was to find better visualization techniques for the length-based traffic count and speed data. In total, 13,901,793 out of 56,146,138 20-second records were analyzed. The vehicles were classified into two categories. Those that were 20 feet or less were considered as passenger vehicles and those above 20 feet were considered as heavy vehicles. The data consisted of approximately 25% heavy vehicles. Results showed the merit of applying more disaggregate data (5-min polar, and radar plots) for better visualization as against hourly, and 15-min plots in order to capture sudden changes in average speed, heavy vehicle volume, and heavy vehicle percentage.

CHAPTER 1: INTRODUCTION

1.1 Background

Classification of the vehicles using traffic data is one of the most important parameters for traffic management. In our era, because of the increasing number of the vehicles and consequently increasing roads, vehicle classification based on traffic data is a useful method to detect and intervene roadway segments which need to be improved. Because of the time and cost constraints, managing roadways can be done by Intelligent Transportation Systems (ITS) easily and efficiently. Due to the ease of installation and use, there is an increasing demand for ITS and to meet this increasing demand, it is essential to use and analyze data obtained via the ITS technologies.

There are many types of ITS devices for classification of vehicles and data collection sources such as piezoelectric sensors, inductive loop detectors, video-image processing systems, or magnetic detectors. Among these, inductive loop detectors (single or dual loop) have wide application spectrum for traffic surveillance. The reason for this is that these detectors are affordable compared to other devices, and installation methods of the loop detectors are easier than other systems. However, these devices may lead to a classification inadequacy due to the device calibration which affects the data quality. On the other hand, data interpretation is another important parameter for classifying vehicles as well as data quality. Technological development requires processing data quickly and efficiently so that data should be analyzed no matter how big it is. Since traffic stream is a dynamic process, successful analysis of the data enables the practitioner to intervene in the traffic conditions and also allows for necessary improvements/innovations on the road segments.

1.2 Motivation

Data analysis and interpretation are essential parts of transportation engineering. Kitamura & Fujii (1997) expressed the importance of the data as a perspective of travel behavior to attract the attention of congestion, energy consumption, and air pollution. Huang et al. (2017) mentioned high-quality data help to find the rate of the casualty caused by motor vehicles so that traffic crashes can be prevented by developing some approaches using the high-quality data. Moreover, traffic parameters can be forecasted to find inflowing or outflowing rates of freeway sections. Davis et al. (1990) investigated lane occupancy and inflow-outflow differences for a short segment of a freeway using few minutes traffic data.

Accurate analysis of traffic data is an efficient way of classifying vehicles. Due to the increasing number of the passenger cars and trucks, detection and verification of these types of vehicle's presence on the road sections are getting harder day by day especially for heavy vehicles. Since trucks operate at a certain time of the day, analyzing raw traffic data gets more meaning. The data obtained by state departments of transportation (DOTs) are converted into meaningful measures such as truck miles traveled and average annual daily truck traffic (Benekohal & Girianna, 2003).

It is also useful to analyze traffic data to understand freight behavior in terms of national economy. There is an increasing percentage of the highway systems caused by trucks so that it leads to increase market share for freight (Bertini et al., 2006). Freight movement is not only a measurement for the gross national product (GNP) but also a measurement which affects other economic sectors because of its influence on the distribution of goods and transportation (Crainic

& Laporte, 1997). Ozkul et al. (2015) mentioned the importance of freight movement in global perspective saying that the US has the biggest consumption rate in terms of demanding services, commodities, and services.

Traffic data analysis is also an effective way to figure out the effects of heavy vehicles on freeway or highway segments. Washburn & Ozkul (2013) analyzed in detail the characteristics of the truck fleet on Florida's freeways and multilane highways. The data are obtained by weigh-in-motion (WIM) stations throughout the State and they are analyzed to determine truck classification, loading conditions, and developing a reasonable passenger car equivalent (PCE) value for Florida roadways.

On the other hand, vehicles which move slower than other vehicles impede the traffic stream and service level severely (Cunha & Setti, 2011). To manage and intervene traffic congestion situations on roadways, data must be analyzed accurately. Well-analyzed and interpreted data give valuable information such as morning or night peak time so that taking necessary precautions would be easier.

Based on the studies mentioned above, it can be deduced that collecting traffic data, analyzing them correctly, and interpreting the data meaningfully are essential parts of ITS.

1.3 Objectives

The main purpose of this thesis is to provide the detailed analysis of 20-second length-based traffic count and speed data obtained from the city of Portland/OR, to express the analysis results graphically, and to interpret the results in terms of truck presence on a given segment of the roadway in Oregon State. Vehicles longer than 20 feet had been considered as heavy vehicles in this study. The specific principles overarching of this study are as follows:

- To obtain, clean, understand and analyze northbound and southbound traffic stream (count and speed) data on I-5 in the Portland/OR region between Alberta Street and Marine Drive
- Using the traffic stream data, to examine the presence and the classification of heavy vehicles in the traffic stream, using length and speed as the categorizing variables
- From the results of the analysis, to generate graphs, timeseries-surface, and timeseries-polar plots to better understand the relationship between these trucks types and the overall traffic stream including time of the day, the day of the week, percentage, and volume of trucks
- To interpret these graphs, and plots in order to derive results that can be useful for trucking and public entities while they make their daily routing decisions.

1.4 Organization of the Thesis

The remainder of this thesis is organized as follows. Chapter 2 gives an extensive literature review about the thesis topic which consists of inductive loop detector technology, vehicle classification methods, algorithms, speed estimation methods, and truck volume estimation based on inductive loop detector data and the importance of traffic stream data. Data visualization using traffic data is also discussed in this chapter. Chapter 3 describes the data using by Portland Transportation Archive Listing (PORTAL) and explains the data obtained from PORTAL for the count and speed analysis. Chapter 4 gives information about the analyzing techniques undertaken in this study. Moreover, graphs, histograms, and plots are also provided in this chapter. Chapter 5 is about analysis methodology and results. Finally, Chapter 6 talks briefly about conclusions, and provides recommendations for future researches.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Vehicle classification using traffic flow data is one of the essential parameters for traffic management. In terms of road infrastructure sustainability, improvement of traffic facilities, management of traffic flow, it is important to have traffic data for classifying vehicles based on their observable characteristics such as speed and length. There are some traffic data collection systems for counting and classifying vehicles as intrusive or non-intrusive systems. Piezoelectric sensors, magnetic detectors, inductive loop detectors, and pneumatic road tubes can be given as examples of intrusive technologies. On the other hand, infrared detectors, video-image processors, ultrasonic detectors, and microwave radars are some examples of the non-intrusive technologies. Among these, inductive loop detectors are used most often throughout the US because of their simple installation methods and affordable prices. Single-loop detectors offer information about traffic volume and occupancy but not necessarily vehicle speed. In literature, however, there are some approaches to estimate vehicle speeds applying algorithms. In terms of pavement design, road safety, and geometric design, analyzing truck characteristic is also important for traffic operation. Moreover, keeping track of the freight movement, it is essential to have truck classification data for the economic purposes. This chapter provides information about the inductive loop detector technology and vehicle classification and speed estimation based on the data which retrieved from inductive loop detectors for both passenger cars and trucks. In addition, data visualization using traffic data also is discussed in this chapter.

2.1.1 Inductive Loop Detector Technology

An inductive loop detector, single or dual loop, consists of two main components which are electronic detector module and inductive loop coil buried beneath the road infrastructure. The detector is a device which is induced by an alternating current (AC) signal and turned them into a resonance circuit. This circuit creates an electromagnetic field ranging from 10 KHz. to 200 KHz. The electromagnetic field induced if a metallic object passes through on it so that it creates a magnetic flux for opposite direction of the field. This opposite magnetic field causes reduction of the magnetic flux. Because of the proportional relationship between the magnetic flux and inductance, decreasing of magnetic flux results in a decreasing of loop inductance. On the other hand, there is an inversely proportional relationship between the inductance and resonance frequency in a resonance circuit. Once the inductance goes down, frequency goes up (Kwon, 2005).

As mentioned above, while a single loop detector can measure only volume and occupancy, a dual loop detector can measure speed and length too. Basically, a dual loop detector is a device which consists of two single loop detectors which are several meters apart from each other (Zhang et al., 2005). Figure 2.1 represents a vehicular movement on dual loop detectors based on time and distance, and also shows the inductance change while the vehicle passes through the loop detectors.

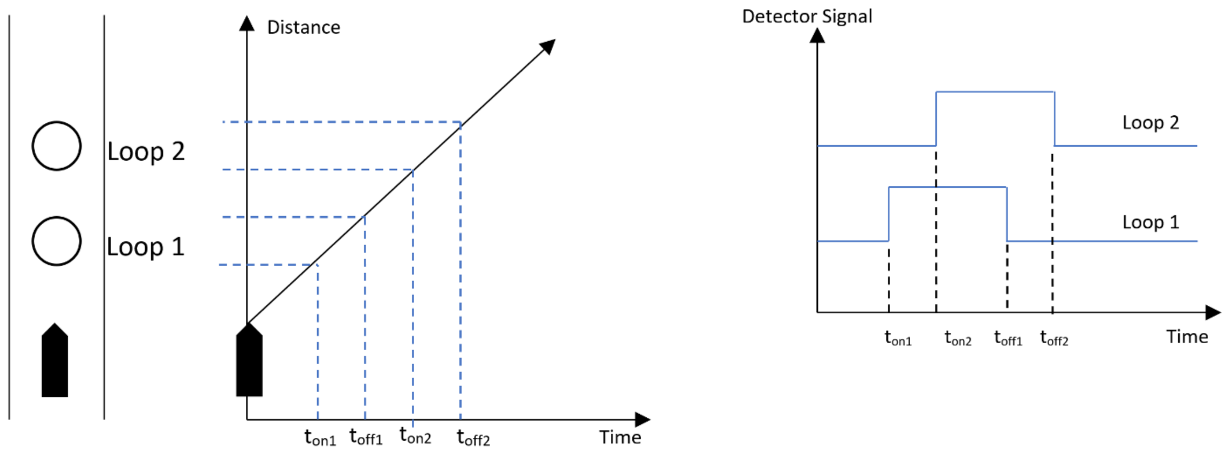

Figure 2.1: Time space relationship for speed measurements using dual-loop detectors (Adapted from Hellinga, 2002)

Due to an inductance changes while a vehicle passes on the detector, it is possible to detect vehicle existence. The detector detects and assigns this inductance changes as a volume and occupancy. Moreover, since loop dimensions and the interval between loops are known as distance, a vehicle speed can be calculated by dividing total length (L_{Loop} + $L_{Interval}$) to the time difference ($t_{off2} - t_{off1}$). Furthermore, vehicle length also can be calculated by multiplying vehicle speed and time difference ($t_{off2} - t_{off1}$) then subtracting by loop length (L_{Loop}) (Hellinga, 2002).

2.2 Vehicle Classification and Speed Estimation Using Inductive Loop Detector Data

Several studies in the literature investigated the classification of the vehicles using inductive loop detector data. Among these, Gajda et al. (2001) proposed to use inductive loop detectors instead of piezoelectric systems which are cheaper vehicle detection systems than piezoelectric systems. Classification of vehicles using inductive loop detectors is based on the detectors' magnetic profiles. Moreover, these magnetic profiles are affected by loop dimensions.

Gajda and his colleagues investigated the effect of loop length to classify different types of vehicles on their studies and proposed an algorithm. Probability function, time domain magnetic profiles, and vehicle length domain magnetic profiles have been used to describe the magnetic profiles of the vehicles. According to the test results, it is possible to preserve high efficiency of the vehicle classification changing inductive loop detectors in lieu of piezoelectric systems.

It is also possible to use single loop detectors instead of dual loop detectors. Wang & Nihan (2003) proposed an algorithm for single loop detectors that makes them act as dual loop detectors. It is essential to have real-time speed and vehicle classification data for traffic management and control systems which are not directly measured by single loop detectors but dual loop detectors. Since the cost of the dual loop detectors are higher than single loop detectors, having an accurate algorithm for single loop detectors is desirable. Before applying the proposed algorithm, they divided vehicles based on their lengths into two different categories which are short vehicles (SVs ≤ 11.89 m) and long vehicles (LVs > 11.89 m). After that, Wang and Nihan estimated speeds and classified vehicles using the algorithm based on two fundamental assumptions. First, it is essential to have steady mean speed for every single period. Second, these single periods need to have at least two vehicles which are SVs. Researchers found that the estimated results for period mean speeds and LV volumes are consistent and give reasonable results if the two fundamental assumptions are met.

Hazelton (2004) presented a new method to predict speed determined by traffic count and occupancy data. His approach mainly focuses on speed estimation for individual vehicles. Analyzing vehicles with aggregation level results in bias so that it is a good technique to estimate vehicle speeds individually. But, the problem is a huge amount of missing data at the level of disaggregation. To deal with this problem, he provides a Markov Chain Monte Carlo (MCMC) methods. It has been used to obtain Bayesian estimates of the average speeds of vehicles over every single time interval. His results show that the root mean squared difference between the data and his estimation is 4.3 mph. It indicates that the approach did an acceptable job of reproducing speeds.

Coifman & Kim (2009) estimated speed and classified vehicles based on their lengths using single loop detectors. They refined their existing speed estimation algorithm to get an accurate speed. After the prediction of the speed, they split up the vehicles into two effective vehicle length categories which are 28 feet and 46 feet using three bins. After that, a vehicle comparison has been made with each other using two classifications. For these two classifications, one can say the vehicles are correctly classified if they are identical. Otherwise, the vehicles can be considered as over-classified or under-classified. Their methods are different than earlier efforts because this approach makes possible classification of individual vehicles instead of using aggregate data which make the classification results close to those from the dual loop detectors.

Monitoring congestion level on freeways is another usage area of traffic flow data. Wang et al. (2002) proposed an approach to monitor freeway congestion using single loop detectors. After obtaining the data, it has been processed taking nine consecutive 20-second intervals from the detectors. According to the processed measurements, it has been estimated 3-minute period of speeds. Based on the speed estimation, they produced a congestion information. Their procedure consists of three steps which are preprocessing of single loop data, prediction of traffic speed, and congestion detection. In the single loop data preprocessing step, they divided vehicles into two categories which are SVs and LVs. Short vehicles represent the vehicles that are shorter than 11.89 meters while long vehicles are longer than that value. For the next step, they estimated traffic speed based on space-mean speed equation using the speed estimation parameter (g) as a constant. As a final step, researchers detected congestion based on the estimated speeds. Two criteria must be met in order to be considered as congestion starts: 1) The speed of traffic reduces two consecutive periods, and 2) Three consecutive period's arithmetic mean speed is less than 90% of the free flow speed. For both congested and uncongested situations, their system performed consistently well.

It is also possible to investigate and to propose a solution for traffic congestion such as bottlenecks or traffic queue using freeway sensor data. Bertini (2006) explained a diagnosis to evaluate the traffic conditions using most raw sensor data. In general, bottlenecks are temporally and spatially parameters. So that, it is hard to detect bottlenecks on the freeway systems. By using inductive loop detectors, it is easier to detect bottlenecks and to get valuable information about traffic conditions on freeway segments at a single point or beyond. Moreover, installation of these detectors on on-ramps or off-ramps also provides a reasonable picture of traffic operations. Several diagnostic tools have been explained in his article such as curves of the total number of arrival vehicles versus time and total occupancy versus time. If these curves transform appropriately, it will be easy to understand and interpret the transition from free flow condition to queue condition. Creating these curves from the data provided by loop detectors indicates that it is possible to realize bottlenecks' locations as well as starting or ending times of the bottlenecks on the freeway systems.

Monitoring traffic is another significant part of roads' performance measurement. Moreover, it helps to figure out which part of the road should be improved or how can we use roads efficiently in terms of traffic flow and safety. So that traffic surveillance data can be used for classifying vehicles. In practice, there are a lot of vehicle classification schemes for classifying vehicles. Among these, Federal Highway Administration (FHWA), FHWA-I, and Real-time Traffic Performance Measurement System (RTPMS) are used by Jeng & Ritchie

(2008) as a classification scheme. As a proposed model, decision tree and K-means clustering approaches presented in their research. According to their results, categorizing vehicles based on FHWA scheme and grouping them in a more detailed class are possible. Furthermore, the proposed model allows categorizing vehicles simply with the existing detection infrastructure.

Even though dual loop detectors work well on free-flow traffic conditions for measuring and classifying vehicles, they do not show the same performance on non-free conditions. Wei et al. (2011) investigated how dual loop detectors work on synchronized or stop-and-go traffic conditions. In their research, they proposed eight different scenarios based on the vehicles' position on dual loop detectors. Moreover, they developed three different models to classify vehicles' length more appropriate based on the scenarios. The first model was developed for the stop-and-go condition while the second one created for the synchronized traffic condition which considers vehicle's acceleration/deceleration rates. The last model was generated for the vehicles which locate in between the loops. According to their results, it has been seen that the proposed models based on the scenarios increase the accuracy of vehicle length classification.

In literature, there are also some other approaches and techniques to classify vehicles based on traffic stream data. Coifman (1996) developed a new digital filtering methodology to make loop detector data smoothly. Zhang et al. (2007) classified vehicles according to their lengths using data which obtained from video-based vehicle detection and classification system. Based on the computer vision-based algorithms which are developed by the authors, the algorithms detect, identify, and extract background images and classify vehicles based on pixel-based vehicle length calculation method. Avery et al. (2004) used an uncalibrated video camera data and extracted image stream from the camera. Vehicles are classified based on their lengths by using an image processing algorithm. Šarčević (2014) classified vehicles using traffic data by applying neural networks. Zhang et al. (2006) classified vehicles using artificial neural network based on the length-based data retrieved from single loop detectors. Toth & Grejner-Brzezinska (2005) estimated traffic flow via airborne imaging sensors data. Oliveira et al. (2010) identified the vehicles by applying the Levenberg-Marquardt algorithm to the artificial neural network (Multiple Layer Perceptron). Zhang et al. (2010) detected vehicles from high sensitive and low-cost magnetic sensors which is called binary proximity sensors and measured vehicles' magnetic field distortion to obtain vehicle geometrical characteristics and identify vehicle types using an intelligent neural network based on these characteristics.

Sun & Ban (2013) proposed a vehicle classification method using geographic positioning system (GPS) data which are retrieved from mobile traffic sensors. Sullivan et al. (1997) used fixed road camera data to make an orthographic approximation on a multi-lane motorway for classifying and monitoring traffic. Fang et al. (2007) used a Doppler signature which was created by the vehicles and processed their signals to get an information about the vehicles' speed and shape. In their research, they detected and classified vehicles based on a K-band (around 24 GHz) unmodulated continuous-wave radar.

2.3 Truck Volume Estimation Using Inductive Loop Detector Data

This section provides a brief overview from some of the studies which are about truck volume estimation using inductive loop detector data. Kwon et al. (2003) proposed an algorithm to estimate truck traffic volume in multilane freeways for real-time which is applied to data retrieved from single loop detectors. In principle, it is essential to have an algorithm that estimates speed, flow, occupancy and effective vehicle length using the known average speed from single loop detectors that reported only traffic volume and occupancy. There is also an average speed relationship between truck-rich lane(s) and truck-free inner lane(s) which makes it possible to high correlate lane-to-lane speed. Using of the proposed algorithm, results show that the algorithm can be used at major urban freeway locations except close to on- and off-ramps.

Wang & Nihan (2004) used an algorithm from the data obtained by single loop detectors for large trucks (LT) to estimate their volumes and they compared these volumes with the data retrieved by dual loop detectors. Their proposed algorithm consists of two steps which are separating intervals. First is an interval which consists of a 20-second duration of a single volume or occupancy measurement with LTs from those without. Second is extraction of possible LT volumes from the data applying by nearest neighbor decision rule. Before applying the algorithm, two fundamental assumptions are required to meet which are every period (multiple intervals) should contain at least two intervals and vehicle speeds considered as a constant and at least two intervals should not have LT volumes in each period. After implementation of the algorithm, they found that LT volume series matched each other very well for both dual loop detectors and single loop detectors particularly when the traffic volume was low.

Another large truck volume estimation study has been done by Zhang et al. (2008). In their research, an Unscented Kalman Filtering (UKF) algorithm was applied to the data obtained from single loop detectors to estimate the vehicle speed. After the estimation of the speed, they estimated mean effective vehicle length (MEVL) and large truck volume respectively. Their results show that their method works well in different traffic conditions. Zhang et al. (2005), proposed an algorithm for Washington State Department of Transportation dual loop detectors to fix its inconsistent truck data due to raw loop actuation signal errors which causes reporting the truck data lower than actual amounts. It has been found that the algorithm proposed by the researchers make a better job in terms of fixing signal errors.

Classifying trucks also helps to analyze freight movements. Bertini et al. (2006) investigated freight movement to better understand the impact of increased number of truck volumes on road networks because, more information about freight movements is essential to improve highway management. In their research, they collect and verify vehicle count and length data by applying current ITS technologies in Portland metropolitan region. Video image processing, closed circle television network (CCTV), and inductive loop detectors can be given as examples for the current ITS technologies. To analyze short and long vehicles, they implemented the Nihan-Wang algorithm to their dataset obtained by existing loop detectors in Oregon Department of Transportation (ODOT) and PORTAL and then compared them with the video image processing data. Findings of the research show that the Nihan-Wang algorithm results accurate in certain situations especially for long vehicles but for other situations the algorithm under- or over- estimated truck volumes. On the other hand, video image processing results did a better job than the algorithm in terms of producing individual vehicle speeds and determining truck and passenger vehicle counts.

Many transportation departments and traffic management agencies use single loop detectors to get traveler information and management of traffic because of its cheapness. These detectors also help to distinguish trucks from passenger cars. Since truck densities change according to time of the day or location, it effects vehicle percentages on road segments. Although single loop detectors provide only traffic flow and occupancy data, to know speeds, especially for trucks, is a necessity in terms of traffic management and vehicle classification. In literature, there are not many studies dealing with the estimation of heavy vehicle speeds. Coifman & Neelisetty (2014) proposed a new methodology to estimate speed using single loop detectors on the freeway segments where the truck percentage is high. Their hybrid algorithm combines two equations which are median on-time estimation and median of all vehicles during time ‘T.’ This hybrid approach provides significant development over conventional speed estimation.

Effects of slow-moving vehicles such as trucks are another parameter to investigate. Level-of-Service (LOS) on highways reduces rapidly because of the truck volumes. Analyzing truck volume data on highways hard to figure out apart from passenger cars. To simplify it, there is an approach that is called as passenger car equivalent (PCE) to solve this problem which converts trucks to the passenger car equivalent. Cunha & Setti (2011) investigated the estimation of truck-passenger car equivalents (PCEs) for divided highways in Brazil. Their truck characteristic samples are based on the observations which are collected from 17 toll plazas. According to the data, four-class truck classification scheme was created. These data recalibrated using a genetic algorithm on CORSIM to derive new PCEs with varying grade magnitudes, grade lengths, and truck percent ranging scenarios. Their results show that obtained PCEs may improve LOS estimates.

2.4 Data Visualization Using Traffic Data

Since traffic stream is a dynamic process, it is essential to visualize traffic data for keeping track of the traffic movement, information about road segments, or intervening a traffic incident etc. Lund & Pack (2010) emphasize that the importance of traffic data visualization saying that because of the interaction deficiency of the traditional data analysis tools between traffic congestion and incident data, it is required to have an effective visualization tool in terms of identifying traffic problems using historical or real-time traffic data.

Identifying congestion areas, displaying major bottlenecks or analyzing travel time reliability provide significant capabilities for analysts using web-based traffic surveillance system and visualization tools. Moreover, traffic monitoring systems are significant opportunities for states which want to improve road segments, travel time reliability or transportation projects (Pack, 2012).

Even though data visualization tools provide various possibilities for states, traffic agencies or public entities, incomplete information from the data retrieved from detectors reduces the accuracy of the data and also visualization. Treiber & Helbing (2003) presented a new method called “adaptive smoothing method” which allows using the data without calibration. Based on researchers’ technique, results show that the method is robust and can be used between detectors not further away 3 km.

In the US, there are three major transportation archives that provide a diverse performance evaluation, measure, and visualization which are IterisPeMS (iPeMS), Regional Integrated Transportation Information System (RITIS), and DRIVENet (Tufte et al., 2015). In general, these tools provide traffic data and visualization tools which allow users for their analysis, displaying, and research purposes. In addition, PORTAL is another transportation archive in the US. The detailed explanations about the PORTAL are provided in next chapter.

In conclusion, vehicle classification using inductive loop detector data has a wide usage area for classifying vehicles. These classifications help to better understand the characteristic of the vehicles and traffic flow. Moreover, visualizing these data makes easier to figure out the road segment where needs to be improved immediately, managing traffic stream appropriately, or tracking freight movement carefully. In light of aforementioned vehicle classification and speed estimation studies, traffic data can be obtained by inductive loop detectors for analyzing vehicle characteristics. In addition, the data which are visualized can be reached by public entities, transportation agencies, or consultants so that they can make their daily decisions easily. The main purpose of this thesis is to classify vehicles as freight and non-freight vehicles based on 20-second length-based traffic data obtained during a week and generating plots to find better illustration methods for vehicle average speed, heavy vehicle volume, and heavy vehicle percentages on the same graph.

CHAPTER 3: DATA DESCRIPTION

3.1 Introduction

Traffic data are highly essential for transportation planners in their jobs. Moreover, traffic data provide information about vehicle speed changes, amount of the vehicles, travel time information, etc. These data also give an opportunity to find road segments which need to be improved. The rapid developments in technology lead to an increasing amount of data for transportation engineers. To overcome this amount of dataset, they must be analyzed very carefully to have meaningful results for the public who use these roads every day. Having meaningful and applicable results may help alleviate any issues that might happen on the analysis of road segments. Furthermore, results of the data can help the public plan their daily trips. The following sections of this chapter give an overview of the traffic data of PORTAL, and the dataset explanations which are provided by PORTAL for this thesis.

3.2 Portland Oregon Regional Transportation Archive Listing (PORTAL)

The PORTAL is an official transportation archive project developed by Portland State University (PSU) and designed for Portland-Vancouver Metropolitan Region. PORTAL have stored data from around 500 loop detectors to collect and archive speed, volume, and occupancy since July 2004 (Bertini et al, 2006). The main purpose of PORTAL is to provide and share information about the data for the public agencies. Before sharing the information, PORTAL collects and archives data from the electronic databases. The collected data by PORTAL include

20-second aggregation data retrieved from inductive loop detectors on the freeway segments of Portland-Vancouver metropolitan region. Apart from 20-second aggregation data, PORTAL also includes;

- Arterial signal data
- Transit data
- Value-Added Service (VAS) data
- Variable Message Signs (VMS) data
- Truck volume data
- Incident data
- Weather data

The archive contains historical and real-time transport data for agencies in the Vancouver-Portland area in one place. Moreover, PORTAL data archive has detailed information about vehicle miles traveled (VMT), vehicle speed, and travel time for the corridors of freeways and separate locations along a freeway. Individuals and traffic agencies such as metropolitan planning organizations (MPOs), traffic management operators, or transportation planners are free to obtain information about hourly delay, travel time, and VMT via PORTAL.

3.2.1 PORTAL Architecture

The PORTAL system mainly focuses on arterial, freeway, and highway data. ODOT Region 1 Traffic Management and Operation Center (TMOC) provides data instantly which is obtained by inductive loop detectors. These detectors are installed in mainline and on-ramps on the Portland region freeways and highways. As shown in Figure 3.1, the data obtained from the detectors is transferred via fiber optic connections between ODOT and PSU. ODOT servers supply data as a 20-second interval period to PSU servers with the format of Extensible Markup

Language (XML). After that, PSU enters the 20-second interval raw data into a software called PostgreSQL which is free and open-source system software as an object-relational database management system (RDBMS). Every morning at 3 a.m., the previous day's data is converted into the level of aggregation of 5-minute, 15-minute, and 1-hour in order to process the data faster.

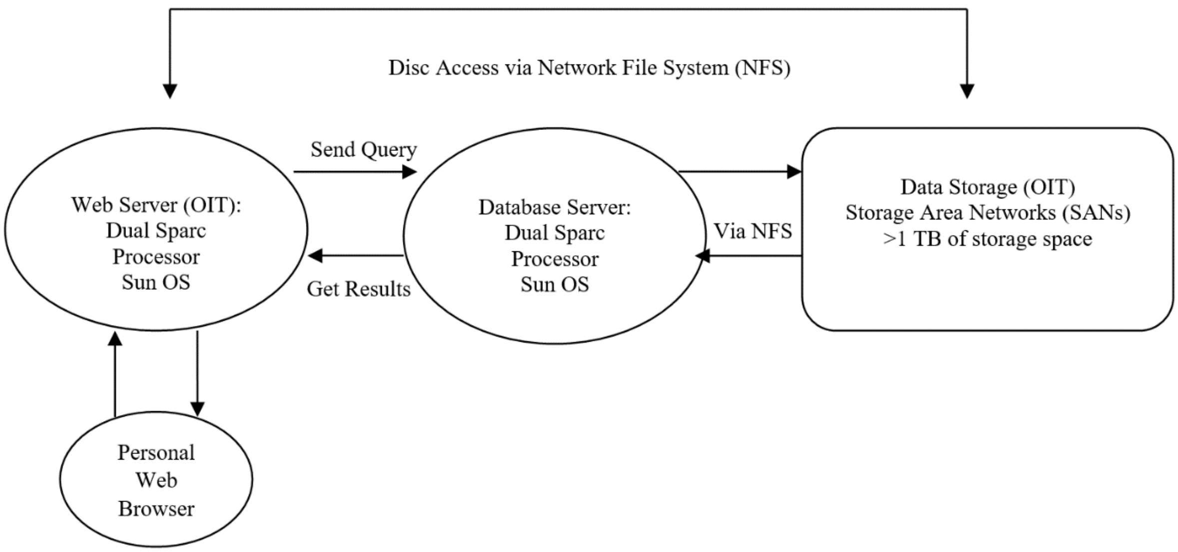

Figure 3.1: Flow chart of PORTAL architecture (Adapted from Bertini et al. 2005)

3.2.2 User Interface of PORTAL Website

PORTAL website provides an access to raw datasets and performance measures for the public and traffic agencies easily. 20-second raw data are available to download for the users as comma-separated values (CSV) files. Figure 3.2 shows PORTAL homepage (https://portal.its.pdx.edu/home). The homepage of PORTAL website shows live traffic speeds and 15-minute average speed over last 5 days and consists of several menu options such as Highways, Stations, Arterial, Freight, or Transit. Some of the menu options are explained below.

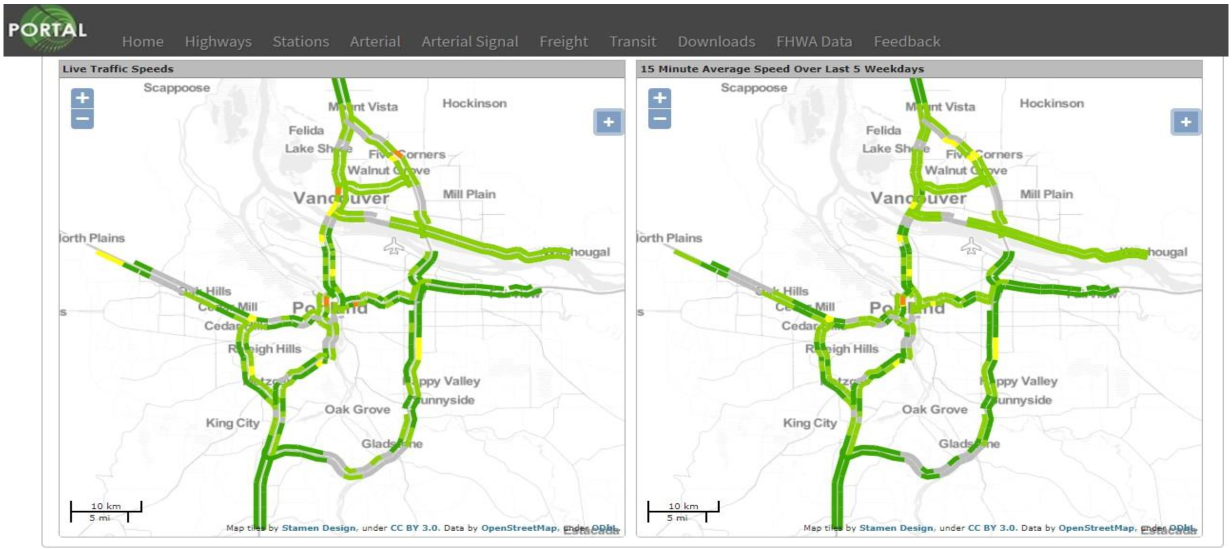

Figure 3.2: Homepage of PORTAL website. Public Domain Image

3.2.2.1 Highways Tab

Highways tab of PORTAL website includes the names of the highways, starting dates, and starting and ending mileposts. Based on the given variables, users can easily access speed, total volume, and VMT versus start time plots and timeseries-speed contours. Highway names are shown in Table 3.1.

Figure 3.3 shows speed-time, total volume-time, and VMT-time relationship on a single graph. One can also see the peak hours, speed changes, and distribution of total volume on the same graph. Figure 3.4 is a timeseries-speed contour which shows the traffic speed changes along the roadway segment. This contour allows users to find bottlenecked area visually. Moreover, it is also possible to analyze the bottlenecks by looking at the graph. Between the starting-ending time and mileposts of the red pixels on the graph, one can easily interpret how long bottleneck lasts and which roadway segment requires precaution. Both Figure 3.3 and Figure 3.4 belong to May 3, 2017.

Table 3.1: Name of the highways and travel direction on PORTAL website

	Travel Direction			
	Eastbound	Westbound	Northbound	Southbound
Name of the Highways	I-84	I-84	I-205	I-205
	SR-14	SR-14	I-405	I-405
	SR-500	SR-500	I-5	I-5
	US-26	US-26	OR-217	OR-217
	-	-	WA I-205	WA I-205
	-	-	WA I-5	WA I-5

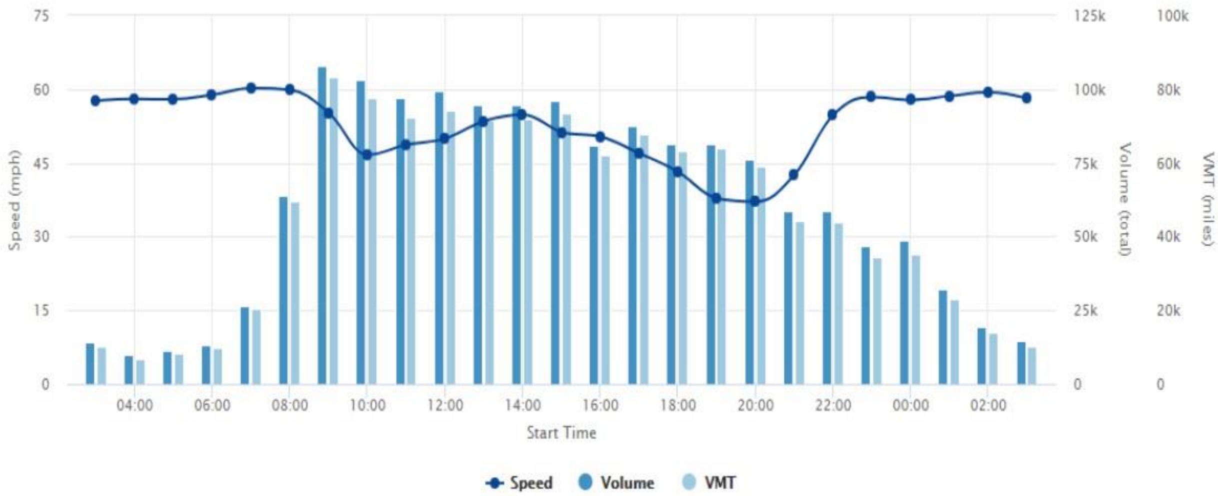

Figure 3.3: Speed-Volume-VMT vs Start Time plot on May 3, 2017. Public Domain Image

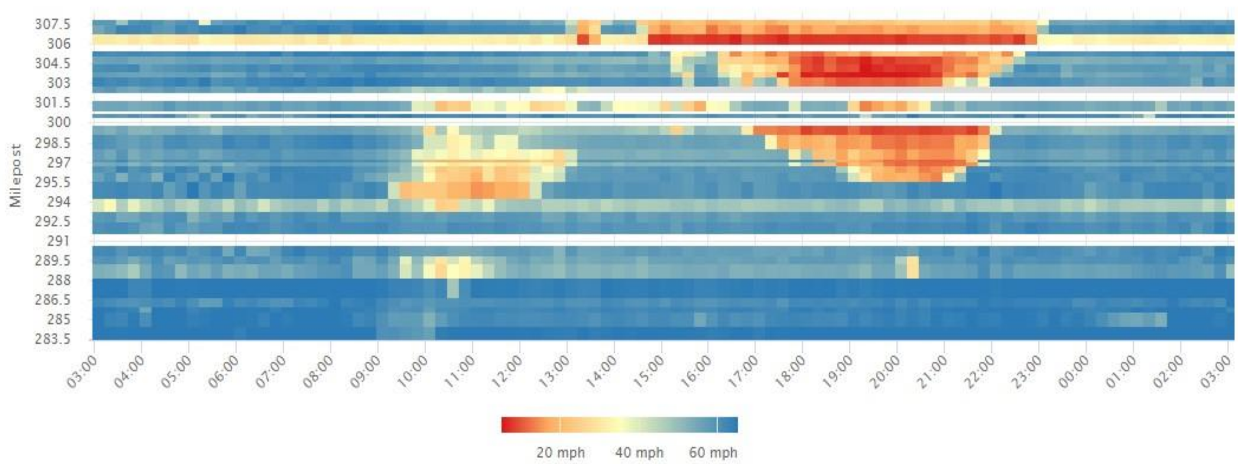

Figure 3.4: Timeseries-speed contour on May 3, 2017. Public Domain Image

3.2.2.2 Freight Tab

Freight tab includes data range, measure type, chart type, and resolution. Data range is the time scale which allows users to find desired time scale while measure type allows desired classification types such as length or speed. Moreover, using chart type, users can see classifications with different charts. There are five types of charts which are line, spline, stacked line, stacked spline, and stacked column with different resolutions such as 15-minute, 1-hour, and 1-day. The graphs also show vehicles in a different length and speed range on desired stations. Figure 3.5 shows a sample of vehicle counts in length ranges while Figure 3.6 shows in speed ranges on May 3, 2017.

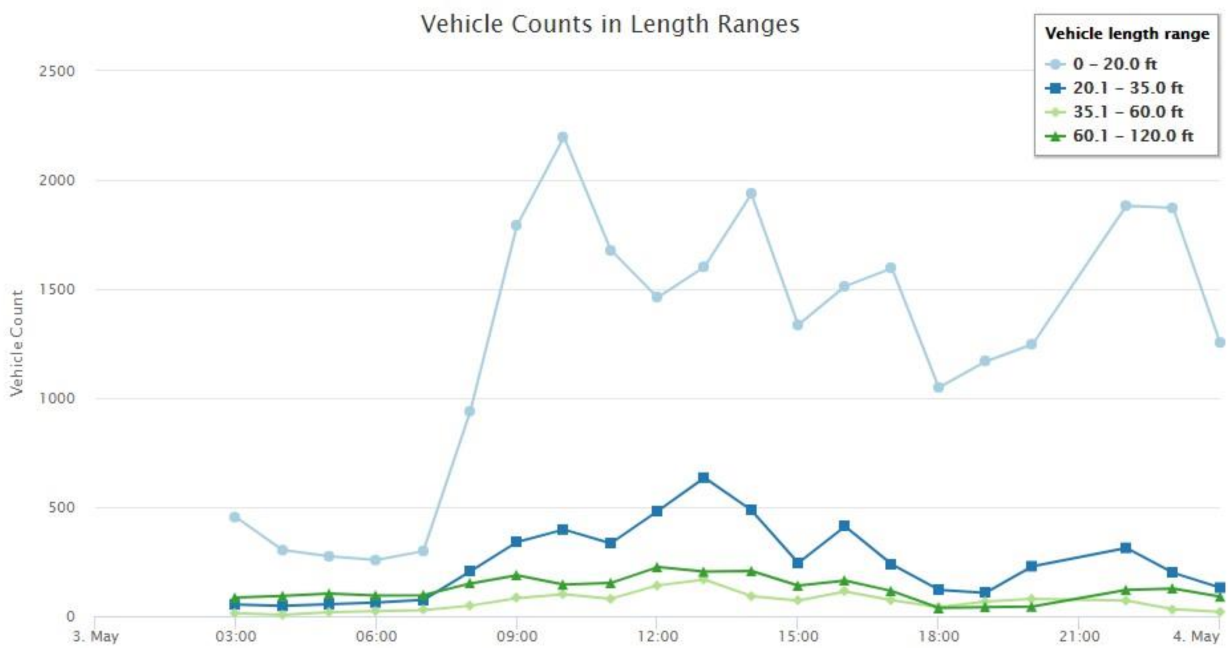

Figure 3.5: Vehicle counts in length ranges on May 3, 2017. Public Domain image

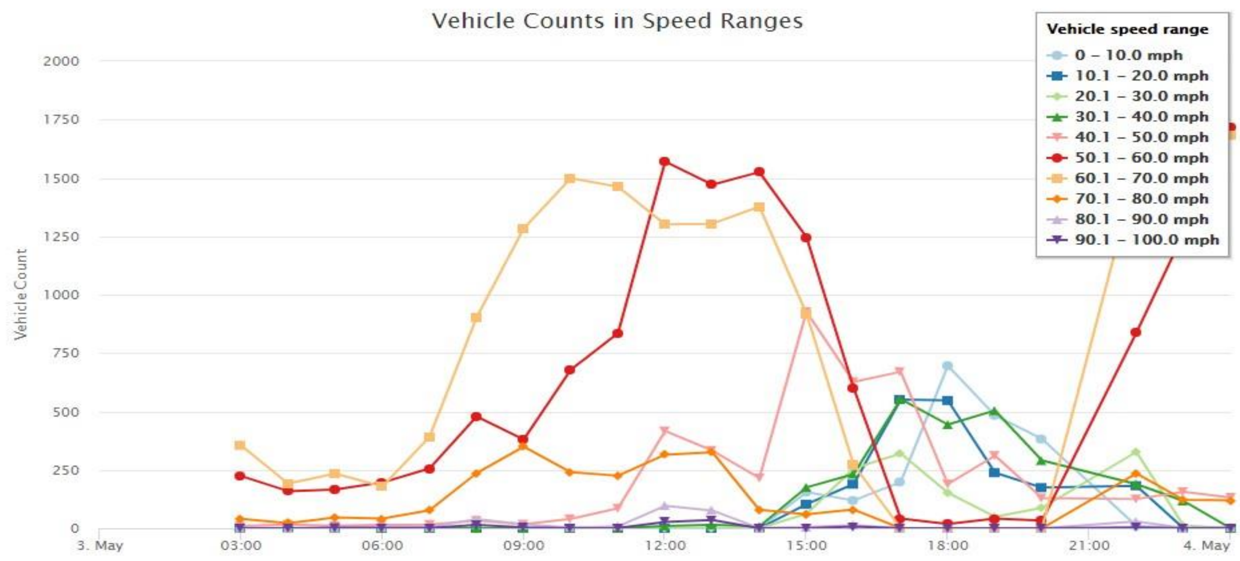

Figure 3.6: Vehicle counts in speed ranges on May 3, 2017. Public Domain image

3.2.2.3 Weather Tab

PORTAL website also includes weather data in order to provide additional information about traffic and roadway conditions. The weather data consist of temperature and rainfall gathered by the National Oceanic and Atmospheric Administration (NOAA). Figure 3.7 shows the rainfall and temperature information about the weather on May 3, 2017.

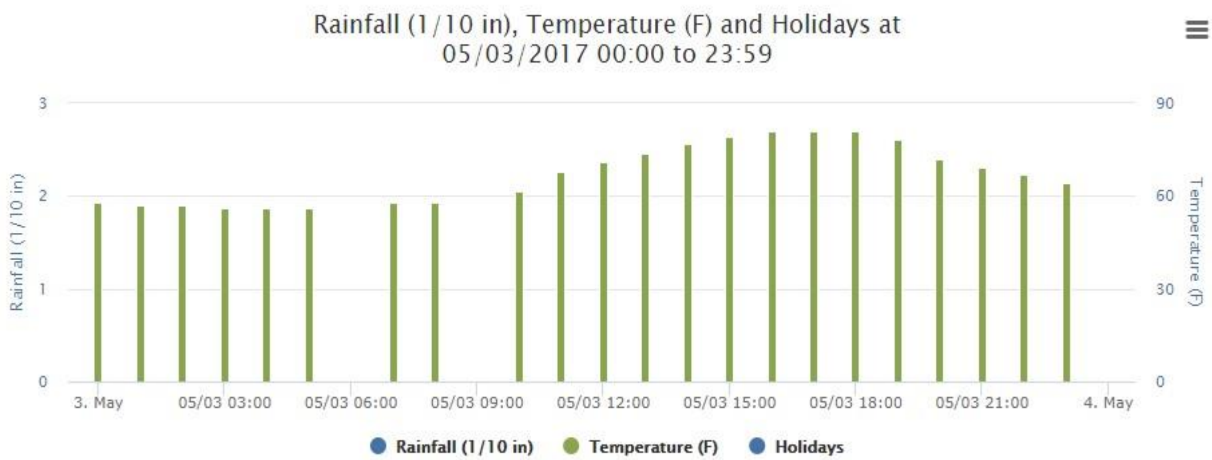

Figure 3.7: Weather data on May 3, 2017. Public Domain image

3.2.3 PORTAL Detectors and Stations

On downloads tab of PORTAL website, users can download detector and station metadata as CSV file formats. As shown in Table 3.2, detector metadata consist of seven different columns which represent detector ID, station ID, station name, lane number, highway ID, highway name, and milepost respectively. In addition, station metadata includes 11 different columns as shown in Table 3.3.

Detector ID consists of a six-digit number which represents every single detector with a specific number while station ID expressed as a four-digit number. Figure 3.8 illustrates representation of detector and station. A detector is a device or connected devices, while a station is a group of detectors on a specific road segment. A detector might be dual or individual. Dual loop detectors on a road segment record speed, length, volume, and occupancy but individual loops on on-ramps record only volume and occupancy.

Table 3.2: Sample of PORTAL detectors

Detector ID	Station ID	Station Name	Lane Number	Highway ID	Highway Name	Milepost
100421	1002	WB Elligsen Slip (2R314) to NB I-5	2	1	I-5	286.3
100422	1002	WB Elligsen Slip (2R314) to NB I-5	1	1	I-5	286.3
100423	1003	EB Nyberg Loop (2R313) to NB I-5	3	1	I-5	289.4
100424	1003	EB Nyberg Loop (2R313) to NB I-5	2	1	I-5	289.4

Table 3.3: Sample of PORTAL stations

Station ID	Agency ID	Highway ID	Highway Name	Milepost	Description	Upstream Station	Downstream Station	Opposite Station	Long.	Lat.
1015	68	1	I-5	299.7	Macadam (2R301) to NB I-5	3193	3119	3187	-122.67273	45.50006
1018	165	1	I-5	302.5	Broadway (2R001) to NB I-5	3168	3169	3121	-122.66727	45.53625
1019	166	1	I-5	303.88	Going (2R002) to NB I-5	3171	1020	-	-122.67791	45.5546
1020	167	1	I-5	304.4	Alberta (2R003) to NB I-5	1019	1021	-	-122.67814	45.56172

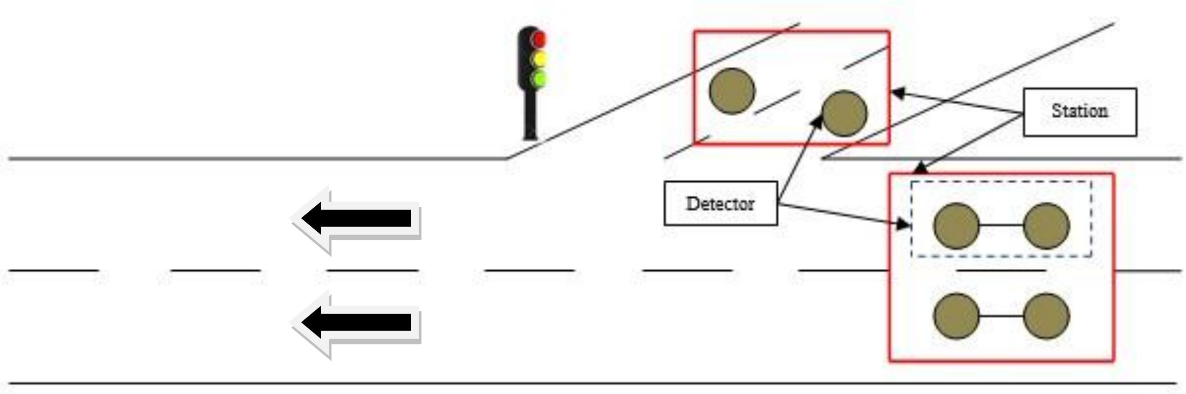

Figure 3.8: Representation of detector and station (Portland State University, April 12, 2012)

3.3 Datasets Used for This Study

The dataset obtained through PORTAL and used for this study was from the week of April 30 through May 6, 2017, for both northbound (NB) and southbound (SB) directions on I-5 highway between mileposts 283.93 and 307.9. This data was selected due to the reason that it belonged to a representative week of an average traffic stream since there are no holidays involved in this week. The data was obtained from Morgan Harvey, the application developer for PORTAL, from Portland State University. In total, there are three types of data which are cls length, cls speed, and average speed data. All datasets consist of a 20-second time interval. Detailed information about the datasets is provided in the following sections.

3.3.1 Cls Length and Cls Speed Data

These datasets provide information about vehicle lengths and speeds. Cls length has four bin categories while cls speed has ten bin categories. These bin categories represent the different length and speed types as shown in Table 3.4. Analyzed stations for this thesis are shown in Table 3.5. The NB section has four stations while SB has seven stations.

Table 3.4: Representation of bin numbers

Location	Highway	Direction	Milepost	Classification	Bin Number	Bin Categories
Alberta Street	I-5	North	304.08	Length Based	1	0-20 ft.
					2	20.1-35 ft.
					3	35.1-60 ft.
					4	60.1-120 ft.
				Speed Based	1	0-10 mph
					2	10-20 mph
					3	20-30 mph
					4	30-40 mph
					5	40-50 mph
					6	50-60 mph
					7	60-70 mph
					8	70-80 mph
					9	80-90 mph
					10	90-100 mph

Table 3.5: Analyzed northbound and southbound stations

Station ID	Location	Highway Name	Direction	Milepost
167	Alberta (2R003) to NB I-5	I-5	NORTH	304.4
168	Rosa Parks (2R004) to NB I-5	I-5	NORTH	305.12
170	Victory (2R006) to NB I-5	I-5	NORTH	306.51
171	Marine Drive / 99E (2R007) to NB I-5	I-5	NORTH	307.46
181	Alberta (2R015) to SB I-5	I-5	SOUTH	304.08
182	Rosa Parks (2R014) to SB I-5	I-5	SOUTH	304.85
183	EB Lombard (2R012) to SB I-5	I-5	SOUTH	305.4
184	WB Lombard (2R013) to SB I-5	I-5	SOUTH	305.51
185	Columbia (2R011) to SB I-5	I-5	SOUTH	305.97
186	Victory (2R021) to SB I-5	I-5	SOUTH	306.6
187	Marine Drive / 99E (2R010) to SB I-5	I-5	SOUTH	307.35

Table 3.6 shows the all cls data stations provided by PORTAL. In the given dataset, stations begin at milepost 283.93 (Wilsonville Road) and end at milepost 307.9 (Jantzen Beach) for NB direction on I-5. On the other hand, SB stations begin at milepost 291.25 (Carman) and end at milepost 307.9 (Jantzen Beach). Table 3.7 indicates combination of both cls length and cls speed as a sample.

3.3.2 Average Speed Data

The other dataset about the average speed consists of six columns as shown in Table 3.8. It includes detector ID, start time, volume, speed, occupancy, and reliability with a 20-second interval. Detector ID is a six-digit number as mentioned above. The start time indicates when the device starts recording. Volume and speed columns represent the amount of the vehicles and their average speeds in the 20-second intervals. Occupancy is the percentage of time in which the vehicle occupied that specific point. Lastly, reliability shows how reliable the detectors are according to occupancy rate. The dataset includes lane by lane average speed information from Alberta Street to Marine Drive on the NB section and also on the SB section.

Table 3.6: Cls data stations

Station ID	Location	Highway Name	Direction	Milepost
113	Wilsonville Rd (2R396) to NB I-5	I-5	NORTH	283.93
103	EB Elligsen Loop (2R315) to NB I-5	I-5	NORTH	286.1
78	WB Elligsen Slip (2R314) to NB I-5	I-5	NORTH	286.3
81	Lower Boones (2R311) to NB I-5	I-5	NORTH	290.54
82	Carman (2R316) to NB I-5	I-5	NORTH	291.38
83	OR 217/Kruse Way (2R317) to NB I-5	I-5	NORTH	292.18
155	Haines (2R308) to NB I-5	I-5	NORTH	293.18
156	99W (2R307) to NB I-5	I-5	NORTH	293.74
157	Capitol (2R306) to NB I-5	I-5	NORTH	295.18
159	Multnomah (2R304) to NB I-5	I-5	NORTH	296.6
355	Bertha (2R309) to NB I-5	I-5	NORTH	297.23
68	Macadam (2R301) to NB I-5	I-5	NORTH	299.7
166	Going (2R002) to NB I-5	I-5	NORTH	303.88
167	Alberta (2R003) to NB I-5	I-5	NORTH	304.4
168	Rosa Parks (2R004) to NB I-5	I-5	NORTH	305.12
170	Victory (2R006) to NB I-5	I-5	NORTH	306.51
171	Marine Drive / 99E (2R007) to NB I-5	I-5	NORTH	307.46
172	Jantzen Beach (2R008) to NB I-5	I-5	NORTH	307.9
87	Carman (2R322) to SB I-5	I-5	SOUTH	291.25
173	Haines (2R323) to SB I-5	I-5	SOUTH	293.1
174	99W (2R324) to SB I-5	I-5	SOUTH	293.36
69	Hood (2R302) to SB I-5	I-5	SOUTH	299.25
177	Wheeler (2R018) to SB I-5	I-5	SOUTH	302.17
179	Greeley (2R019) to SB I-5	I-5	SOUTH	303.1
180	Going (2R020) to SB I-5	I-5	SOUTH	303.9
181	Alberta (2R015) to SB I-5	I-5	SOUTH	304.08
182	Rosa Parks (2R014) to SB I-5	I-5	SOUTH	304.85
183	EB Lombard (2R012) to SB I-5	I-5	SOUTH	305.4
184	WB Lombard (2R013) to SB I-5	I-5	SOUTH	305.51
185	Columbia (2R011) to SB I-5	I-5	SOUTH	305.97
186	Victory (2R021) to SB I-5	I-5	SOUTH	306.6
187	Marine Drive / 99E (2R010) to SB I-5	I-5	SOUTH	307.35
188	Jantzen Beach (2R009) to SB I-5	I-5	SOUTH	307.9

Table 3.7: Sample of cls length and cls speed data

CLS I-5 DATA										
Station ID	Location	Highway	Direction	Milepost	Classification Type	Bin Number	Bin Description	Lane	Bin Count	Bin Time
113	Wilsonville Rd	I-5	North	283.93	Length	3	35-60 feet	1	2	4/30/2017 14:53:19
103	EB Elligsen Loop	I-5	North	286.1	Speed	7	70-80 mph	3	5	4/30/2017 19:23:00
87	Carman	I-5	North	291.25	Length	2	20-35 feet	2	9	4/30/2017 20:23:18

Table 3.8: Sample of average speed data

Detector ID	Start Time	Volume	Speed	Occupancy	Reliability
100894	5/1/2017 00:00:00	3	80	5	100
100909	5/1/2017 00:00:20	2	47	3	100
100911	5/1/2017 05:40:40	0	0	100	0
101918	5/1/2017 22:15:20	1	57	1	100
102032	5/1/2017 23:45:40	2	0	3	0

3.4 Illustration of the Analyzed Highway Segment

This part of the chapter provides illustrations of the highway segment used for this study. Figure 3.9 shows the I-5 highway section from Alberta Street to Interstate Bridge. Black dots represent detector locations. There are three lanes in the NB direction which are lane 1, lane 2, and lane 13. Lane 13 represents High-Occupancy Vehicle (HOV) lane starting at milepost 303.963, before Alberta Street detectors, to milepost 307.336, between Victory Boulevard and Marine Drive detectors. Lane 13 turns to lane 3 after HOV ends. HOV lane operates from Monday to Friday between 3 p.m. and 6 p.m. On the other hand, there is no lane 13 (HOV) on SB direction between Alberta Street and Marine Drive. There are five on-ramps and seven off-ramps on the analyzed NB section of I-5 highway and seven on-ramps and five off-ramps on the SB section.

Figure 3.10 shows station numbers and corresponding locations of stations for the analyzed highway section. Blue and red pins represent NB and SB stations and their station numbers respectively. Figure 3.11 indicates that the truck route of the I-5. As seen in the figure, terminals belonging to Port of Portland are located on the west side of the I-5, and Portland International Airport on the east side of the highway. These are the main reasons for choosing this road segment for the current thesis. These facilities make a huge impact on the heavy vehicle traffic on the highway so that understanding traffic flow on this route can give an opportunity to solve and manage truck volume around the ports.

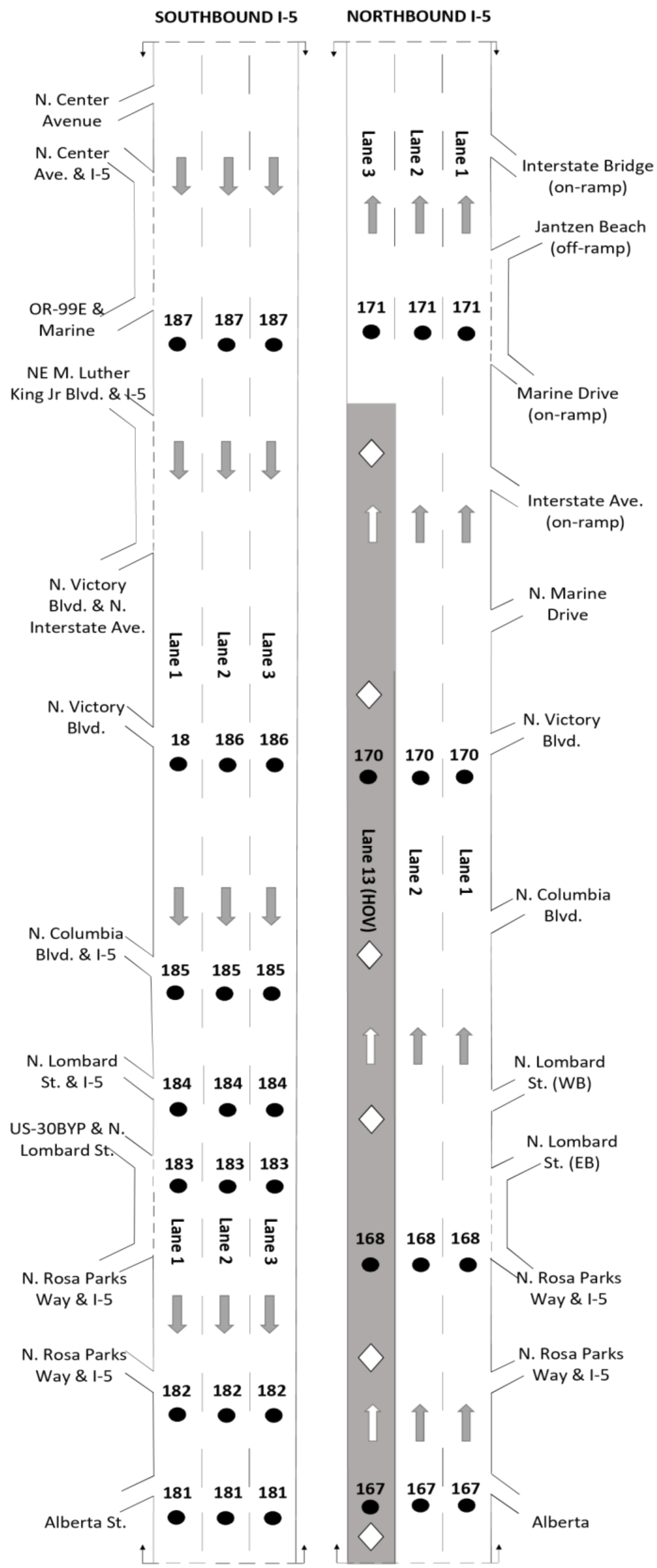

Figure 3.9: Section of I-5, Portland-OR

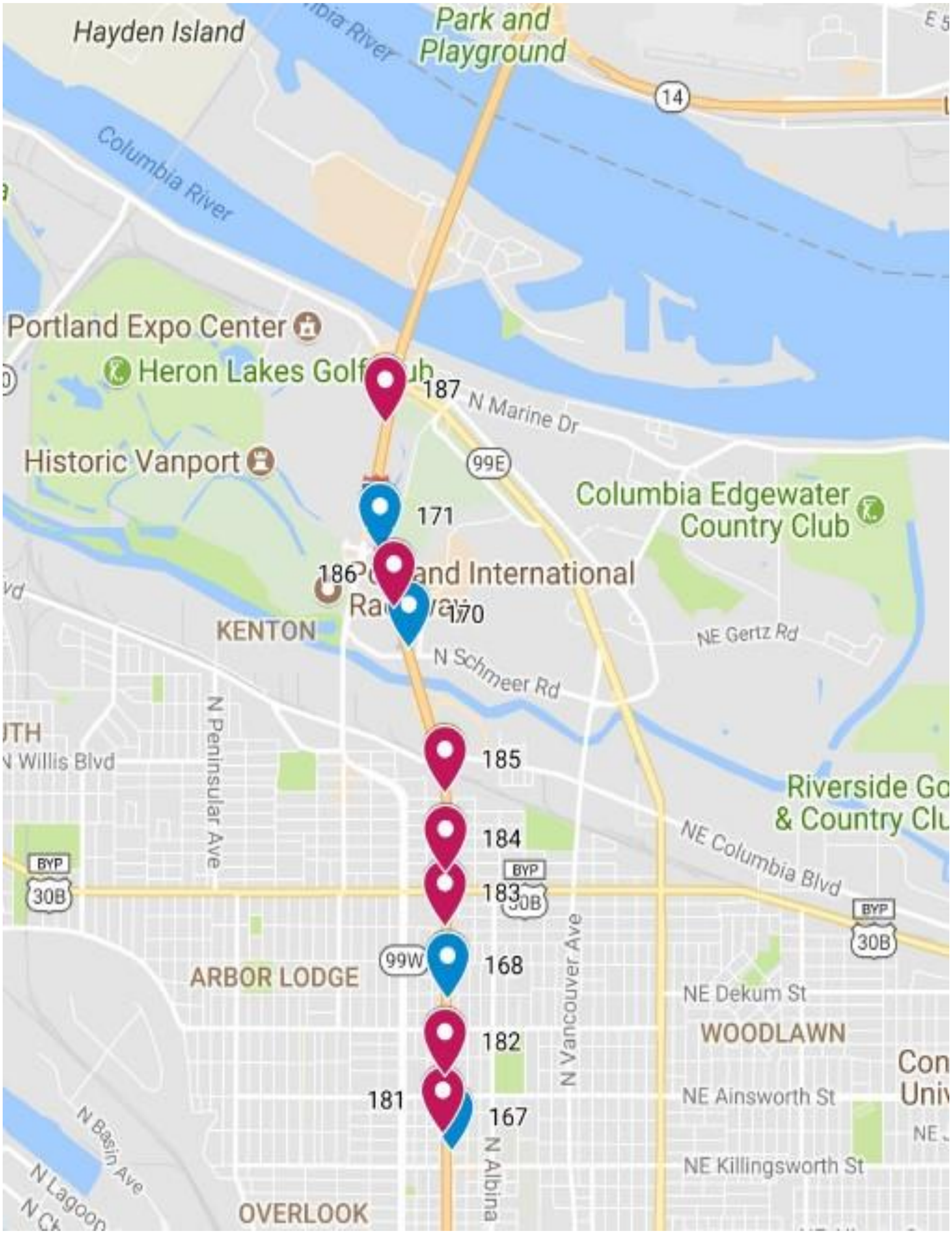

Figure 3.10: Location and station numbers of stations on I-5, Portland-OR

Figure 3.11: Truck routes on I-5, Portland-OR[1]

[1] Source: http://www.oregon.gov/ODOT/Forms/Motcarr/C-51A.pdf accessed on 02-10-2018.

3.5 Summary of the PORTAL Data

In summary, this chapter gives an overview of PORTAL and the dataset provided by PORTAL. In addition, truck routes around the analyzed section are discussed. PORTAL is an archiving listing that allows reaching the dataset by users as mentioned above. It stores arterial signal data, transit data, VAS-VMS data, truck volume data, incident data, or weather data in a 20-second interval. Moreover, these data are also downloadable and observable so that individuals or traffic agencies are free to have information via PORTAL. There is a current need for ITS infrastructure, retrieval technologies, and data processing algorithms to obtain and analyze enough amount of data and PORTAL is one of the archive listings which succeeds in processing the data.

This chapter also discusses the given dataset by PORTAL. There are three datasets which are length, speed, and average speed in a 20-second interval as a CSV file format. In the given dataset, there were 33 locations, but 11 of them were analyzed for the current research. On the NB section, there are four stations while SB has seven stations. Investigated road sections consist of three lanes and one of them in between Alberta Street and Victory Boulevard is HOV lane which operates from Monday to Friday, between 3 p.m. and 6 p.m. on NB direction. On the other hand, there is no HOV lane on SB direction. Overall mileage of the section is around 2.5 miles.

Even though PORTAL offers traffic stream data with successful visual plots, it needs to be improved. In general, PORTAL allows users to have visual plots as yearly, monthly, daily, hourly, 15-minute, 5-minute, and 20-second data. Among these, visualization below 15-minute data are not available for displaying.

Overall, the tables and figures mentioned in this chapter were a starting point for analyzing the datasets. All the datasets obtained by PORTAL were analyzed and interpreted carefully. Among the datasets, the only data which was not analyzed was cls speed because of its lack of information about average speed. To understand the vehicle length distribution, speed information, and the travel peak times on the given roadway segments were analyzed and plotted using RStudio and Excel software. Next chapter gives information about data analysis and plotted graphs based on the length-based data.

CHAPTER 4: DATA ANALYSIS

4.1 Introduction

Sample (data) description is a starting point of this chapter followed by data processing, sample analysis, graphs, timeseries plots, and results for analyzing the vehicle distribution in terms of average vehicle speed, truck volume and truck percentage on the given roadway segment using the data provided by PORTAL.

The length-based vehicle count dataset consists of four bins as mentioned earlier. Bin 1 represents vehicles with a length up to 20 ft. It can be considered as a passenger car, pickups, panels, vans, and short single-unit trucks. Vehicle lengths between 20 ft. and 35 ft. are represented as Bin 2 and trucks with trailer and long single-unit trucks can be counted in this category. Bin 3 refers to the combination of the trucks varying in length from 35 ft. to 60 ft. Finally, Bin 4 represents vehicle lengths between 60 ft. and 120 ft. Multi-trailer trucks can be given as an example of this category. Table 4.1 illustrates bin categories and corresponding vehicle samples with FHWA vehicle classification scheme. Moreover, Figure 4.1 shows FHWA classification scheme completely. In this study, Bin 2, Bin 3, and Bin 4 vehicle categories are considered as long vehicles. The reason behind this, combining all these three bins ensures covering long vehicle types for both freight and non-freight purposes. In this section, average vehicle speed, truck count and truck percentage trends were analyzed for NB Marine Dr. on May 3, 2017. Graphs which have hourly, 15-min, and 5-min time interval were generated to find a better illustration method for representing of average speed, truck count, and percentages.

Table 4.1: Bin categories and corresponded vehicle samples (Adapted from Byad, A. 2016)

Bin Number	Vehicle Length Range	FHWA Equivalent	Vehicle Types	Samples
1	< 20 feet	1-2-3	Cars, pickups, vans, and panels	
2	20.1-35 feet	4-5-6-7	Trucks with trailer, single-unit trucks	
3	35.1-60 feet	8-9-10	Truck combinations	
4	> 60 feet	11-12-13	Multi-trailer trucks	

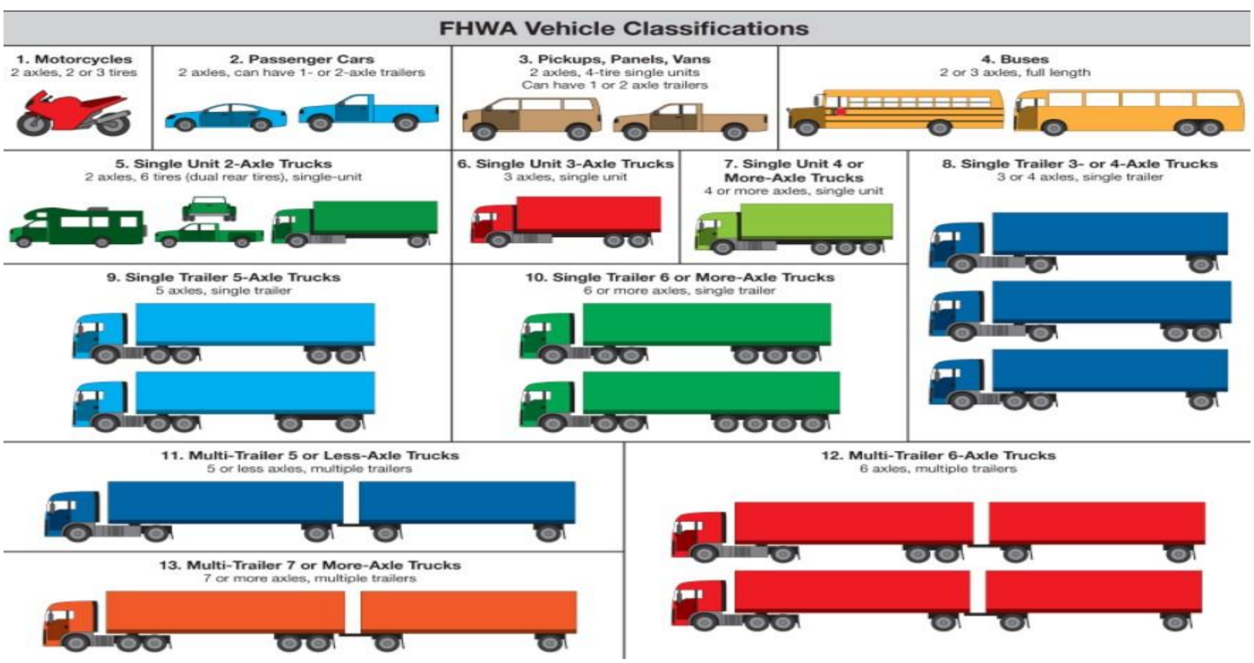

Figure 4.1: FHWA vehicle classification scheme[2]

[2] Source: http://onlinemanuals.txdot.gov/txdotmanuals/tri/images/FHWA_Classification_Chart_FINAL.png accessed on 02-15-2018.

4.2 Data Processing

The data obtained as a CSV file cannot be opened in Excel due to the size of the data. Because of that, it was opened using RStudio which is an open-source programming language for plotting and statistical computing. Then, it was grouped based on the station numbers, saved as CSV format, and converted to XLSX format. Data opened in Excel were then categorized according to the days. Next, the data were investigated as to whether there was a conflict in the data using the advanced filtering method on excel, and no conflict was found. But, it was found out that the data for Victory Blvd. (lane 1) on NB and Rosa Parks Way (all lanes) on SB in all weeks had data discrepancies. Finally, the data were categorized day by day and station by station.

4.3 Data Visualization

This subsection provides information about the data visualization based on the day of May 3, 2017 (Wednesday) for the NB section of Interstate 5. Truck volume and percentages are designed with stacked column-line and radar plot for hourly, 15-minute, and 5-minute to find a better illustration graphic for truck volume and percentages. Furthermore, timeseries-speed surface and polar plots are generated as average speed on Marine Drive for the same day.

4.3.1 Stacked Column-Line Graphics

This part illustrates truck volume and percentage plots using stacked column-line graphic for hourly, 15-minute, and 5-minute time intervals. The reason of that is to better understand and analyze truck mobility based on the time scale and to find which visual representation express truck volume better. The missing side of these graphics is the increasing difficulty of understanding the images as the time scale is narrowed. To analyze that, Figure 4.4, Figure 4.5, and Figure 4.6 were generated hourly, 15-minute, and 5-minute stacked column-line graphs for all NB stations respectively.

According to the graphs, it can be seen that there is an increasing trend for truck volume in early morning until noon and late evening time. Between these times, truck percentages stay around 20-40%. Moreover, higher percentages of the trucks belong to the time which truck volumes are relatively lower than other times mentioned above. It can be explained by the fact that passenger cars do not appear on the analyzed road segment after the nighttime and noon.

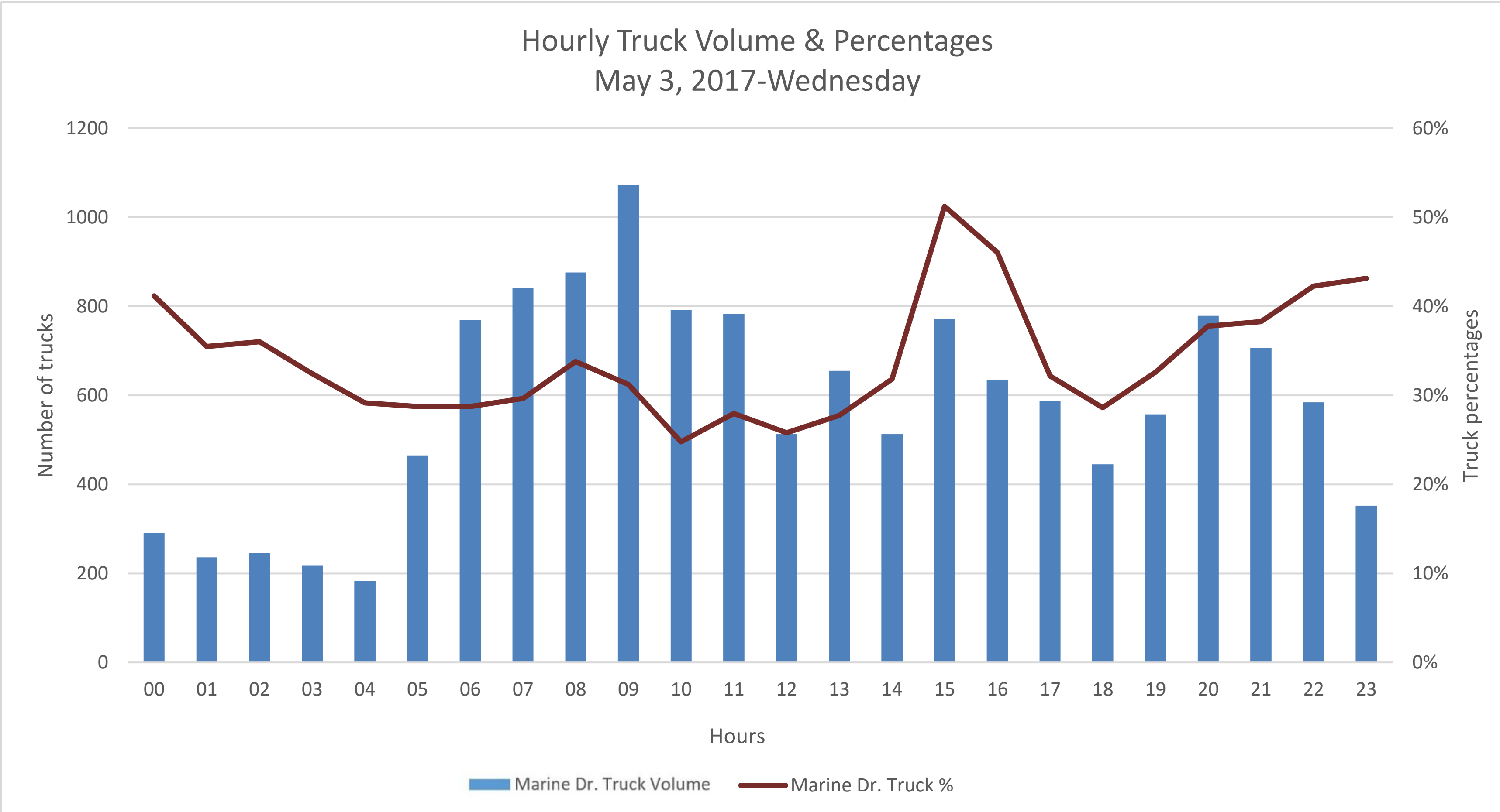

Figure 4.2: Number and percentage of trucks for northbound stations (hourly)

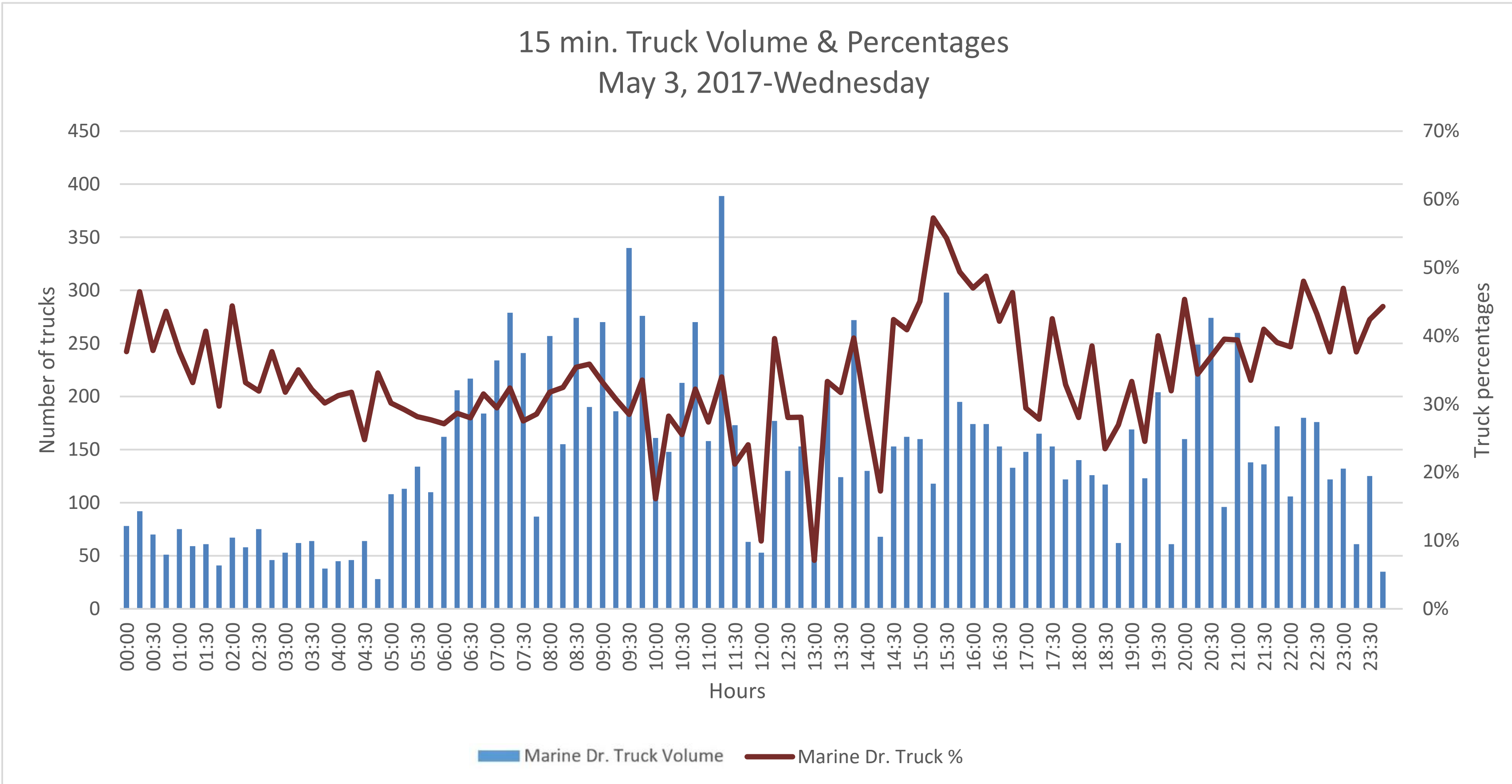

Figure 4.3: Number and percentage of trucks for northbound stations (15-min)

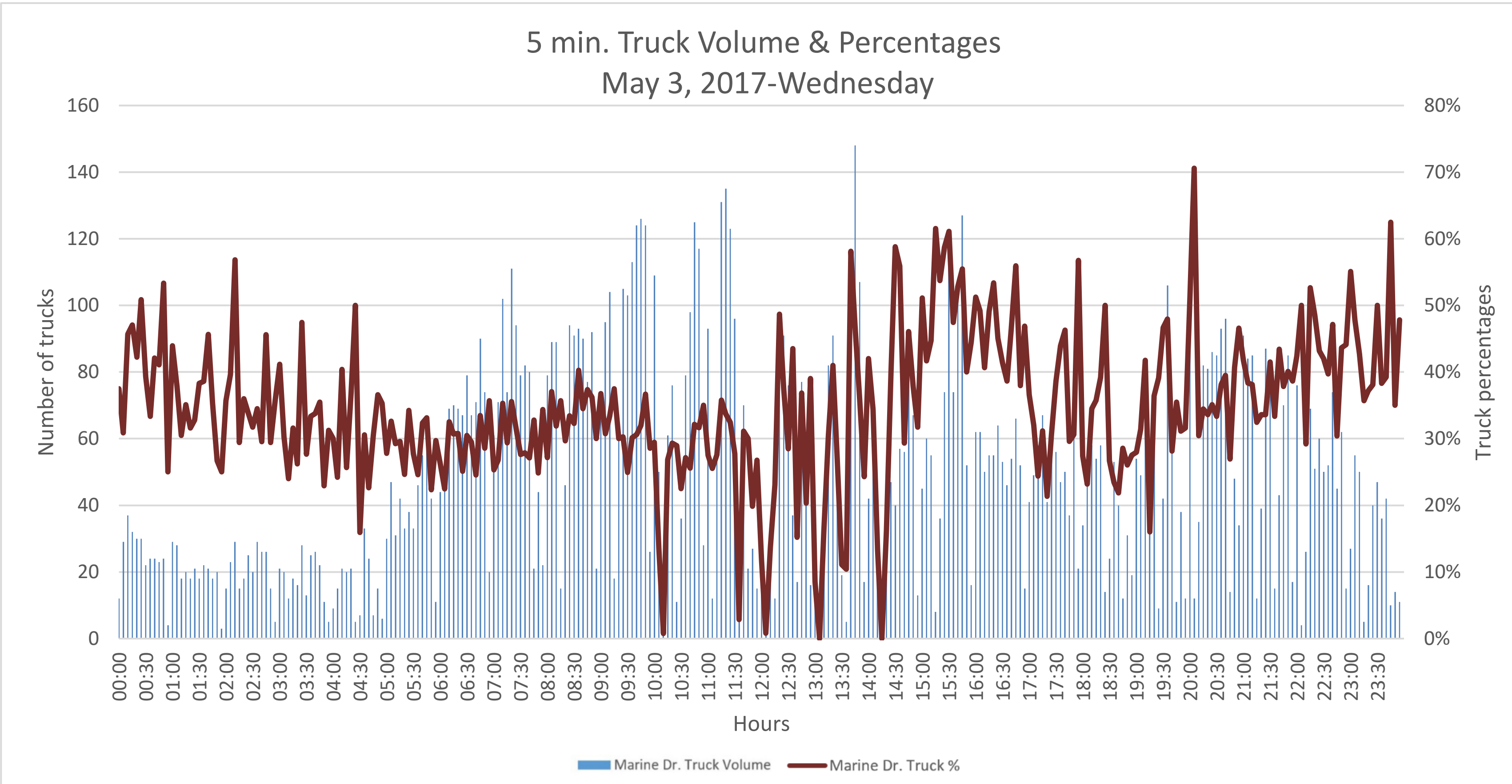

Figure 4.4: Number and percentage of trucks for northbound stations (5-min)

4.3.2 Radar Plots

Radar plot is another way of illustration for this dataset. In this subsection, the radar plots which are generated for truck volume and percentages, are presented. The dataset was divided into hourly, 15-minute, and 5-minute time intervals for NB Marine Dr. with its truck volume and percentage. After that two different radar plots were created using Excel which shows the amount of the trucks and their percentages.

Figure 4.7 shows hourly truck volume and percentages. Despite the fact that this graph is easy to understand, it is difficult, however, to catch sudden changes in the volume and percentage of trucks. Figure 4.8 illustrates the same station’s truck volume and percentage as 15-minute time interval. This graph is clearer to understand of sudden changes rather than the hourly graph. Finally, Figure 4.9 indicates the graph which is generated for a 5-minute period of the truck volume and percentages. More disaggregated time interval provides more detailed information rather than the previous radar plots visually.

Overall, it has been decided to be used the 5-minute radar plot for truck volumes and percentages, based on its generic, clarity, and concise representation for the future analysis.

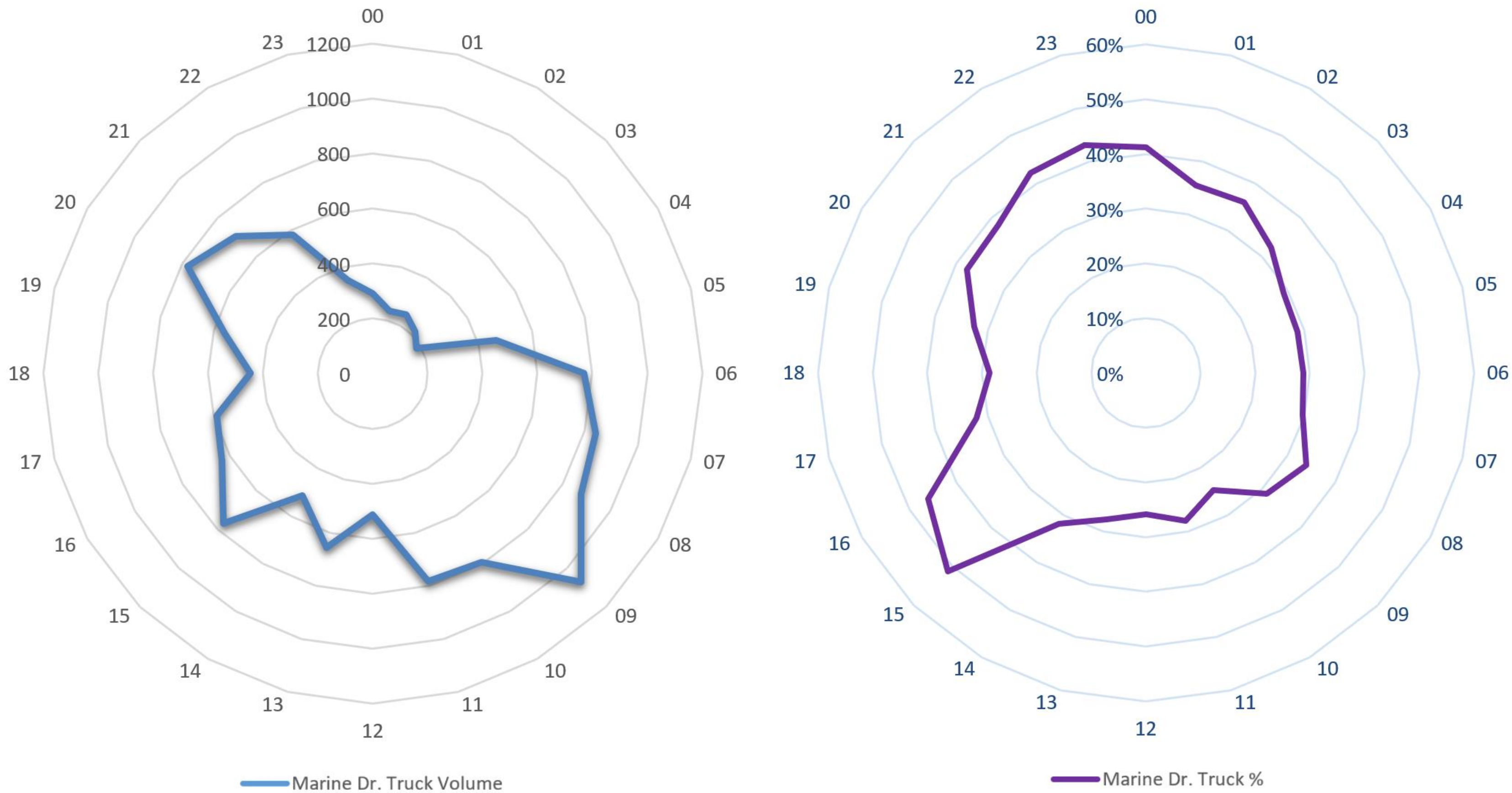

Figure 4.5: Hourly radar plots for truck volume and percentages on NB Marine Dr. (May 3, 2017-Wednesday)

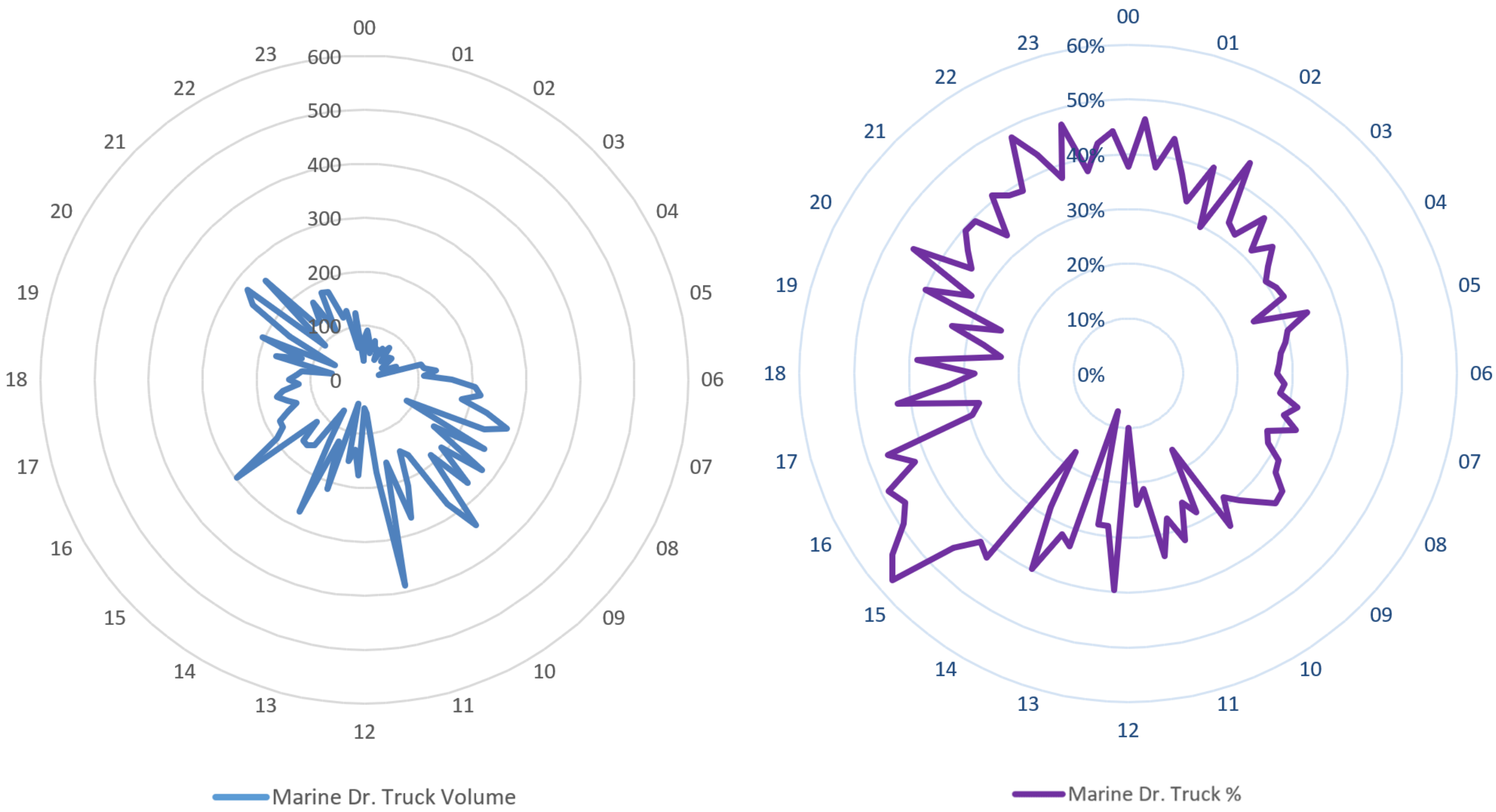

Figure 4.6: 15-min. radar plots for truck volume and percentages on NB Marine Dr. (May 3, 2017-Wednesday)

Figure 4.7: 5-min. radar plots for truck volume and percentages on NB Marine Dr. (May 3, 2017-Wednesday)

4.3.3 Timeseries-Speed Surface and Polar Plots

This section provides information about the average vehicle speed on Marine Drive (NB) using timeseries-speed surface and polar plots. The dataset is prepared as hourly, 15-minute, and 5-minute to find a better illustration for the average vehicle speed on the given road segment. RStudio programming language has been used to obtain the plots. Figure 4.10, Figure 4.11, and Figure 4.12 show hourly, 15-minute, and 5-minute which are designed as speed surface plots while Figure 4.13, Figure 4.14, and Figure 4.15 demonstrate timeseries speed polar plots.

Sudden changes of average speed are more understandable when 15 and 5-minute plots are used in terms of visualization rather than hourly timeseries speed plots' representation. Although, there are small variations between average speeds, there is generally no visual differences between 15 and 5-minute plots in general. However, using 5-minute plots are more convenient for quick and easy processing of the data. On the other hand, it is hard to catch the true time interval for average speed using the surface plot. But, the polar plot is more useful and easy to find the desired average in terms of the design of its time axis.

For a better understanding the relationship between truck volume-percentages and average vehicle speed, it has been decided to use 5-minute timeseries speed polar plot with truck percentage and average speed radar plots together for the next chapter for both NB and SB highway segments.

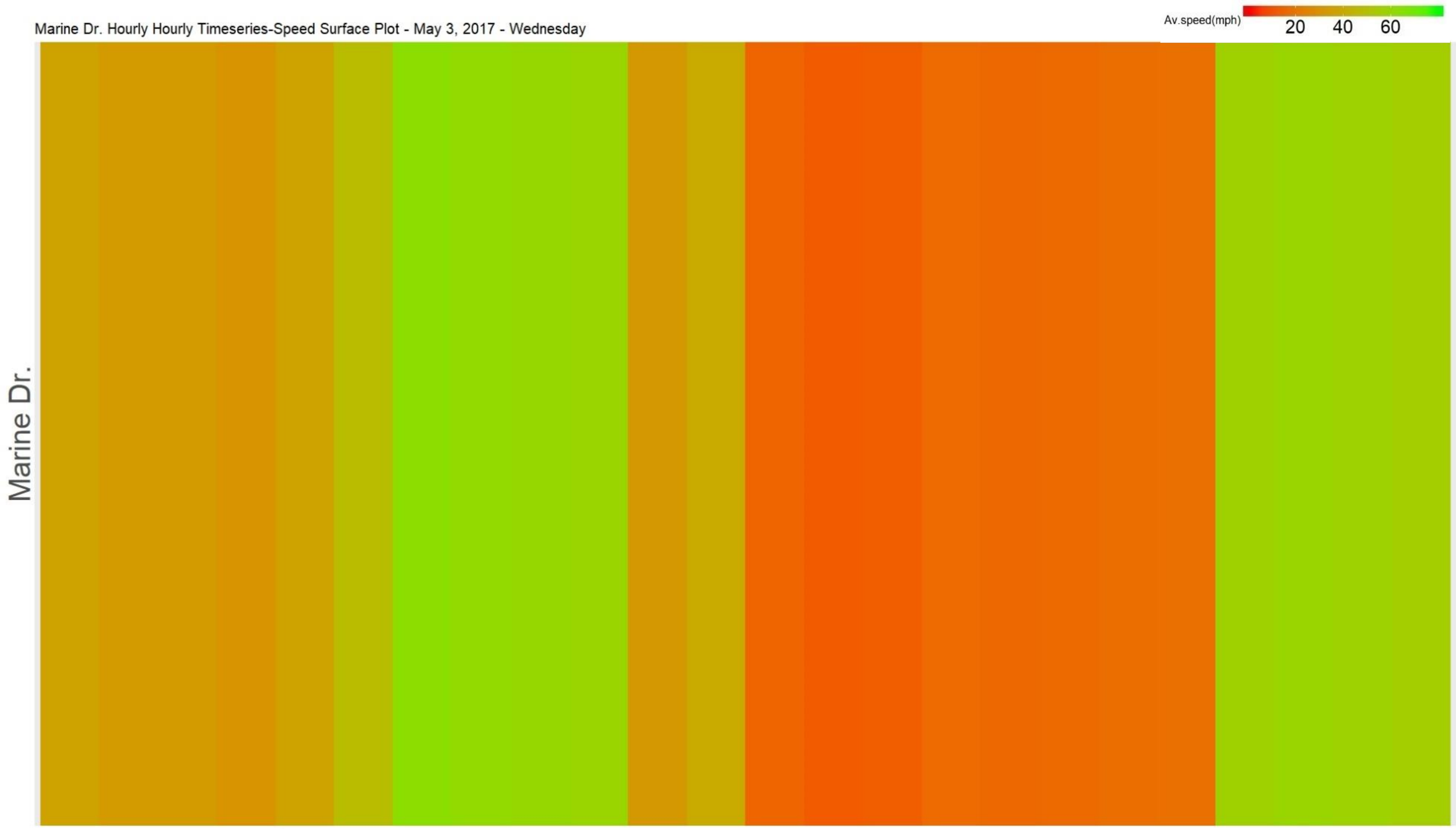

Figure 4.8: Hourly timeseries-speed surface plot for average vehicle speed on NB Marine Dr. (May 3, 2017-Wednesday)

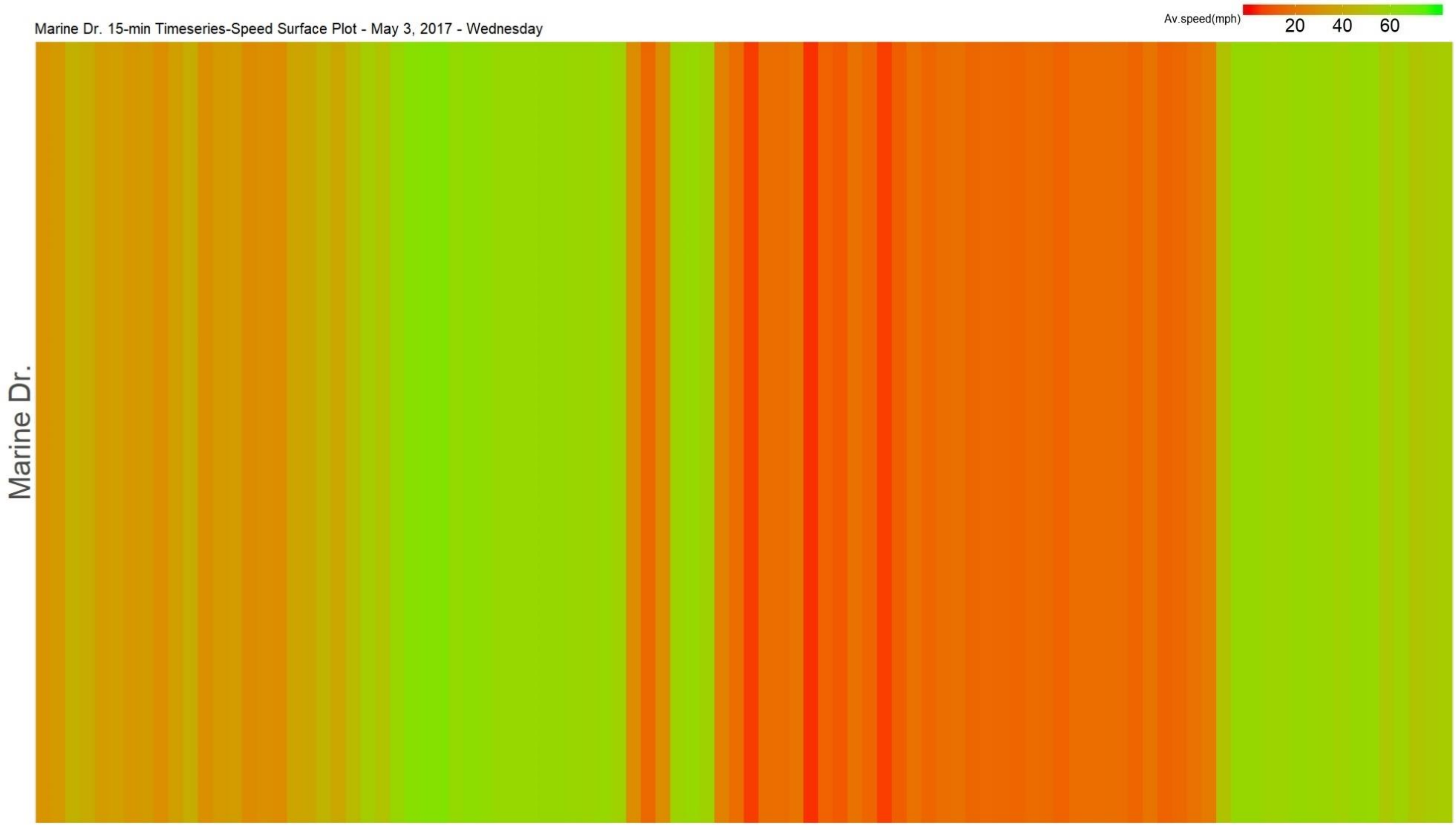

Figure 4.9: 15-min. timeseries-speed surface plot for average vehicle speed on NB Marine Dr. (May 3, 2017-Wednesday)

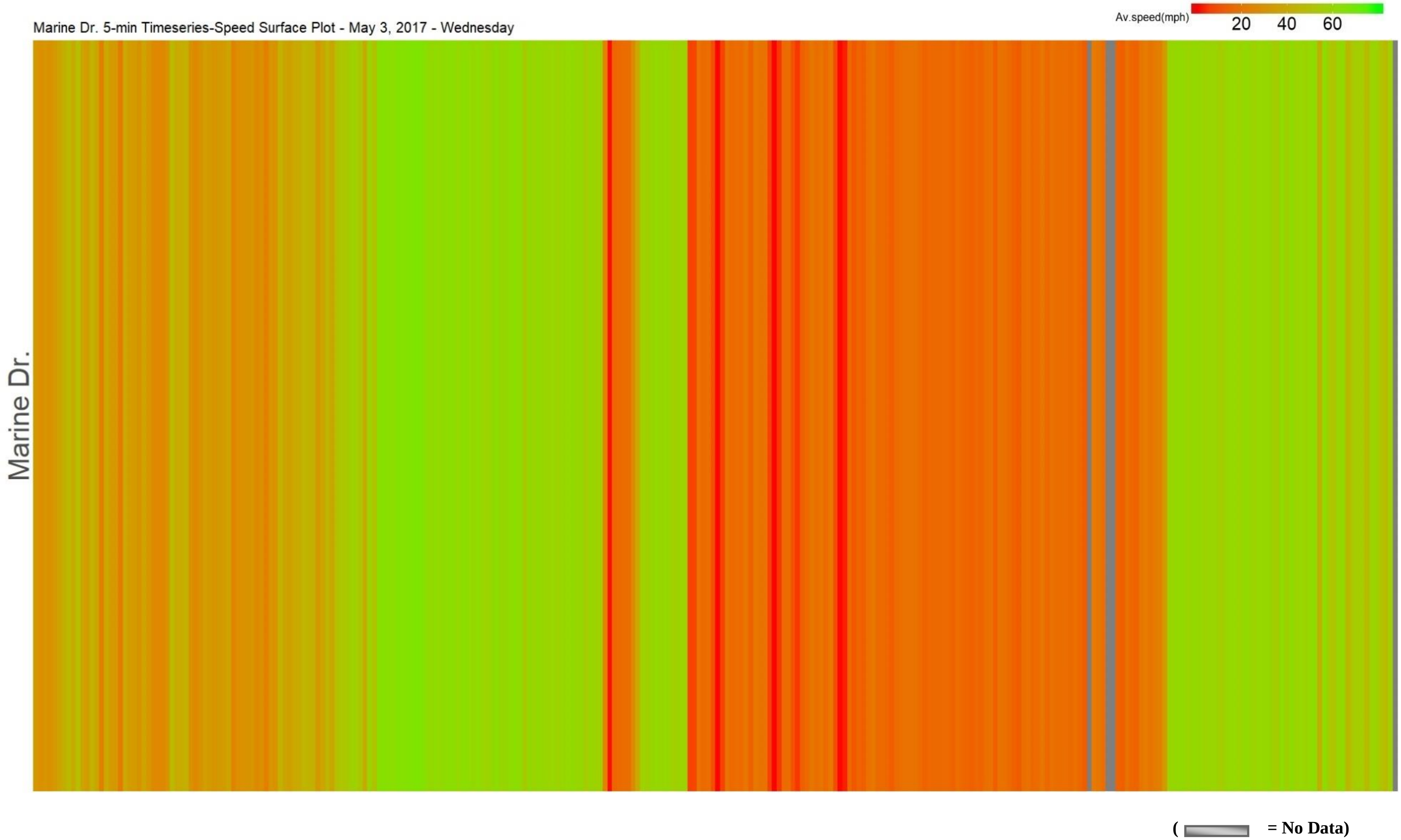

Figure 4.10: 5-min. timeseries-speed surface plot for average vehicle speed on NB Marine Dr. (May 3, 2017-Wednesday)

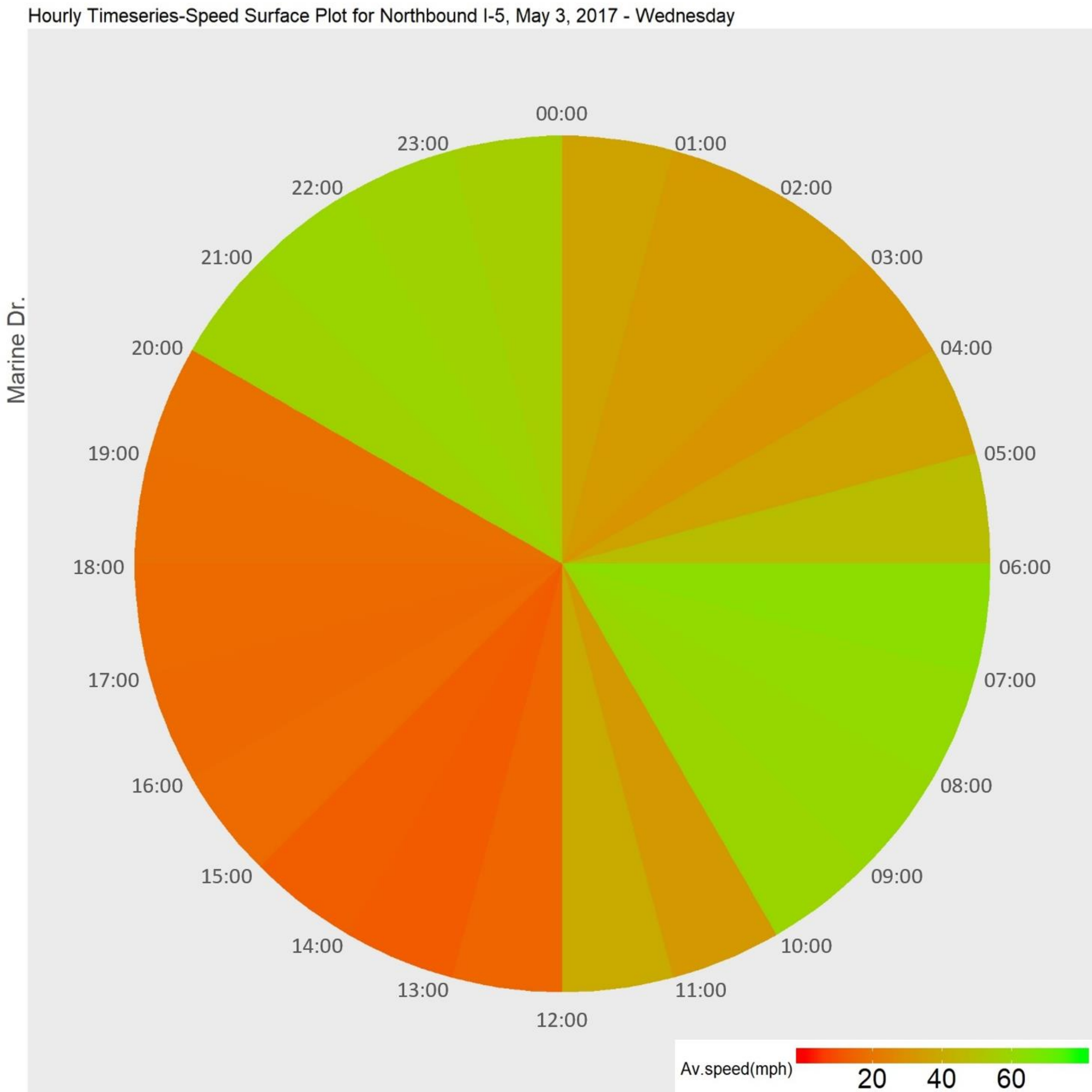

Figure 4.11: Hourly timeseries-speed polar plot for average vehicle speed NB Marine Dr. (May 3, 2017-Wednesday)

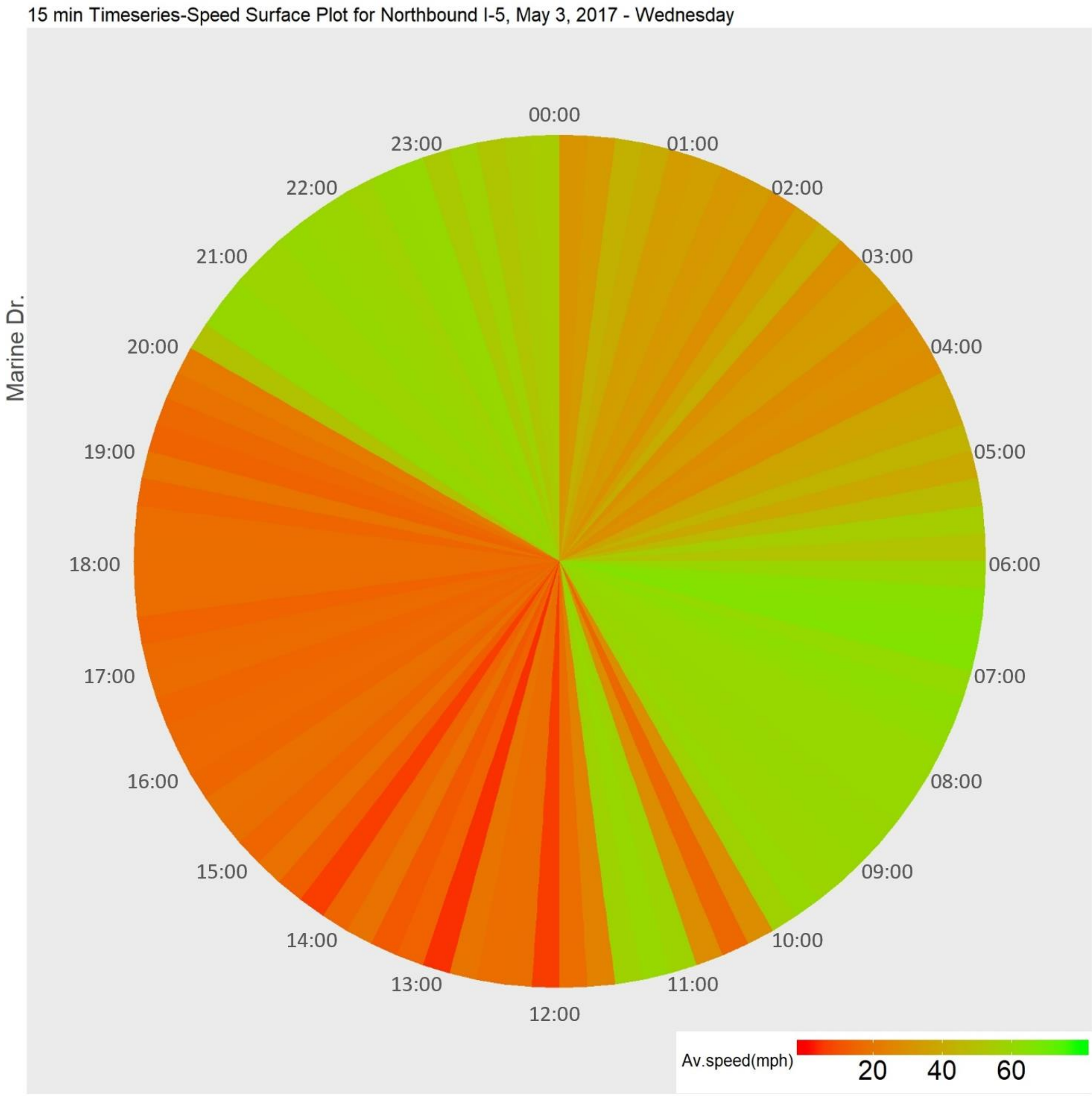

Figure 4.12: 15-min. timeseries-speed polar plot for average vehicle speed NB Marine Dr. (May 3, 2017-Wednesday)

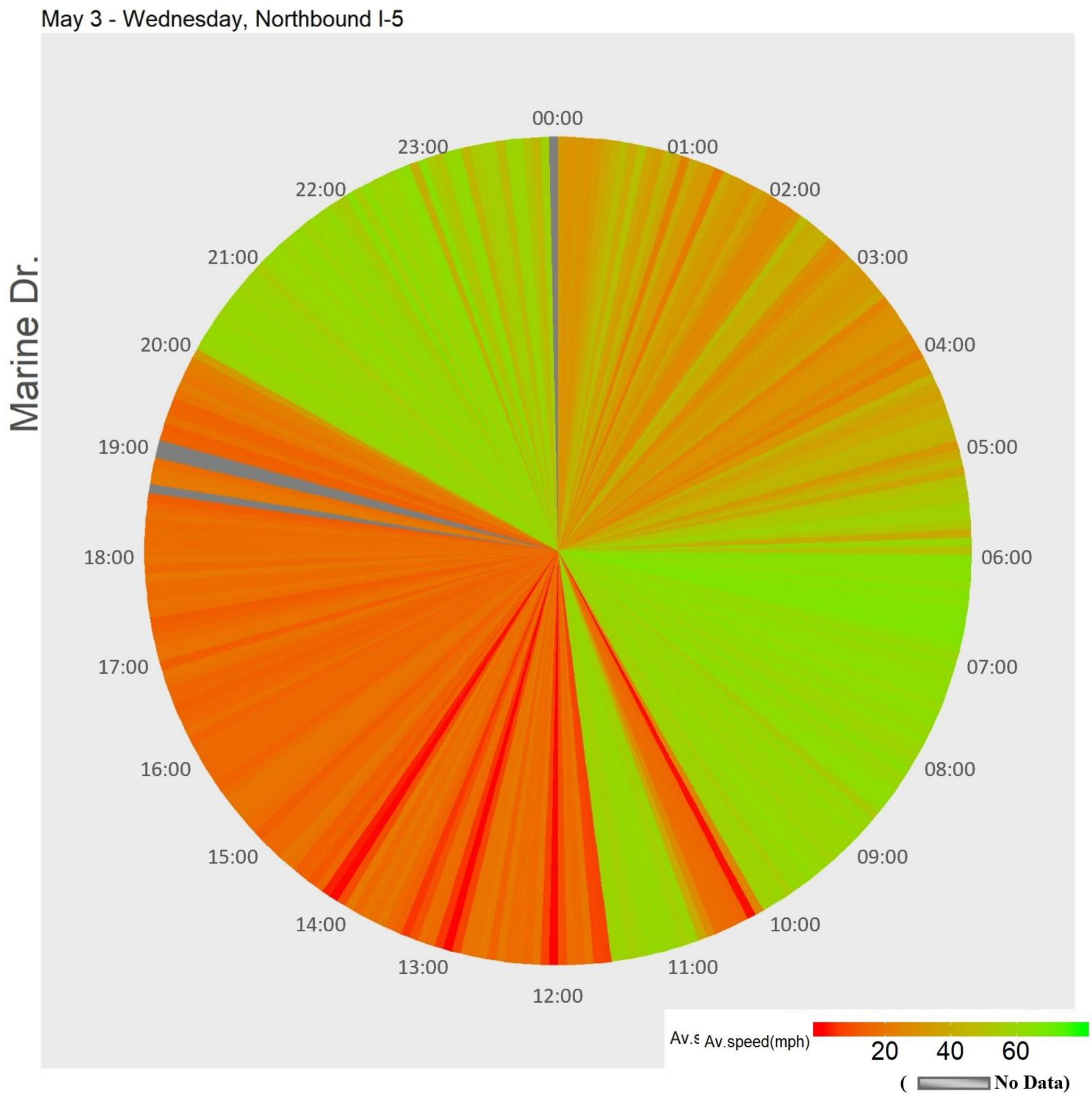

Figure 4.13: 5-min. timeseries-speed polar plot for average vehicle speed NB Marine Dr. (May 3, 2017-Wednesday)

CHAPTER 5: ANALYSIS METHODOLOGY AND RESULTS

5.1 Introduction

This chapter provides a detailed visual representation for both NB and SB stations on May 3, 2017. Generated plots for remaining days (April 30, May 1, May 2, May 4, May 5, and May 6) are provided in Appendix B. Furthermore, the chapter gives a weekly statistical summary of the passenger car - truck volume and average vehicle speed for both NB and SB stations.

5.2 Analysis Methodology

Based on the analyzed data and generated plots, it has been decided to make a combination of timeseries-speed polar plot with truck volume and percentage radar plot for 5-minute period. The main reason behind this approach is that 5-minute plots give understandable results both in terms of visualization and showing the instantaneous changes in average vehicle speed and heavy vehicle quantities. The process of creating combine plots has three steps. First, timeseries-speed polar plots had been generated. Then, truck volume and percentage radar plots are put onto the polar plot carefully. Finally, scale arrangement was done. Because of the truck volume and percentage radar plots have two different axis values, every single location's scales were assigned automatically by excel at the time of the process separately. The axes, then, have been manually re-arranged for percentage axis as 100% and for volume axis as 2500 vehicle per hour because the graphics caused bias in terms of visual representation. Figure 5.1, 5.2, 5.3, and 5.4 are combined plots which designed for NB stations. Moreover, Figure 5.6, 5.7, 5.8, 5.9, and 5.10 are the plots that are designed for SB stations. On the other hand, Figure 5.5, and 5.11 show the timeseries speed surface plot of all the stations on the NB and SB segments, respectively. Rosa Parks Way on SB direction contained a large amount of erroneous data and it was omitted in this analysis. Interpretations of the plots are provided under the results section.

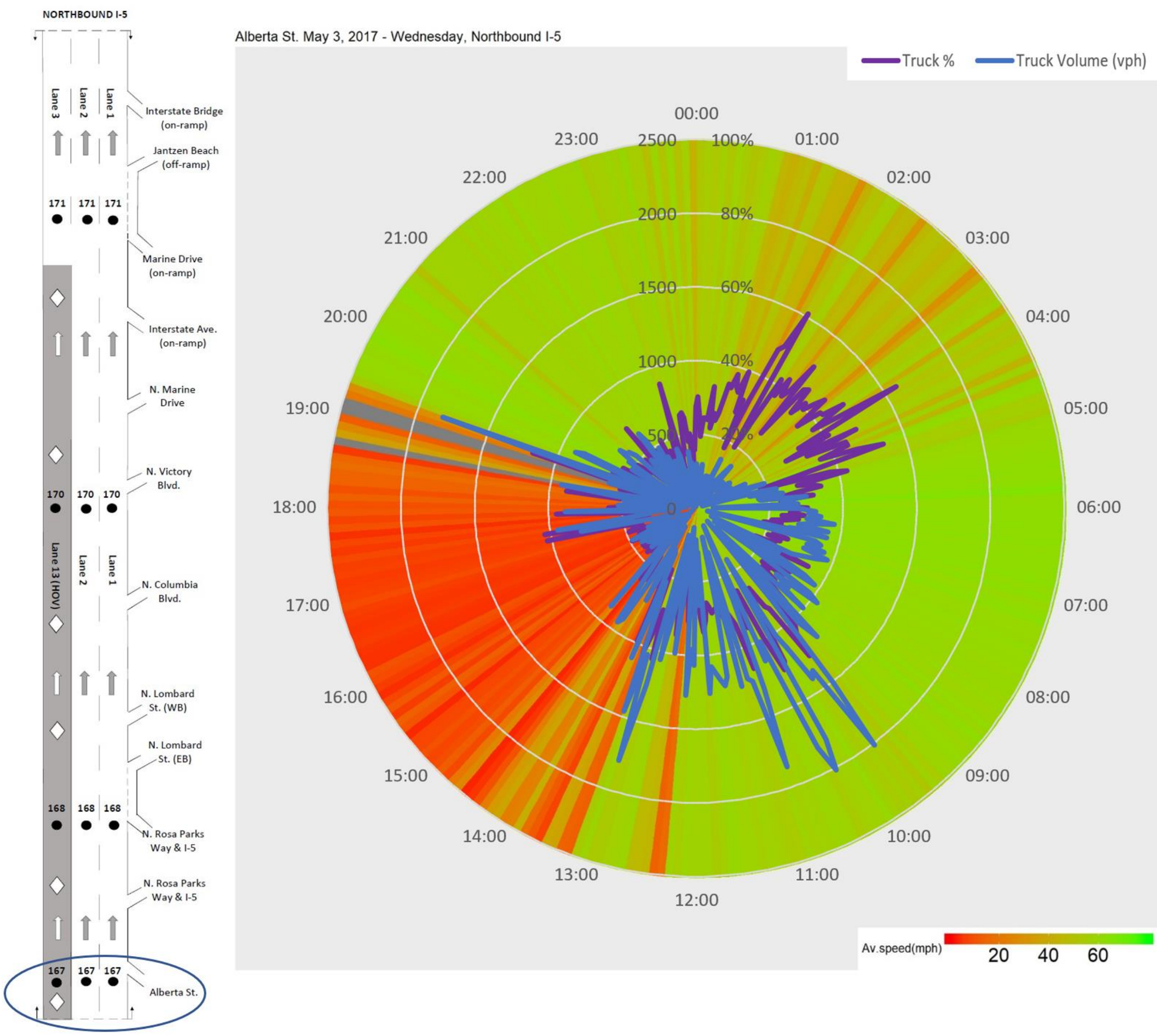

Figure 5.1: 5-min. combo plot for Alberta Street – NB (May 3, 2017-Wednesday)

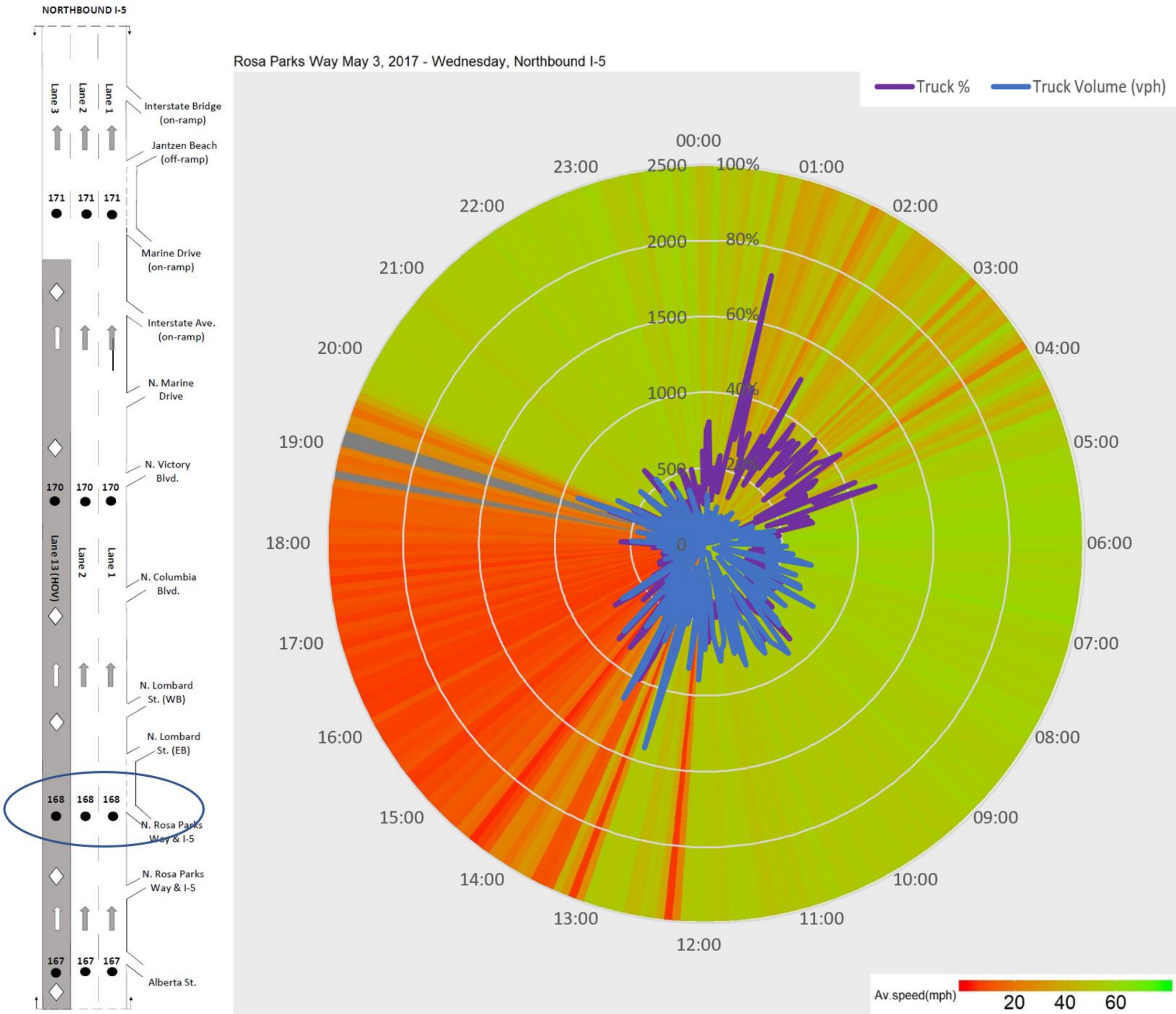

Figure 5.2: 5-min. combo plot for Rosa Parks Way - NB (May 3, 2017-Wednesday)

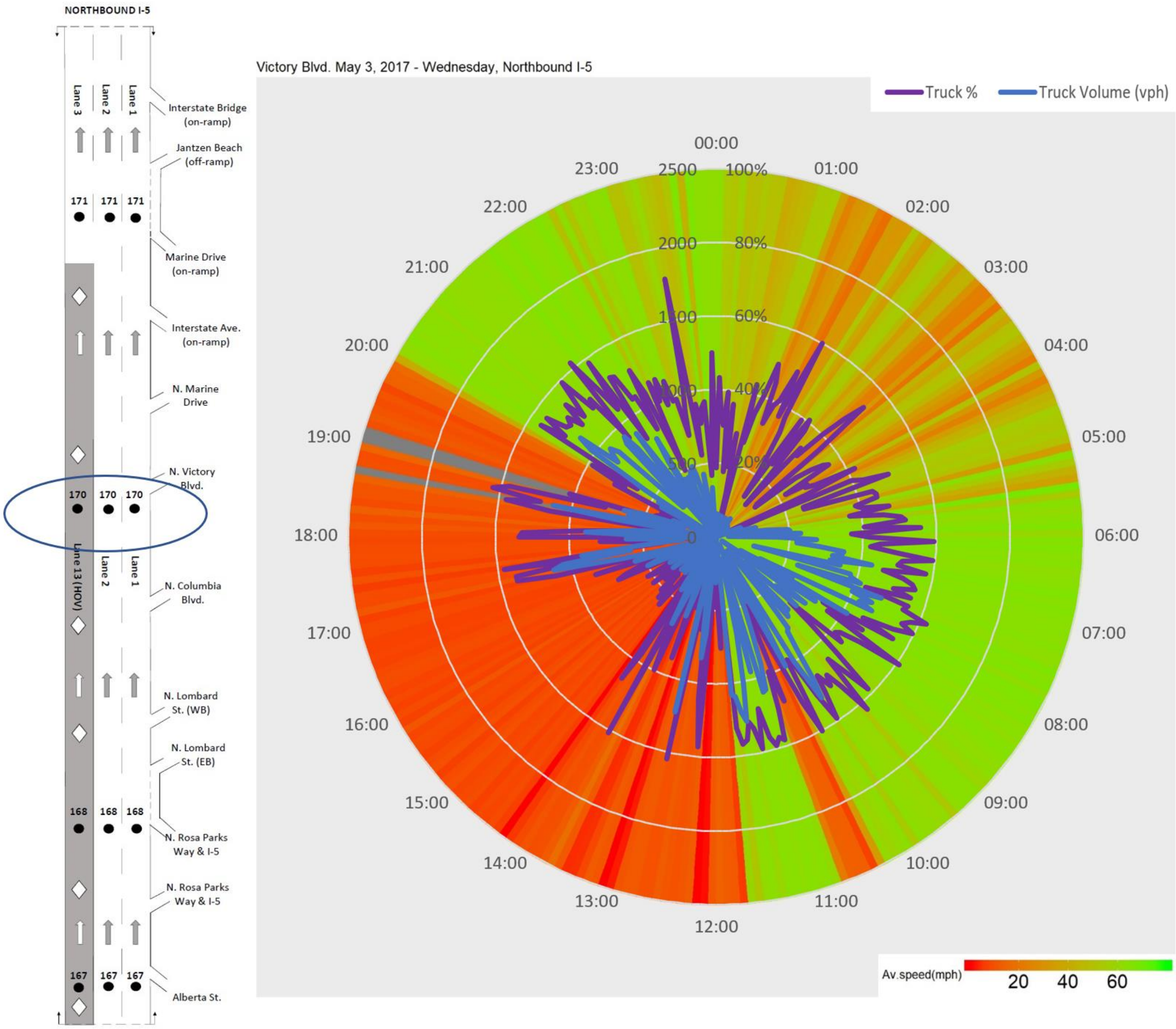

Figure 5.3: 5-min. combo plot for Victory Boulevard – NB (May 3, 2017-Wednesday)

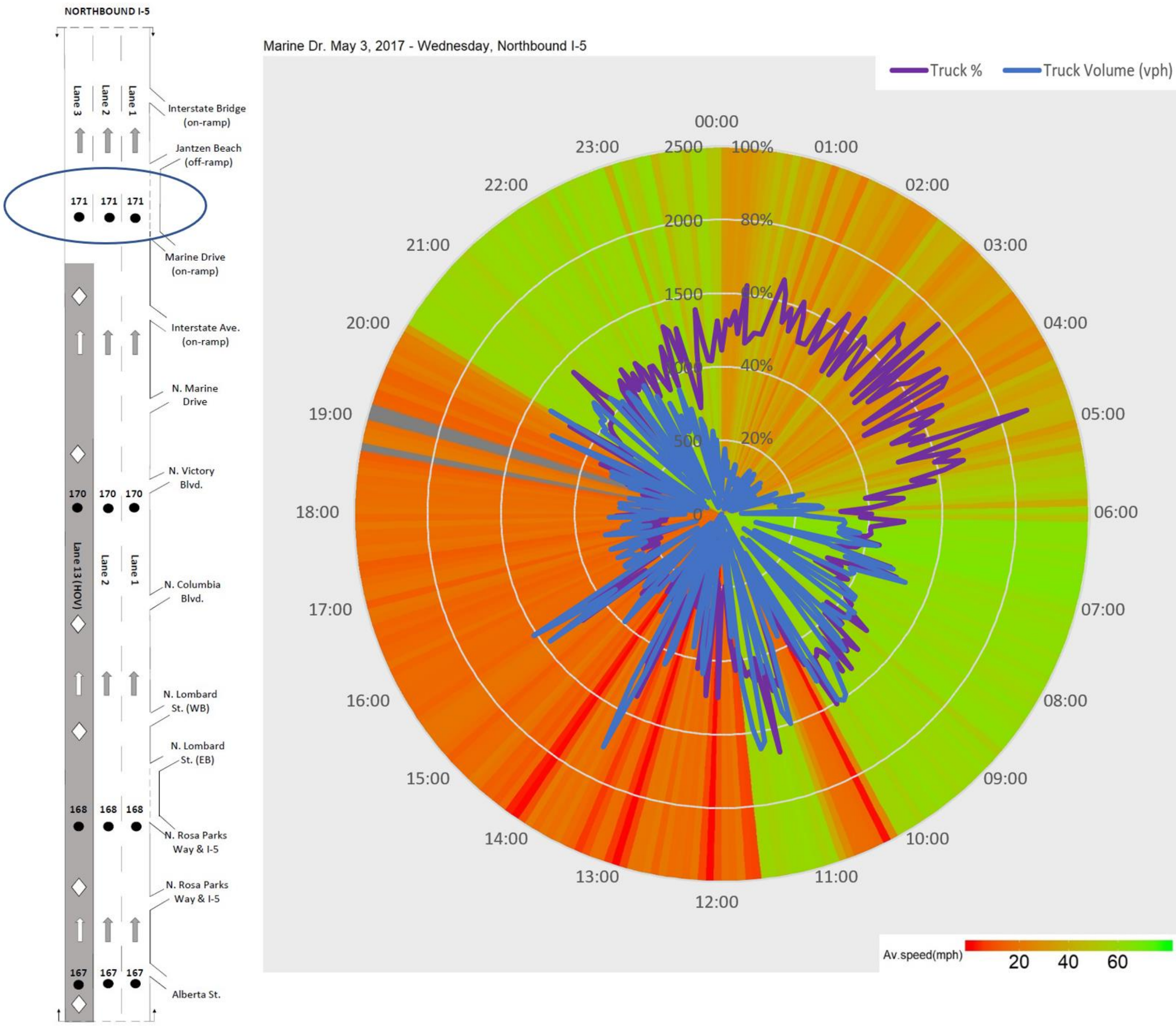

Figure 5.4: 5-min. combo plot for Marine Drive - NB (May 3, 2017-Wednesday)

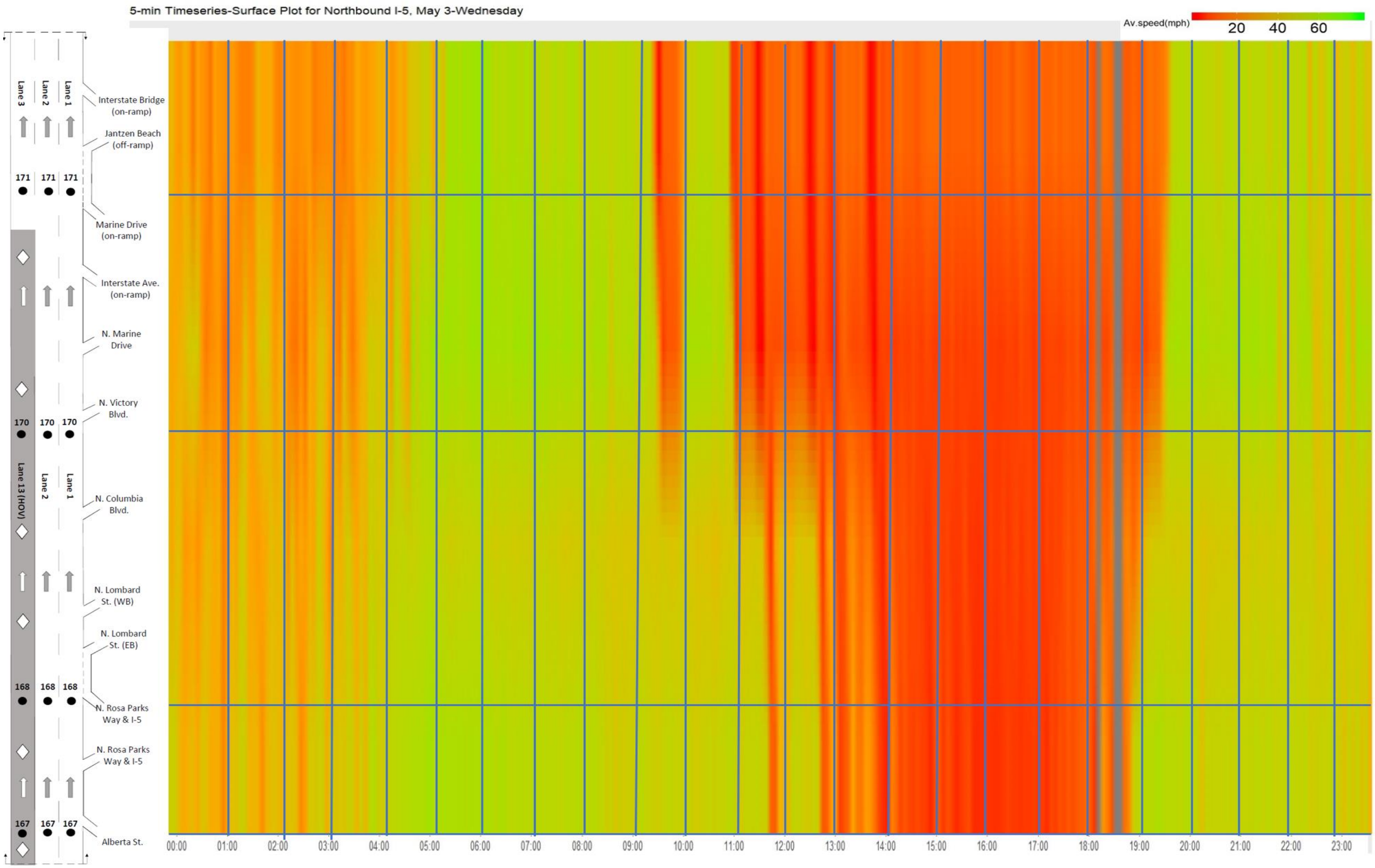

Figure 5.5: 5-min. timeseries-speed surface plot for NB stations (May 3, 2017-Wednesday)

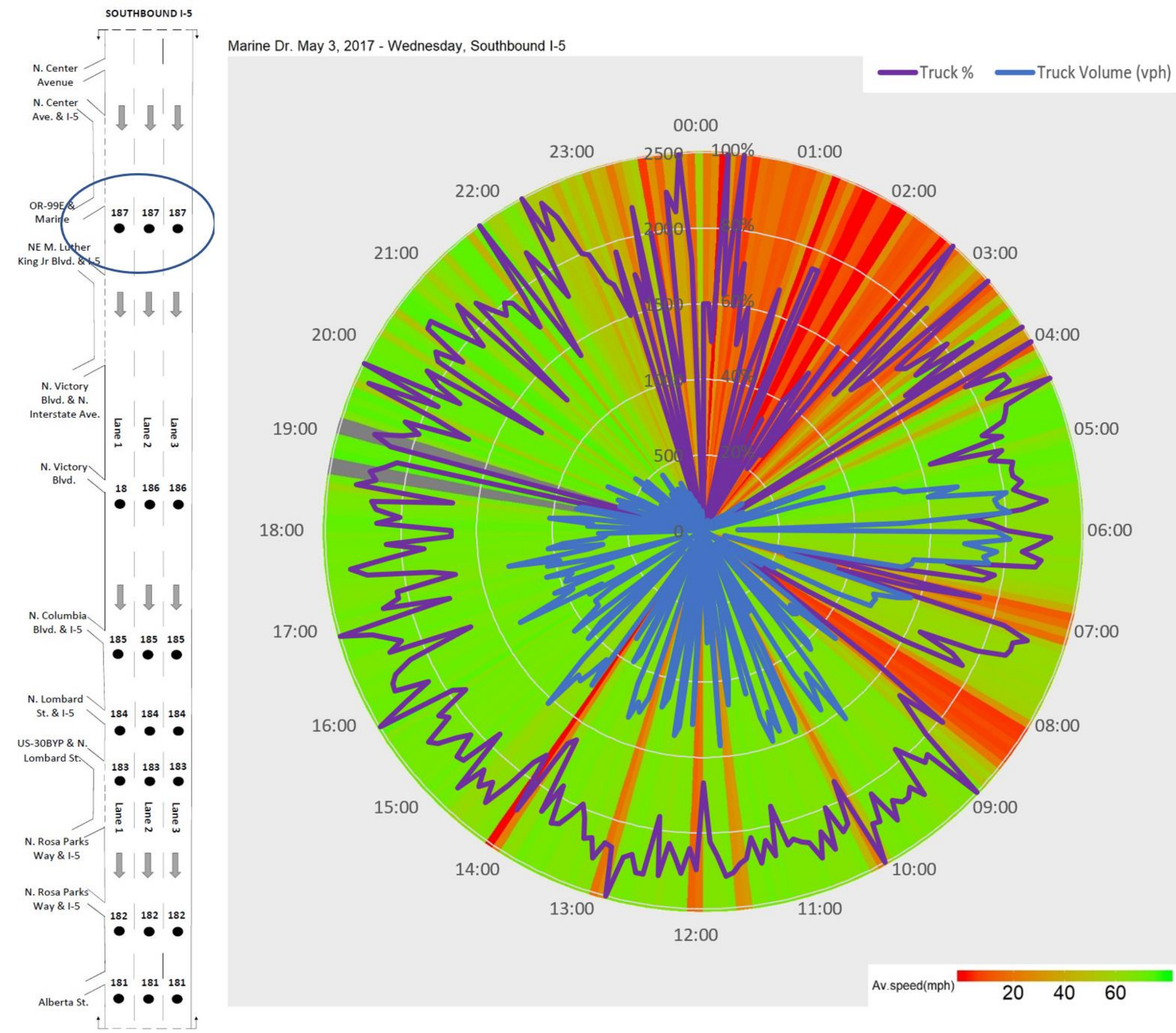

Figure 5.6: 5-min. combo plot for Marine Drive – SB (May 3, 2017-Wednesday)

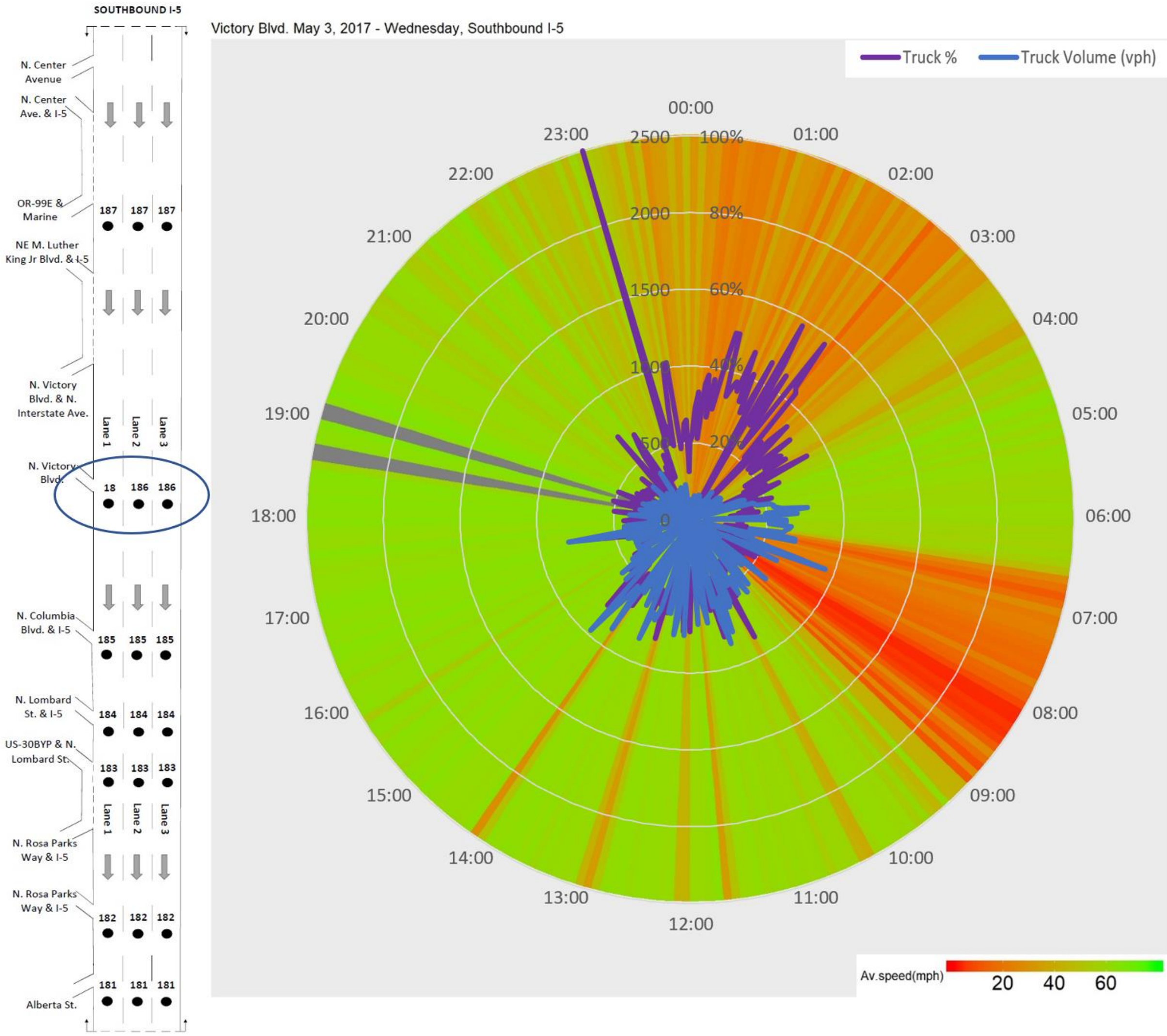

Figure 5.7: 5-min. combo plot for Victory Boulevard – SB (May 3, 2017-Wednesday)

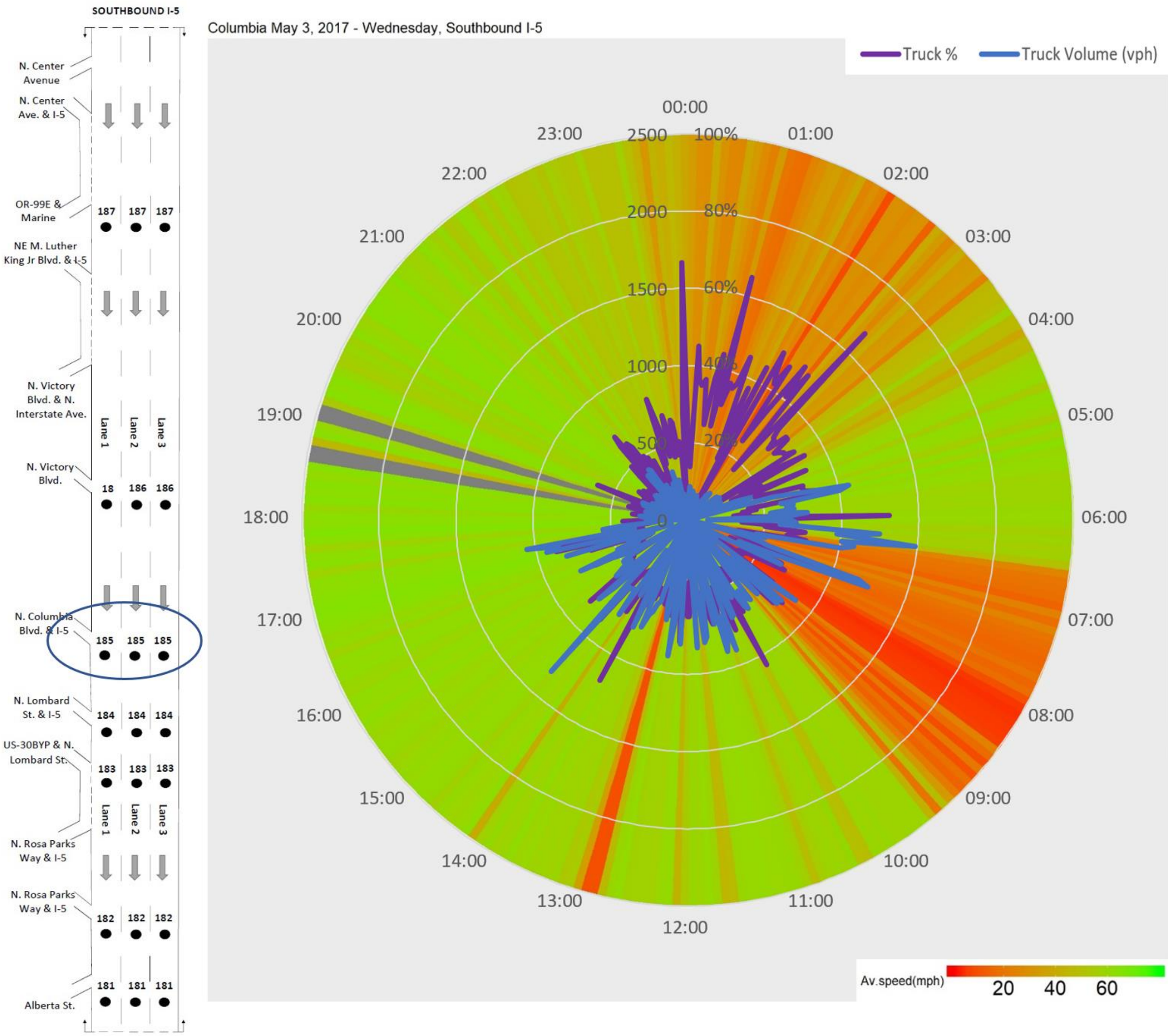

Figure 5.8: 5-min. combo plot for Columbia - SB (May 3, 2017-Wednesday)

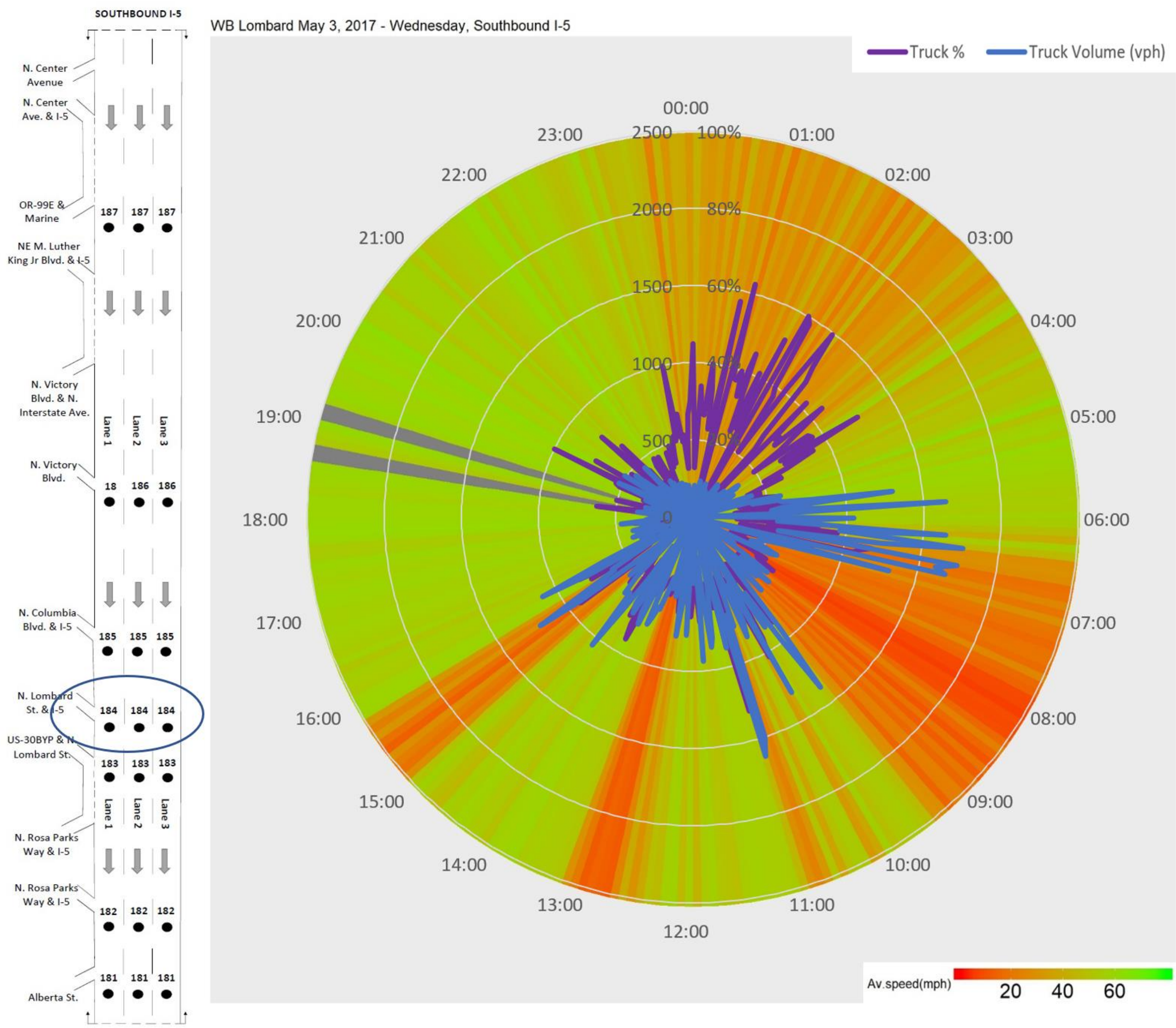

Figure 5.9: 5-min. combo plot for WB Lombard – SB (May 3, 2017-Wednesday)

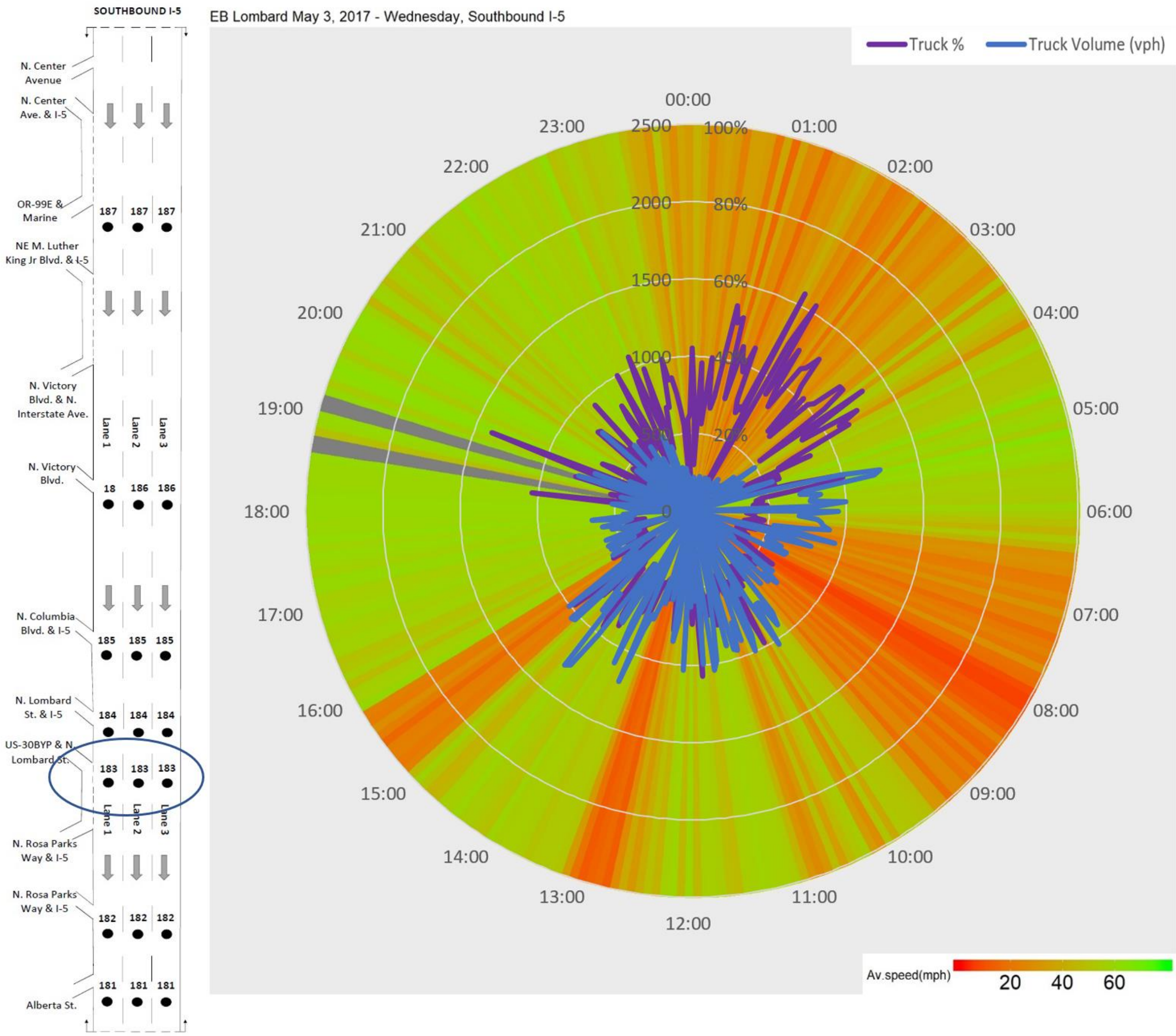

Figure 5.10: 5-min. combo plot for EB Lombard – SB (May 3, 2017-Wednesday)

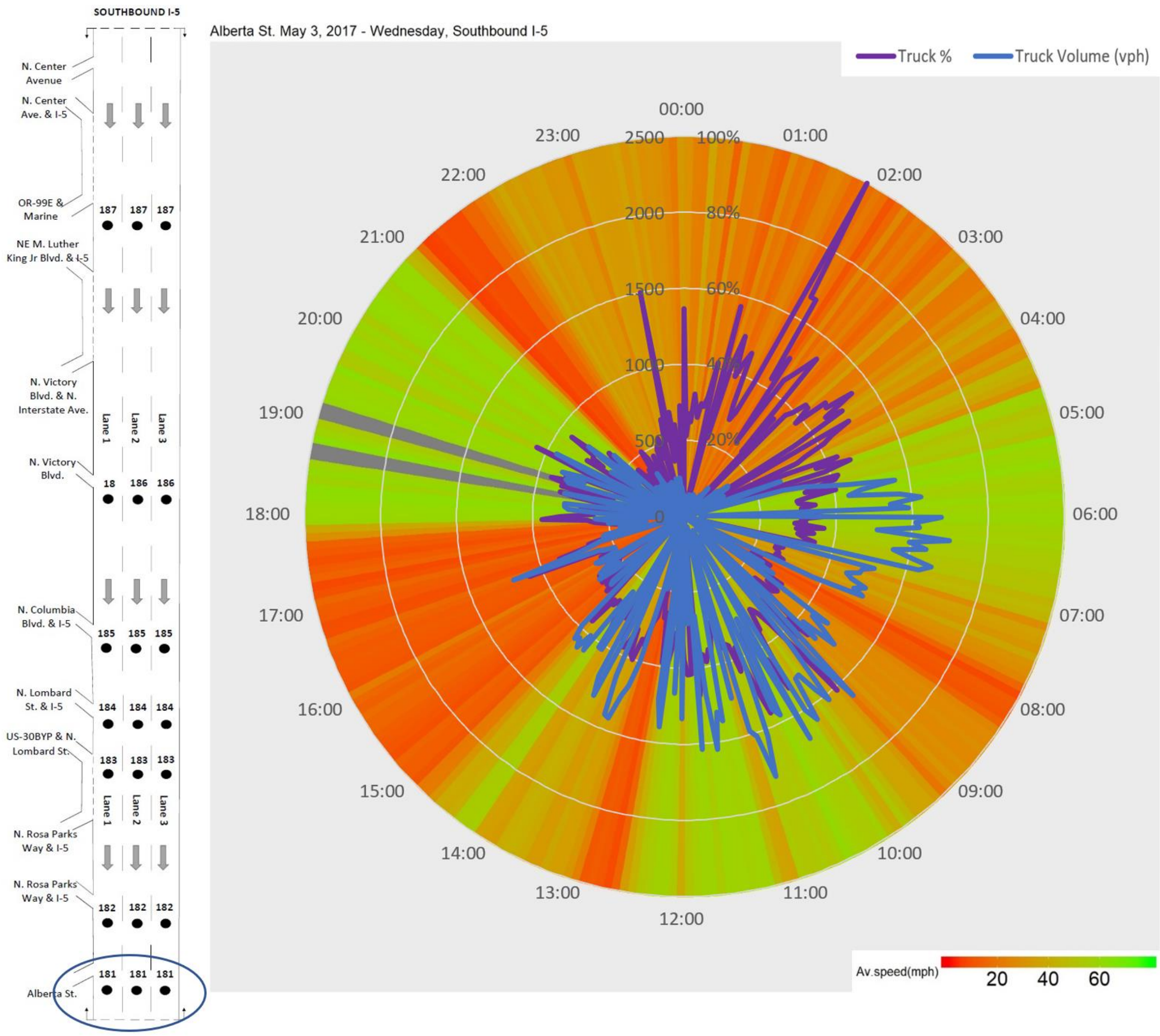

Figure 5.11: 5-min. combo plot for Alberta Street – SB (May 3, 2017-Wednesday)

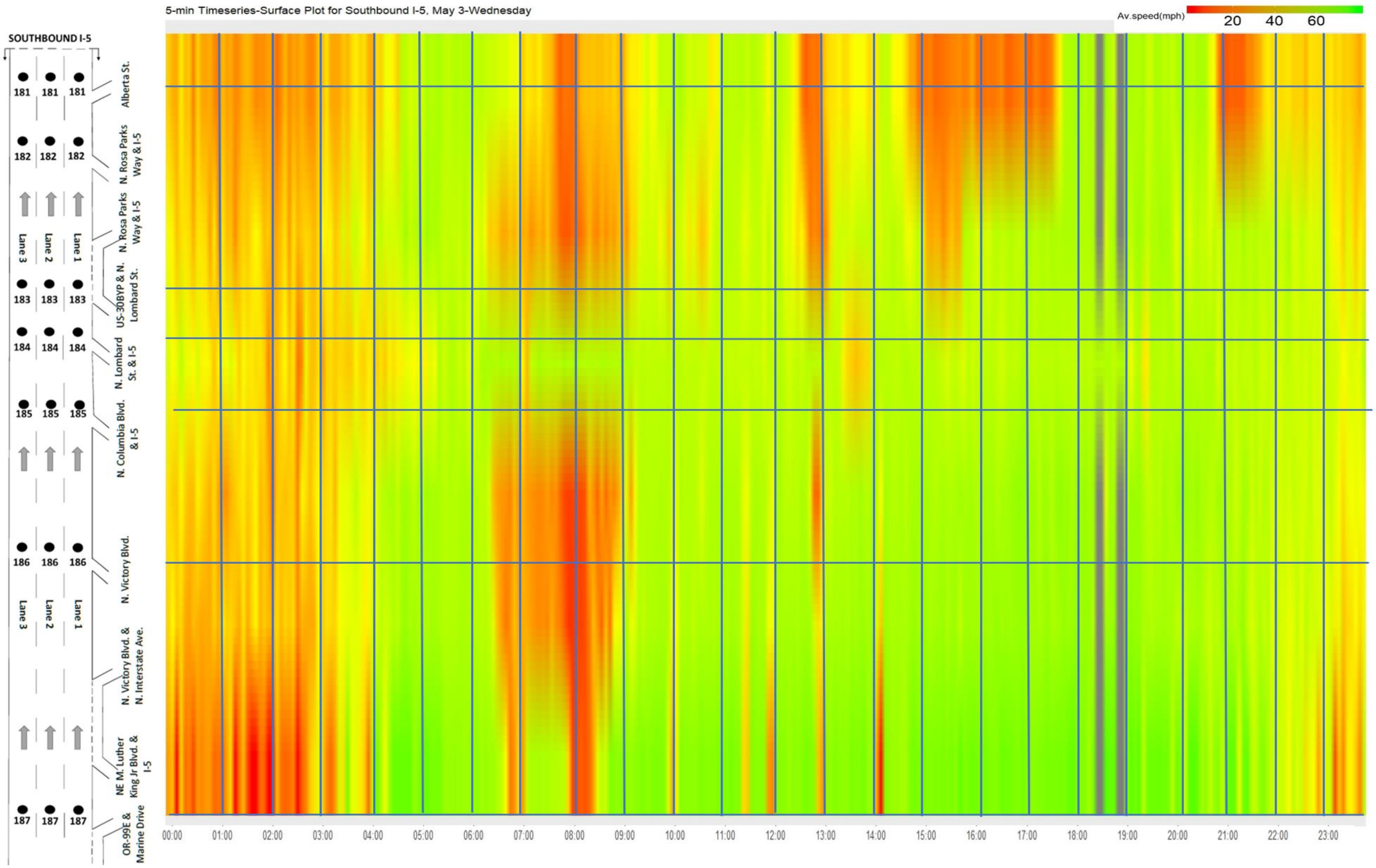

Figure 5.12: 5-min. timeseries-speed surface plot for SB stations (May 3, 2017-Wednesday)

5.3 Descriptive Statistics

Table 5.1 and Table 5.2 indicate the total amount of passenger car and heavy vehicle day by day and station by station for both NB and SB within 5-minute interval respectively. According to the tables, all the stations show an almost consistent volume distribution for all days. Alberta St. on NB and WB Lombard on SB have the maximum value in terms of passenger car volume while Victory Blvd. and Marine Dr. have the minimum value. On the other hand, Marine Dr. for both NB and SB stations have the maximum heavy vehicle volume while Rosa Parks Way on NB and Victory Boulevard on SB have the minimum amount of heavy vehicle.

Table 5.3 and Table 5.4 show weekly descriptive statistics for both NB and SB stations for the passenger car and truck volume within 5-minute count interval respectively. The tables include mean, standard deviation, minimum, and maximum values. As seen on the tables, all maximum values belong to passenger cars except Marine Drive on SB. In addition, in terms of standard deviation, passenger cars show almost similar dispersion from their mean values which are lower than 10% except Marine Drive on SB (20%) while heavy vehicles are between around 10%-30%.

Table 5.5 and Table 5.6 indicate descriptive statistics for average vehicle speed both weekend and weekdays. In terms of mean values, NB and SB segments show a consistent average speed distribution along the stations. Victory Boulevard and Marine Drive show a higher standard deviation value which is dispersion from their mean value.

Table 5.1: Passenger car and heavy vehicle volume for a week on NB

Stations	Bin Categories	April 30	May 1	May 2	May 3	May 4	May 5	May 6
Alberta St.	Bin1	43449	39722	38177	35937	36405	44283	34529
	Bin2+Bin3+Bin4	8470	13316	12766	11901	11716	12679	6162
Rosa Parks Way	Bin1	44903	43124	41373	38979	39040	47619	39808
	Bin2+Bin3+Bin4	3937	7931	8005	7611	7055	7773	3008
Victory Blvd.	Bin1	15607	14308	14391	14808	14526	17495	13893
	Bin2+Bin3+Bin4	9882	12332	11482	9168	10215	11383	9402
Marine Dr.	Bin1	28254	28277	27855	27092	26917	33200	25176
	Bin2+Bin3+Bin4	14539	16647	16626	13869	14310	16875	16803

Table 5.2: Passenger car and heavy vehicle volume for a week on SB

Stations	Bin Categories	April 30	May 1	May 2	May 3	May 4	May 5	May 6
Alberta St.	Bin1	32663	33290	30366	31634	28913	36894	38025
	Bin2+Bin3+Bin4	10963	15067	14170	13759	13067	16630	12041
Rosa Parks Way	Bin1	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Bin2+Bin3+Bin4	No Data	No Data	No Data	No Data	No Data	No Data	No Data
EB Lombard	Bin1	36827	38520	36649	37616	32721	44082	41753
	Bin2+Bin3+Bin4	6602	11146	10162	9942	9564	10932	8197
WB Lombard	Bin1	38821	39372	36561	36940	34092	44936	43986
	Bin2+Bin3+Bin4	4013	8763	8637	8947	7269	8508	5044
Columbia	Bin1	35780	34971	32262	32907	29761	40346	40193
	Bin2+Bin3+Bin4	4536	8471	8213	8260	6927	8254	5749
Victory Blvd.	Bin1	34037	34261	31697	32896	29118	39616	37444
	Bin2+Bin3+Bin4	3988	7540	7061	6832	5990	7271	5439
Marine Dr.	Bin1	1636	2644	3212	3355	2912	3478	2607
	Bin2+Bin3+Bin4	11946	14156	12831	13566	11344	16226	13305

Table 5.3: Descriptive statistics for the passenger cars and heavy vehicles with 5 min interval on NB stations (weekly volume)

	Passenger Car (x1000)				Heavy Vehicle (x1000)			
Stations	Mean	SD	Min	Max	Mean	SD	Min	Max
Alberta St.	38.93	3.48	34.53	44.28	11.00	2.46	6.16	13.32
Rosa Parks Way	42.12	3.03	38.98	47.62	6.47	1.94	3.01	8.01
Victory Blvd.	15.00	1.13	13.89	17.50	10.55	1.10	9.17	12.33
Marine Dr.	28.11	2.30	25.18	33.20	15.67	1.25	13.87	16.88

Table 5.4: Descriptive statistics for the passenger cars and heavy vehicles with 5 min interval on SB stations (weekly volume)

	Passenger Car (x1000)				Heavy Vehicle (x1000)			
Stations	Mean	SD	Min	Max	Mean	SD	Min	Max
Alberta St.	33.11	3.07	28.91	38.03	13.67	1.75	10.96	16.63
Rosa Parks Way	-	-	-	-	-	-	-	-
EB Lombard	38.31	3.42	32.72	44.08	9.51	1.49	6.60	11.14
WB Lombard	39.24	3.67	3.67	44.94	7.31	1.85	4.01	8.95
Columbia	35.17	3.69	3.69	40.35	7.20	1.42	4.54	8.47
Victory Blvd.	34.15	3.24	3.24	39.62	6.30	1.17	3.99	7.54
Marine Dr.	2.83	0.58	1.64	3.48	13.34	1.48	11.34	16.23

Table 5.5: Descriptive statistics for average speed of the vehicles 5 min interval on NB stations (weekly)

	Weekday				Weekend			
Stations	Mean	SD	Min	Max	Mean	SD	Min	Max
Alberta St.	47.24	18.02	2.2	66.4	57.84	7.07	25.89	67.13
Rosa Parks Way	43.25	16.19	2.43	60.17	52.41	6.38	23.07	61.53
Victory Blvd.	42.94	22.68	0.47	69.47	52.28	17.30	0.8	69.6
Marine Dr.	41.05	18.68	0.11	66.76	46.72	16.31	1.82	66.29

Table 5.6: Descriptive statistics for average speed of vehicles 5 min interval on SB stations (weekly)

	Weekday				Weekend			
Stations	Mean	SD	Min	Max	Mean	SD	Min	Max
Alberta St.	38.38	16.90	5.34	64.31	46.56	14.13	8.6	65.07
Rosa Parks Way	-	-	-	-	-	-	-	-
EB Lombard	45.14	14.68	6.62	64.84	51.01	11.50	8.13	64.56
WB Lombard	44.60	14.67	5.78	62.22	50.34	11.27	10.44	65.07
Columbia	47.93	16.66	3.44	66.61	53.25	13.24	7.47	66.76
Victory Blvd.	48.62	16.66	2.4	66.63	53.51	13.48	2.53	66.84
Marine Dr.	54.82	20.05	4.0	76.27	55.57	19.89	4.0	76.57

5.4 Validation

After generated plots, it has been observed that there are low average speeds between 12-06 am. for all stations. In general, free-flow traffic stream is expected between these times since lower passenger car volume. To understand and solve this problem, the data was investigated and analyzed again for validation between those time intervals. The data which contains zero count with non-zero average vehicle speed and also non-zero count with zero average vehicle speed has been omitted for SB Alberta St. Figure 5.13 shows before and after plots which were generated based on eliminated and non-eliminated data. Even though there are not too much average speed changes after data cleaning, it would be better to get more specific results if the traffic count devices calibrated more accurately.

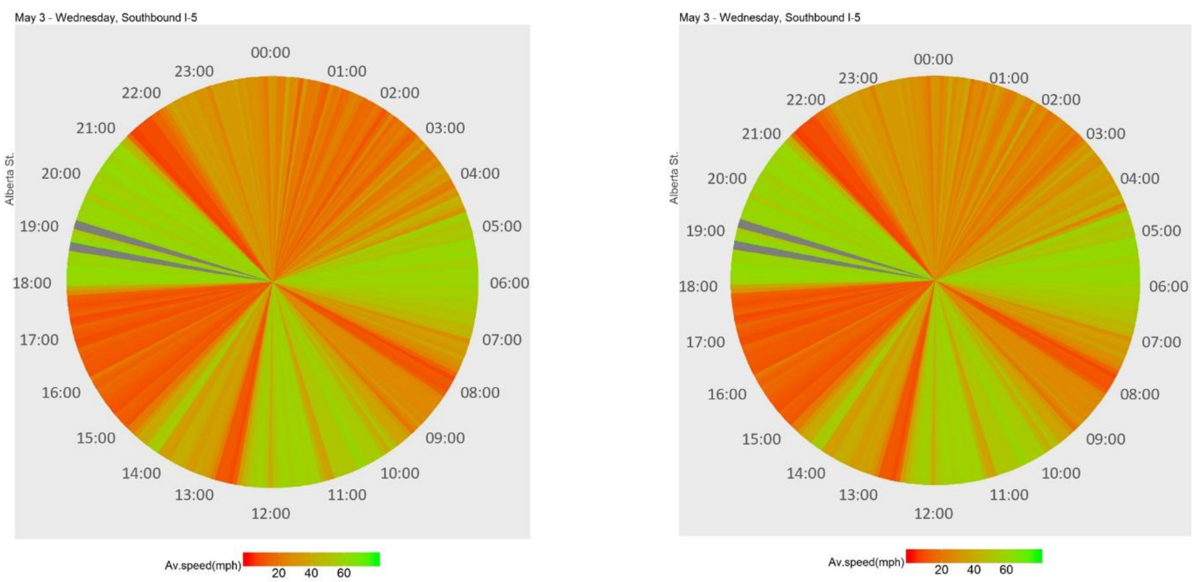

Figure 5.13: Before validation (left) and after validation (right) plots for SB Alberta St. (May 3, 2017-Wednesday)

5.5 Results

According to the generated plots, it can be observed that downgrade trade of the average speed afternoon is significantly bigger than after midnight decrease. This can be explained because of the passenger car existence in the afternoon rush hours. The time intervals of average speed reduction for NB stations are almost stable over the stations and over the days except for the weekend. On the other hand, decrease of average speed on SB direction of I-5 occurs after midnight until early morning for SB. Moreover, it has been observed that there are some specific times which average speeds drop suddenly for both directions.

On the other hand, there is a free-flow in afternoon peak hour for SB Marine Dr. The reason of that might be because of the truckers return from unloading their loads from this point. Moreover, there are a lot of on-off points on this road segment which increases truck traffic. So, it is possible to see a high percentage of heavy vehicles. For SB Alberta St., it is seen that average speed decrease distributed over the day. It can be explained that truckers who joined before this point from on-ramps to I-5 to load or unload their carrier to the industrial area might reduce the average speed. SB stations show the same average speed characteristic among each other as NB stations except Alberta St. on SB.

It can also be deducted that the existence of Port of Portland, Portland International Airport, and Wilsonville-Tualatin industrial area around the analyzed highway sections have a huge impact in terms of having a high truck percentage which leads to decrease of average vehicle speed. Distribution of these speed reduces in a day within a specific time interval might be the result of the existence of these ports and industrial areas.

According to the timeseries speed surface plots which are generated for both NB and SB stations show that early AM decrease in traffic stream speed occurs almost at the same time for both highway segments as trucks are going out on delivery around this time of the day. PM peak hours can clearly be observed afternoon for NB stations. On the other hand, average speed reduces are distributed over the time for the SB segment. Moreover, there are some specific locations which bottlenecks occur. Finally, calibrating traffic count devices allows obtaining more accurate and specific results.

CHAPTER 6: CONCLUSIONS AND FUTURE RESEARCH

6.1 Conclusions

This thesis aimed to explore the freight movement in disaggregate detail by proposing a methodology to better classify long/heavy vehicles using length-based vehicle count and average speed data. Both NB and SB stations on I-5 between Alberta Street and Marine Drive, which is about 2.5 miles long, have been analyzed. I-5 in Portland, OR (USA) was used as a case primarily due to its important position in the freight movement across the North-South axis between Mexico and Canada (and vice versa). This connection increases the importance of I-5 in terms of freight movement. The thesis discusses various approaches for vehicle classification (stacked column line graphics, and radar plots) as well as average speed (time series speed surface plots and polar plots). Moreover, Appendix A shows different kinds of graphs generated for the sake of finding a better visualization method. Results show the merit in using more disaggregate data (5-minute intervals) to better account for variations in average speed and truck volumes. For the analysis section, it was chosen the day of May 3, 2017-Wednesday for all NB and SB stations. The reason behind this approach was because that day was the middle day of the week and was thought it may give a general idea of the traffic flow of the whole week. According to the generated plots, analyzing one day for both directions gives a general perspective in terms of understanding of heavy vehicle movement and average vehicle speed for all other weekdays even though there are some differences for the weekend. Remaining days are shown on the Appendix B.

6.2 Future Research and Recommendations

Longer time interval of the data is the most recommended suggestion for the future researches. Even though one-week data period gives a point of view for the analyzed section, it would have been good to have long-term data for precise results. Long-term data may give more detailed analysis results for the segments in which need to be improved, planned, and managed.

Data error is another issue for the analysis results. There are some data which missing or have discrepancies. Moreover, it has been expected free-flow traffic stream from midnight to early morning. According to the plots, there is no free-flow as expected at this time interval. To solve these problems, it might be suggested that the data collection devices should be calibrated carefully and checked at more frequent time intervals. Additionally, highway conditions such as road work, weather circumstances, and traffic incidents can be investigated to obtain more specific results.

It has been founded that there are sudden changes of average speed, truck percentage, and volume within some 5-minute period. These sudden changes negatively affect traffic density and traffic flow. Making time changes on truck movements to avoid these effects on the density and flow can be suggested.

Another suggestion for the future analysis would be the improvement of road structure such as constructing new lanes or by-pass roads. Although such arrangements increase vehicle miles traveled, it might be necessary for the sake of the relief of the traffic conditions where the environmental conditions are available.

The proposed combinatorial methodology is able to better capture these variations and provide more insights to guide policies on traffic operations in the Portland region. From a policy perspective, city/local authorities could focus on allotting specific times for movements of heavy vehicles along the corridors with an eye on improving traffic flow. Because of PORTAL's lack of showing graphics below 15-minute interval on its website, this study might be useful for PORTAL to show average speed, truck percentage, and truck volume on the same graph with a 5-minute interval. Moreover, policymakers can intervene highway sections which need to intervene immediately using the plots from this study or to change the restriction hours for trucks. Finally, the proposed method can be used in terms of showing truck speed versus overall traffic speed for future analysis.

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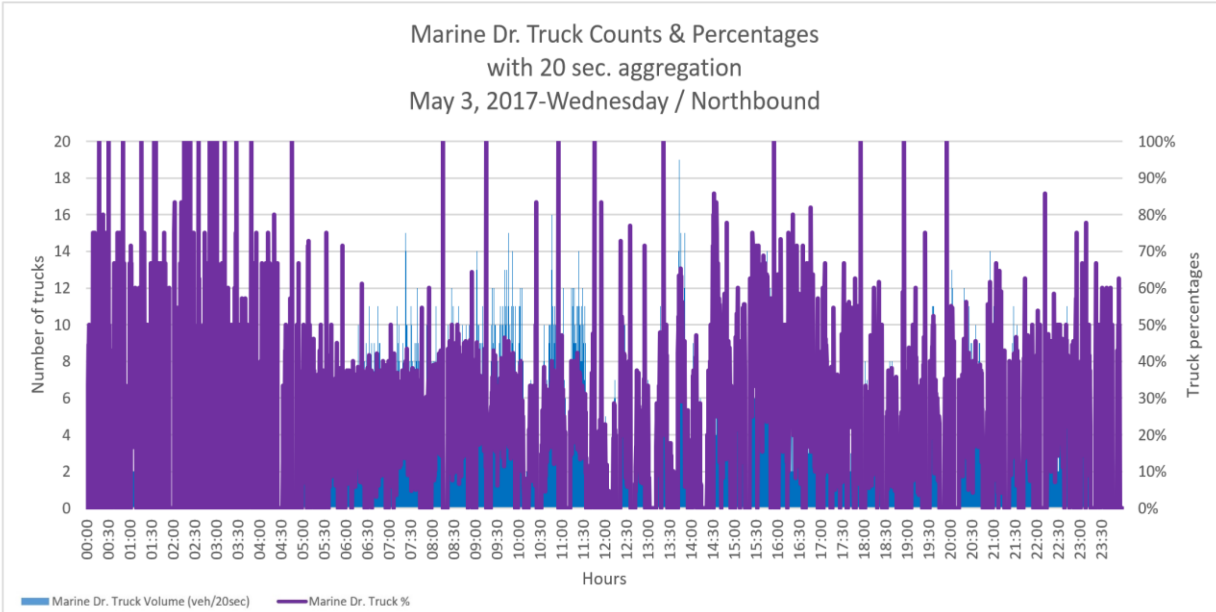
APPENDIX A: ALL GRAPHS GENERATED FOR UNDERSTANDING THE DATA AND FINDING A BETTER VISUALIZATION METHOD



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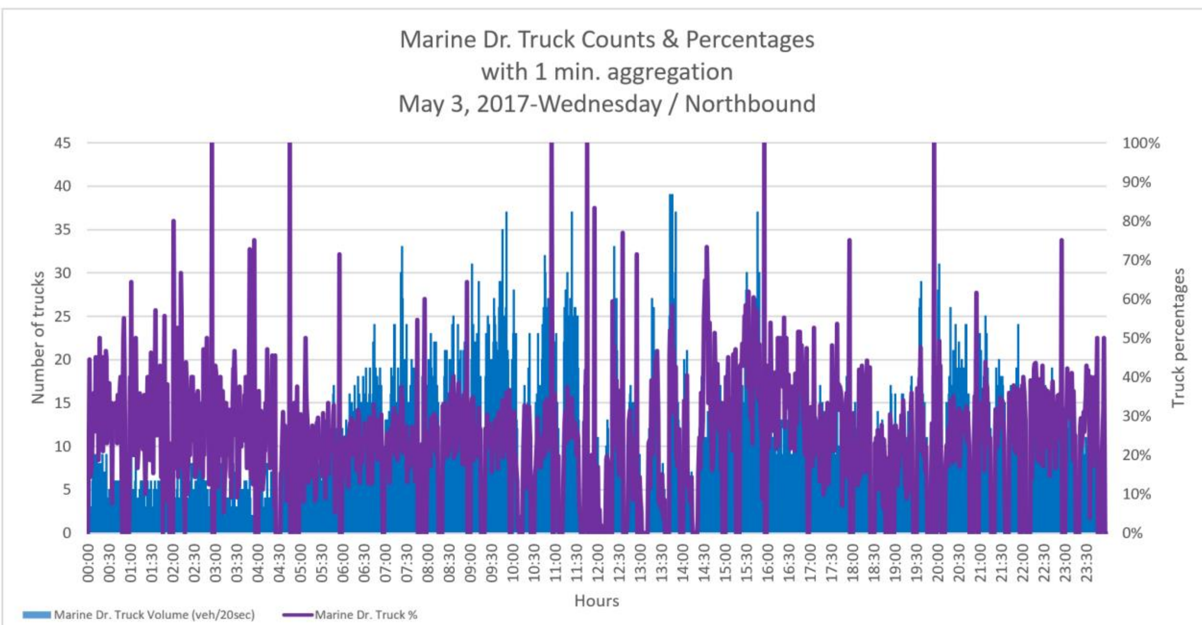
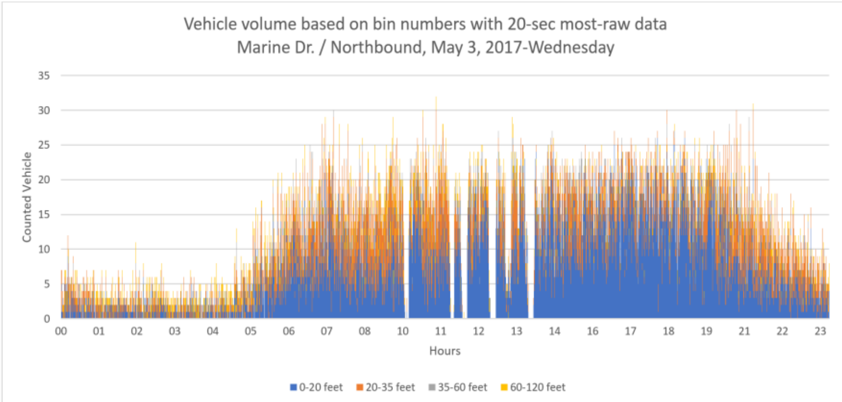


(b)

Figure A.1: Truck count and percentage with different aggregation level for Marine Dr. northbound, May 3, 2017 (a) 20-sec. aggregation, (b) 1-min. aggregation



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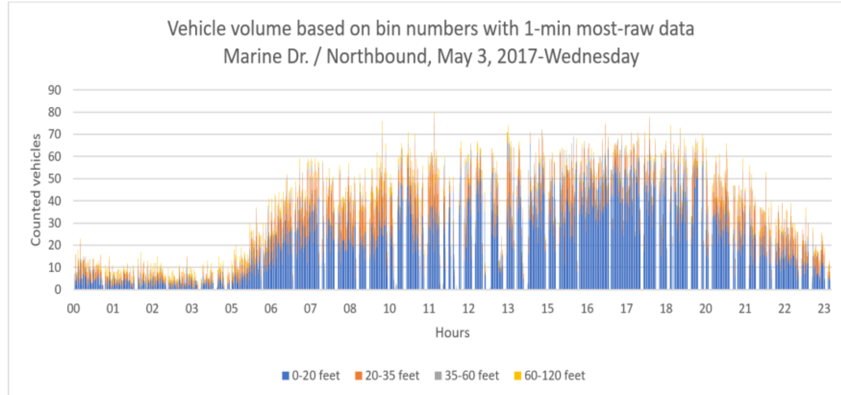

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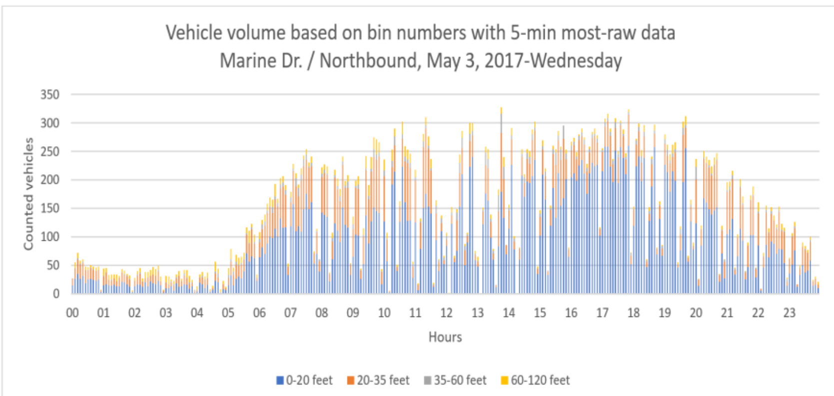

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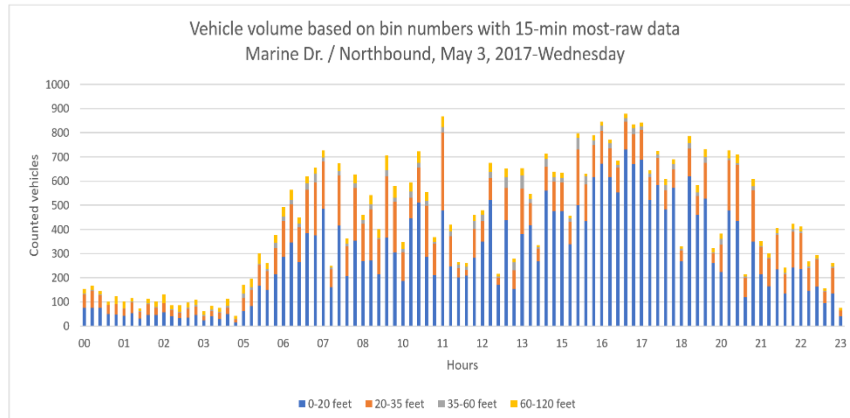
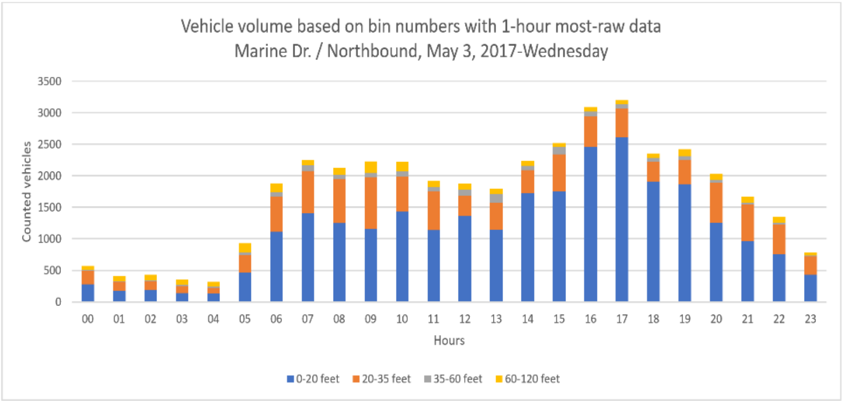


(d)

Figure A.2: Vehicle volume with different aggregation level using most-raw data / stacked column graphs Marine Dr. northbound, May 3, 2017 (a) 20-sec. aggregation, (b) 1-min. aggregation, (c) 5-min. aggregation, (d) 15-min. aggregation, (e) 1-hour aggregation



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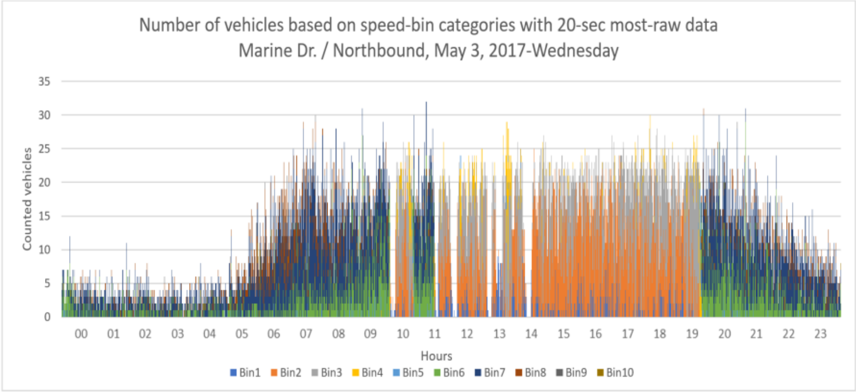

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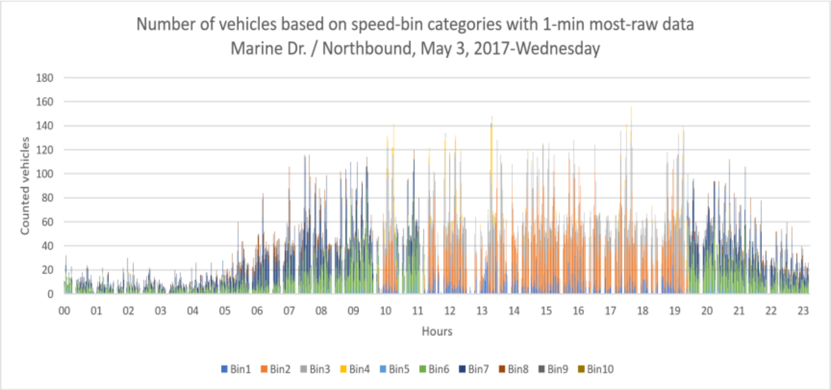
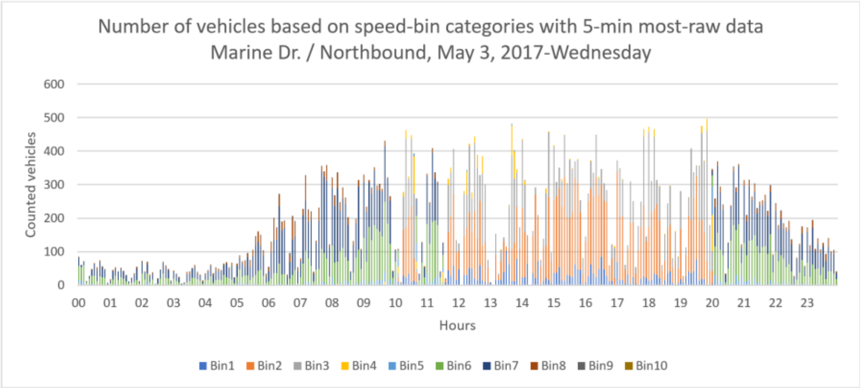


(b)

Figure A.3: Vehicle volume with different aggregation level using speed-bin categorical most-raw data / stacked column graphs Marine Dr. northbound, May 3, 2017 (a) 20-sec. aggregation, (b) 1-min. aggregation, (c) 5-min. aggregation, (d) 15-min. aggregation, (e) 1-hour aggregation



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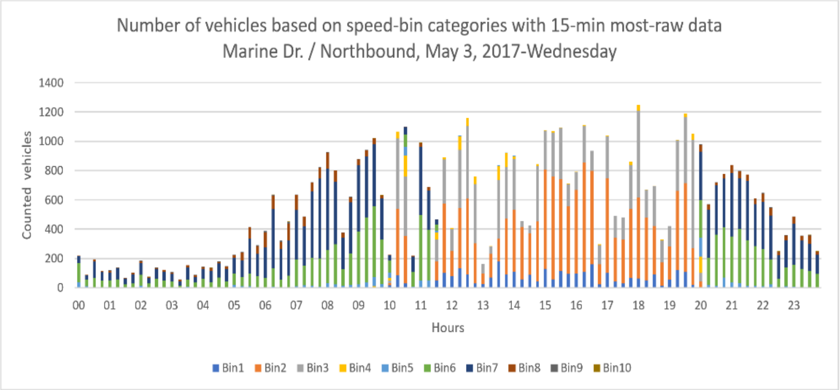

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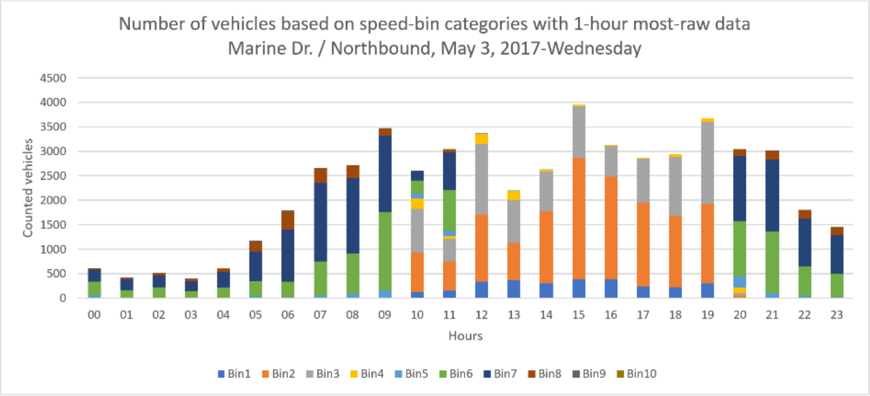

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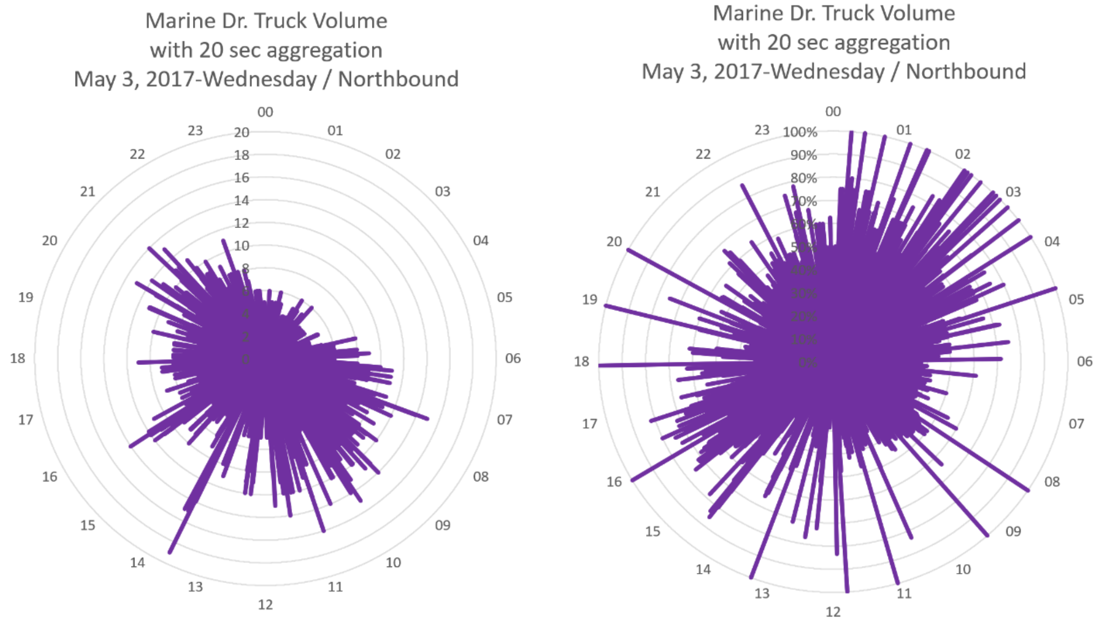

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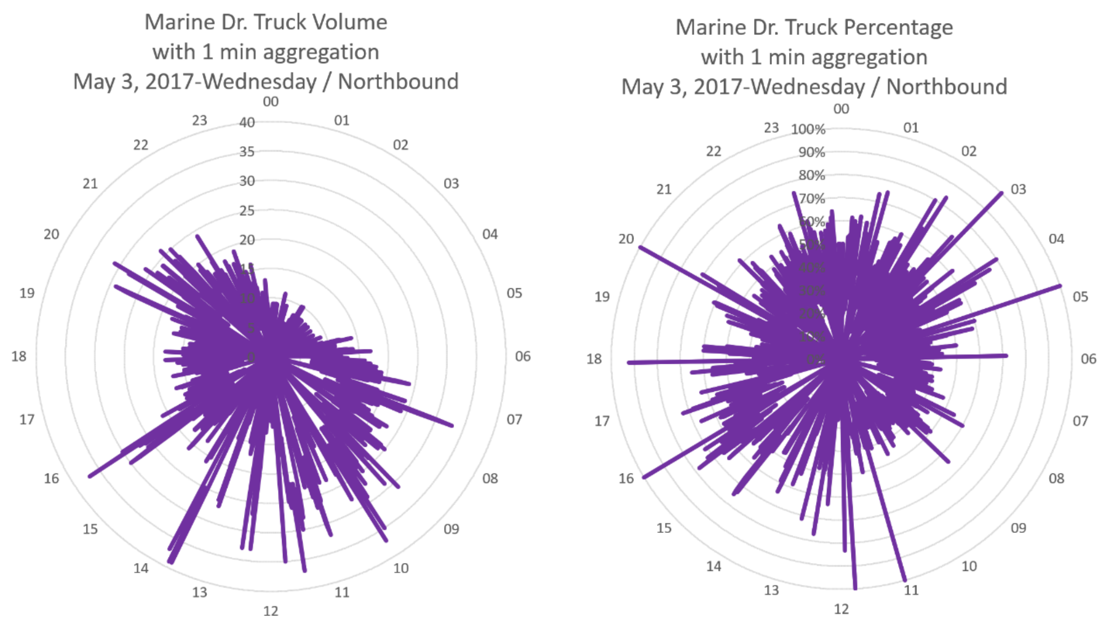
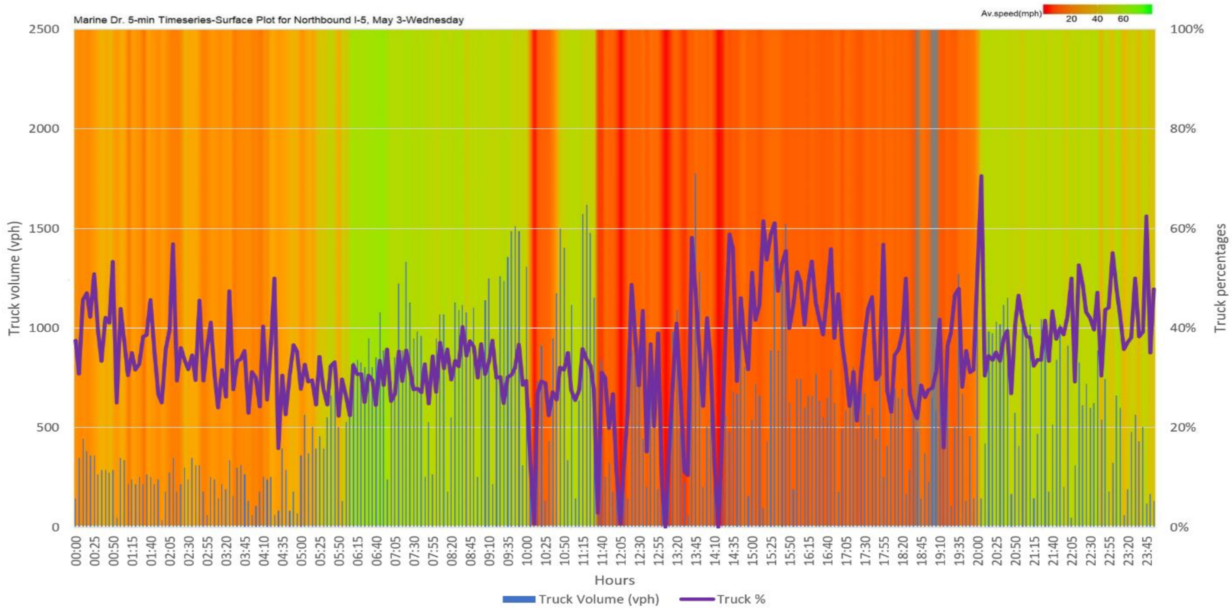


(b)

Figure A.4: Truck volume and percentages with different aggregation level / radar plots Marine Dr. northbound, May 3, 2017 (a) 20-sec. aggregation, (b) 1-min. aggregation



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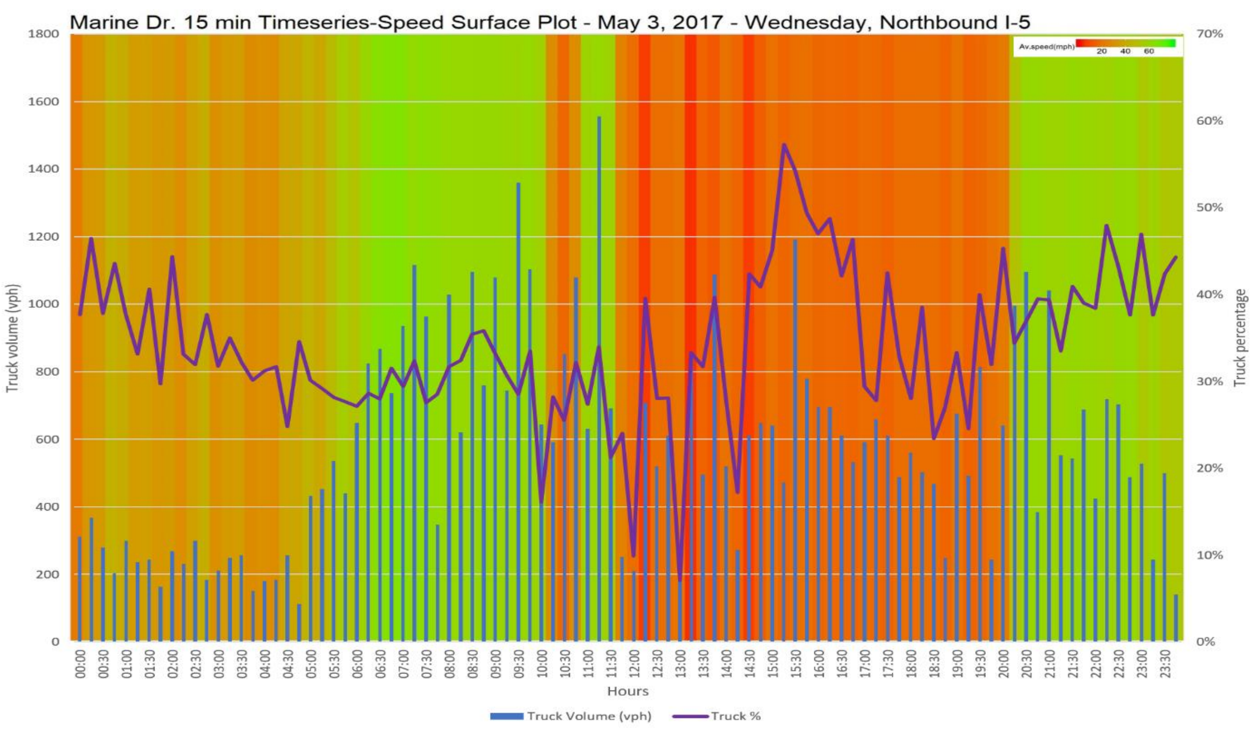
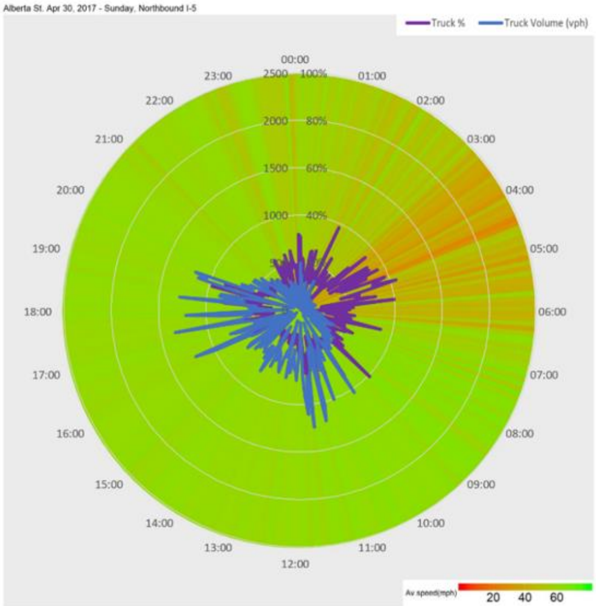


(b)

Figure A.5: Timeseries-speed surface plot with truck count & percentage graphs Marine Dr. northbound, May 3, 2017 (a) 5-min aggregation, (b) 15-min. aggregation

APPENDIX B: GENERATED 5-MIN COMBO PLOTS FOR REMAINING DAYS



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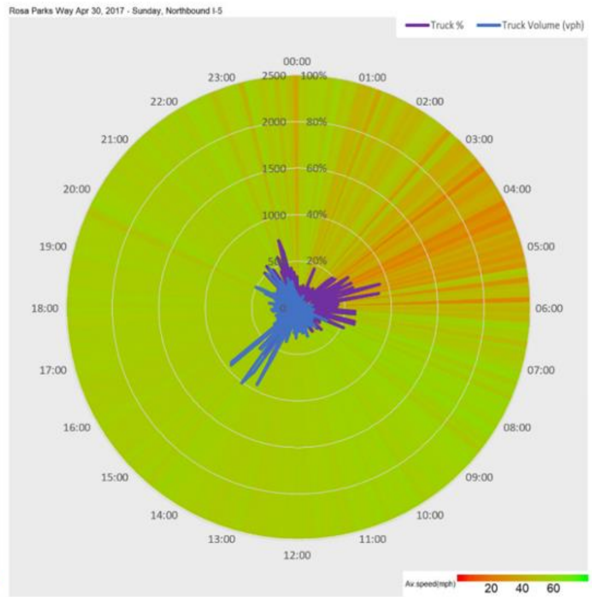

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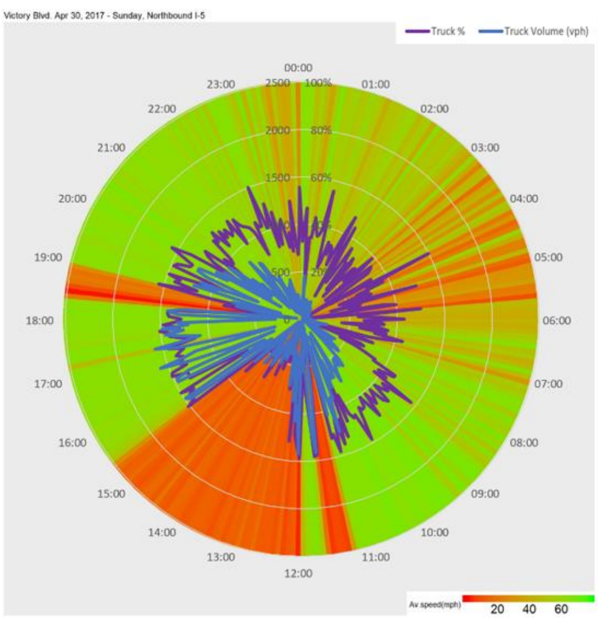

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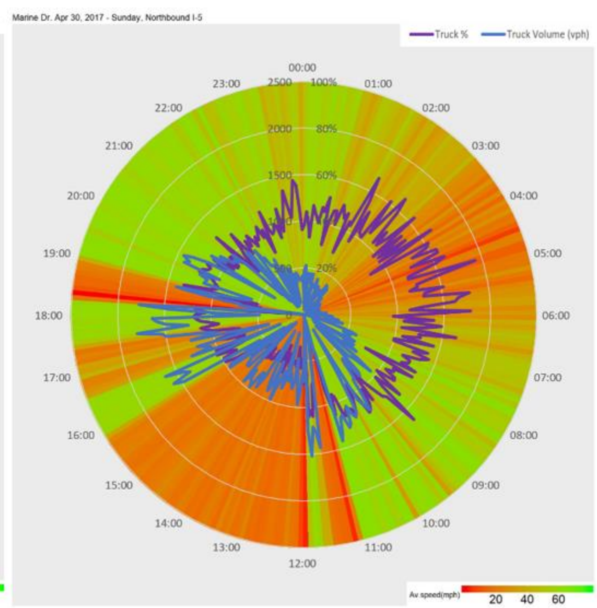


(d)

Figure B.1: 5-min combo plots for April 30, 2017 - northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.

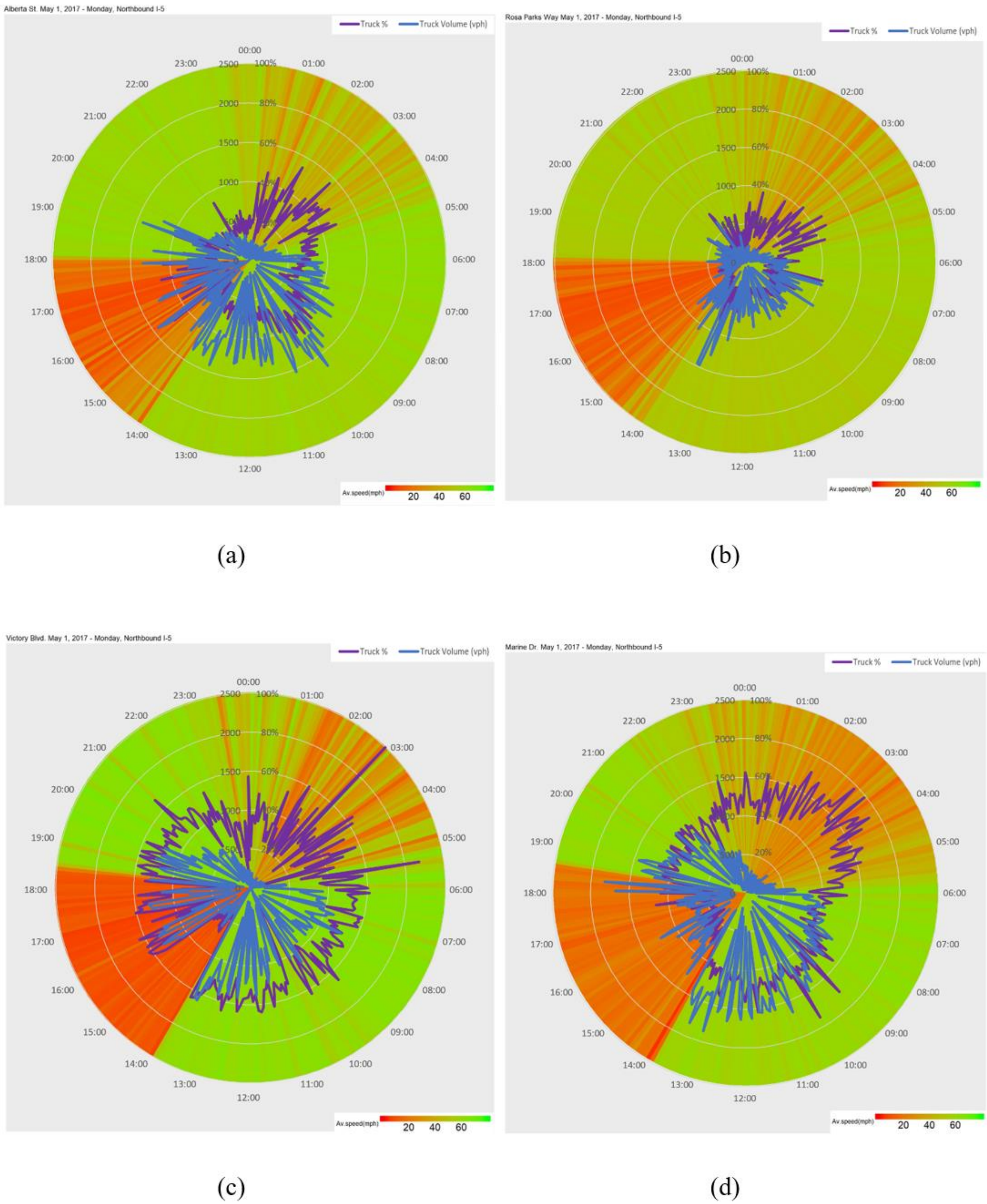
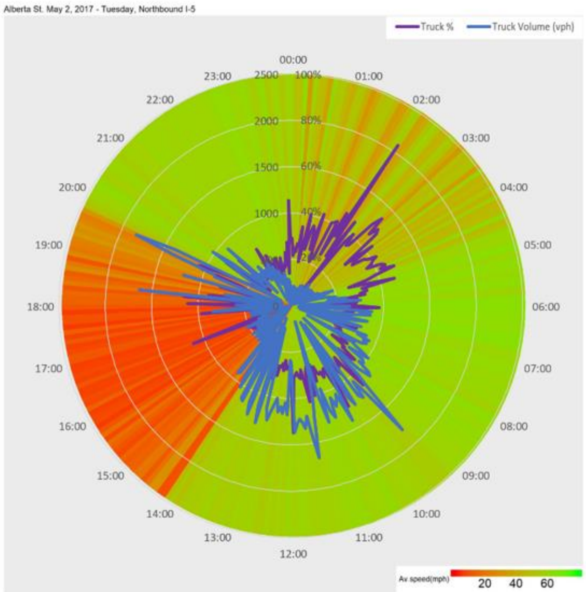


Figure B.2: 5-min combo plots for May 1, 2017 - northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.



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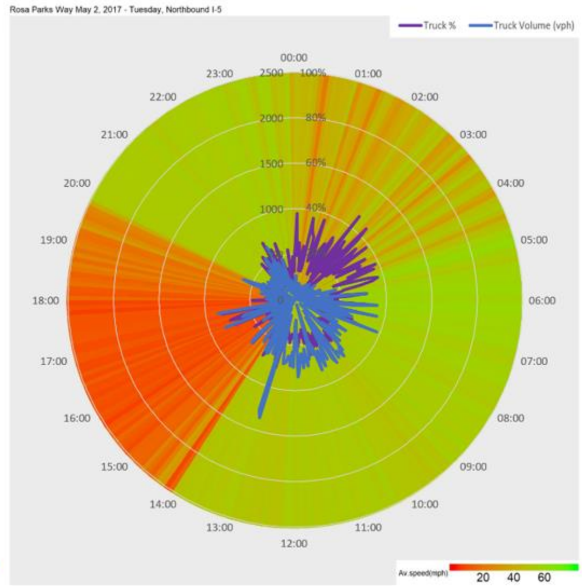

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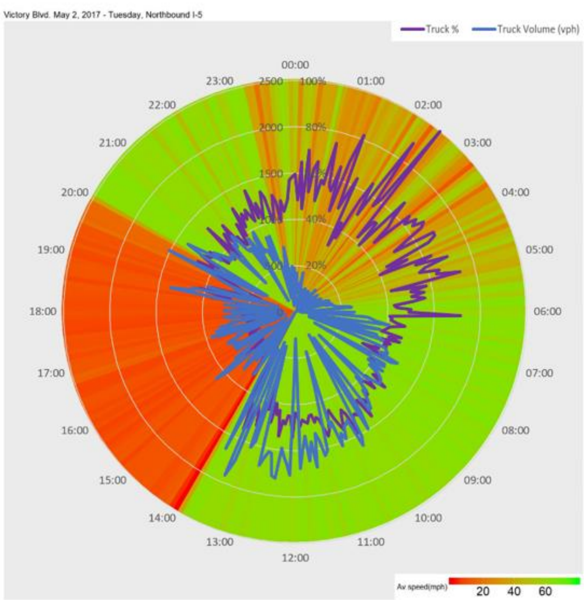

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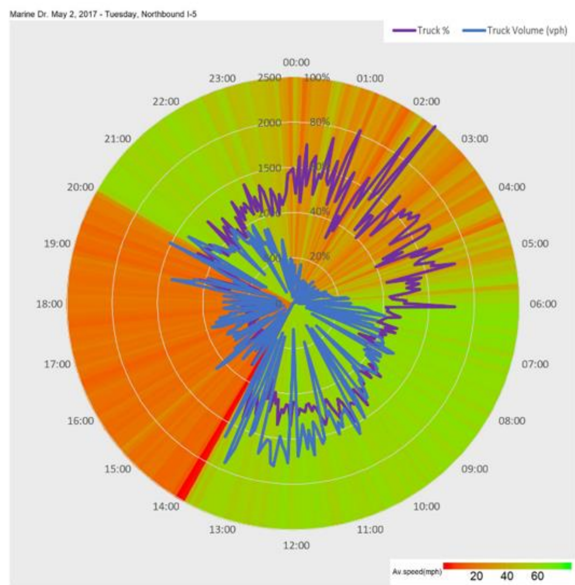

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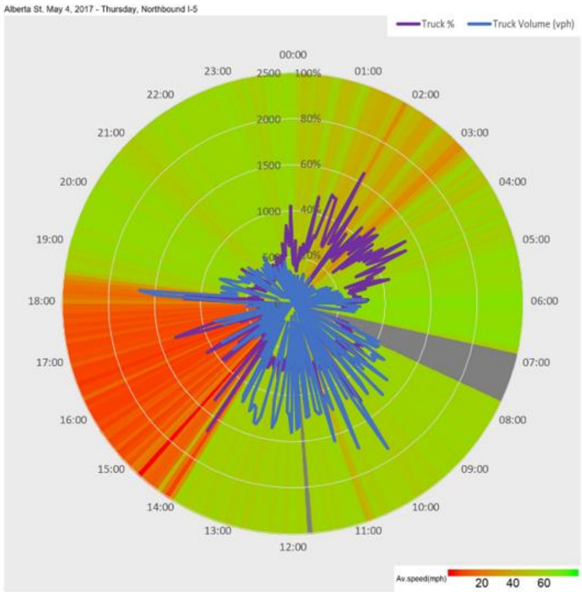
Figure B.3: 5-min combo plots for May 2, 2017 - northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.



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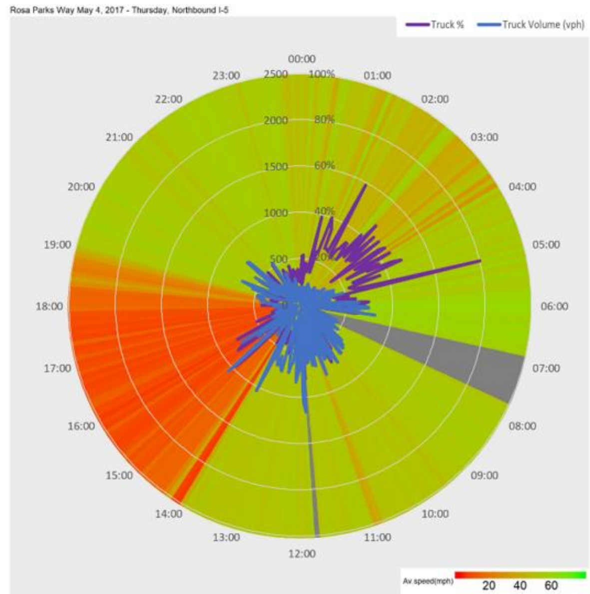

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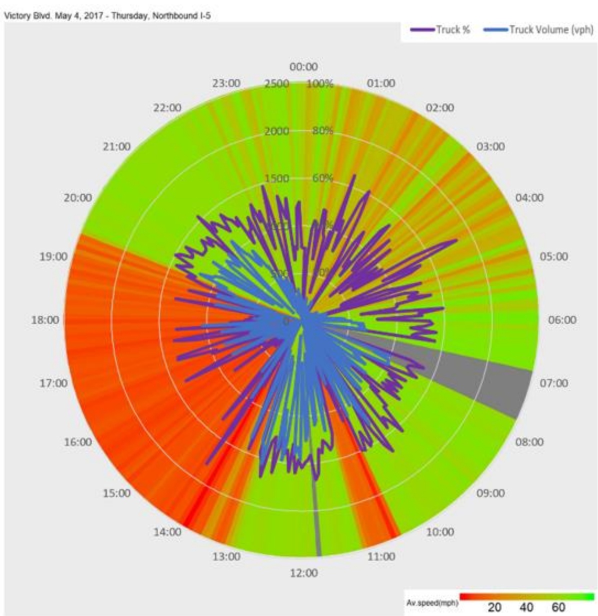

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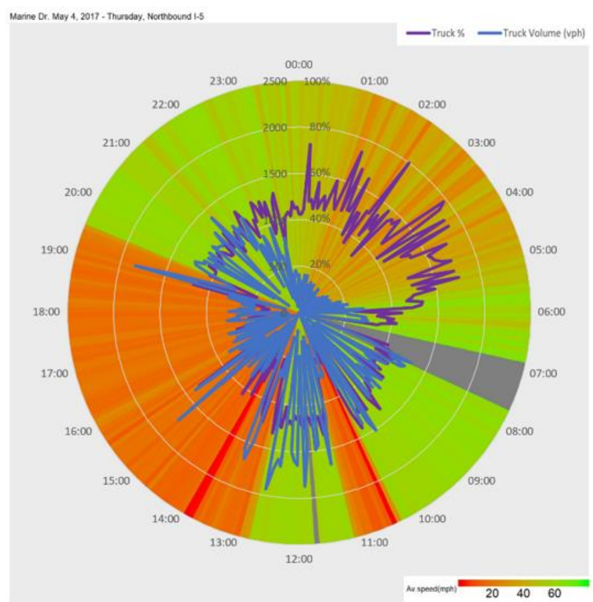

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Figure B.4: 5-min combo plots for May 4, 2017 – northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.

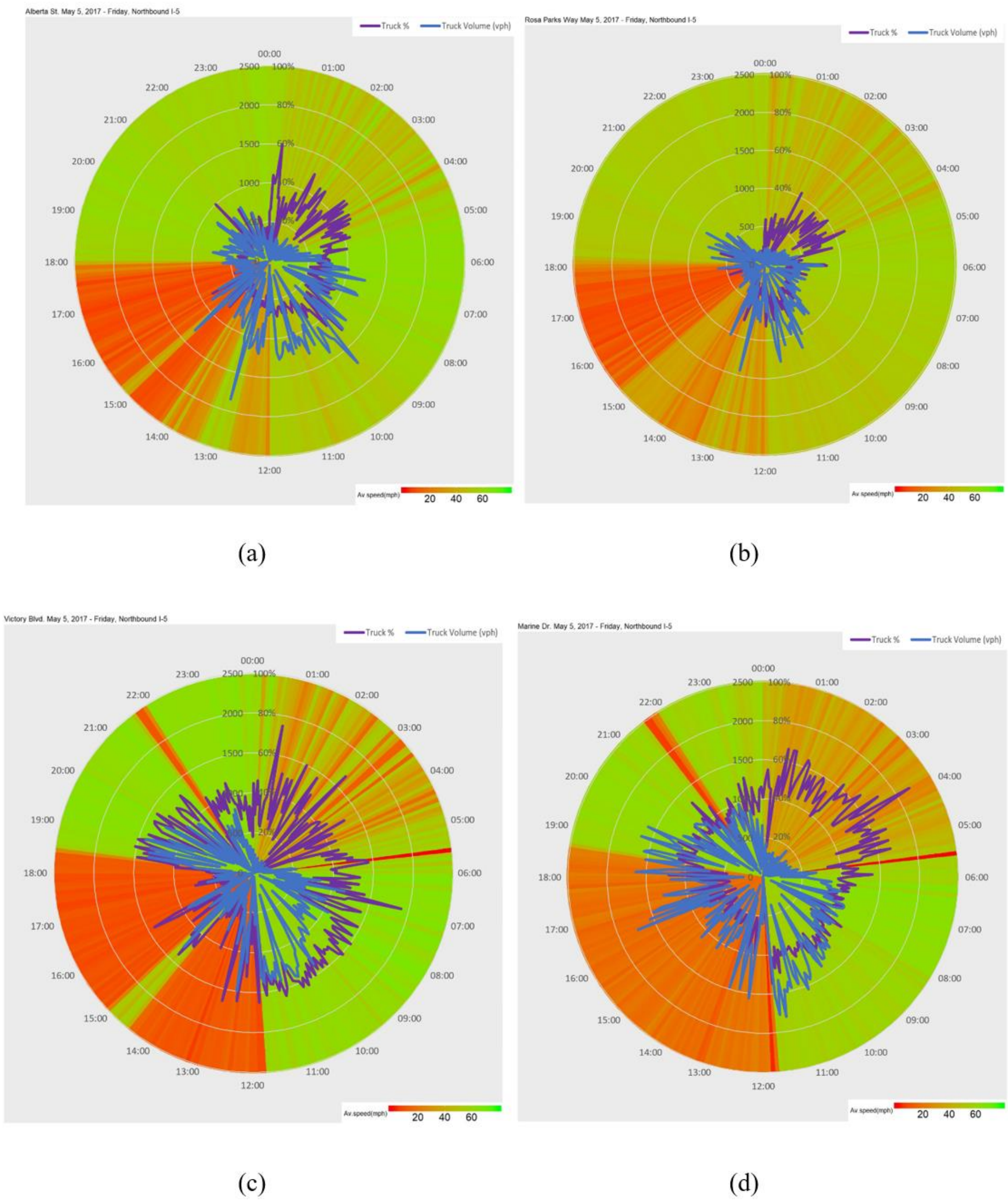
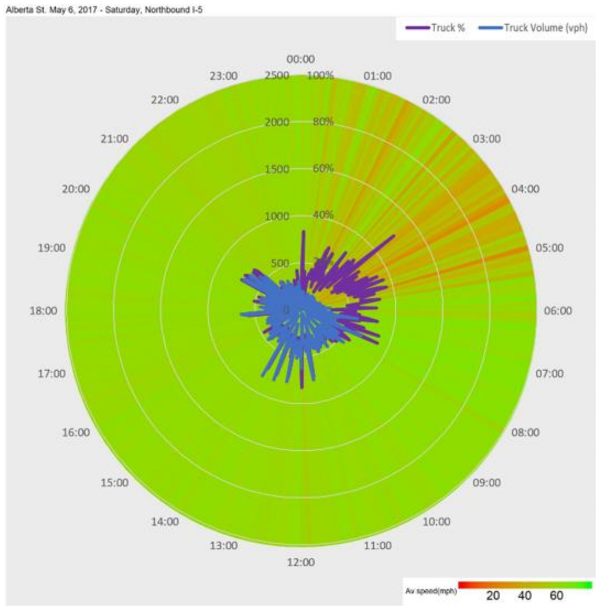
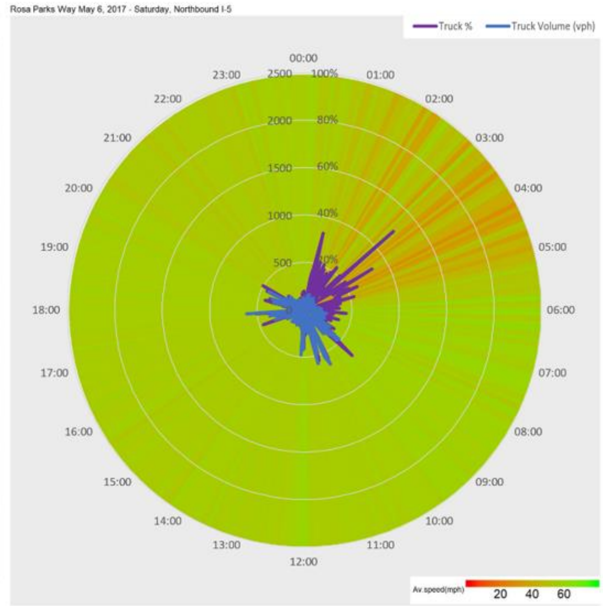


Figure B.5: 5-min combo plots for May 5, 2017 - northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.





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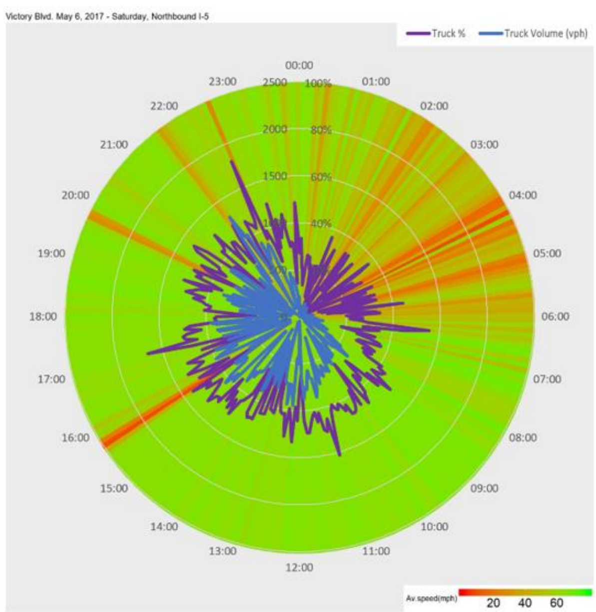
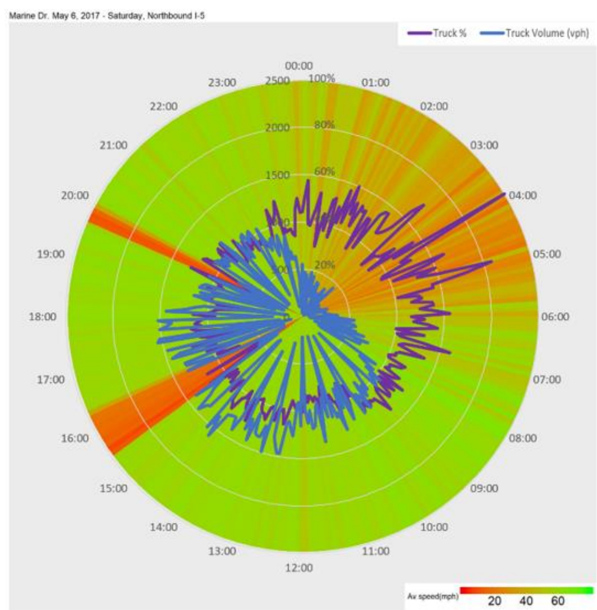




(c) (d)

Figure B.6: 5-min combo plots for May 6, 2017 – northbound (a) Alberta St., (b) Rosa Parks Way, (c) Victory Blvd., (d) Marine Dr.

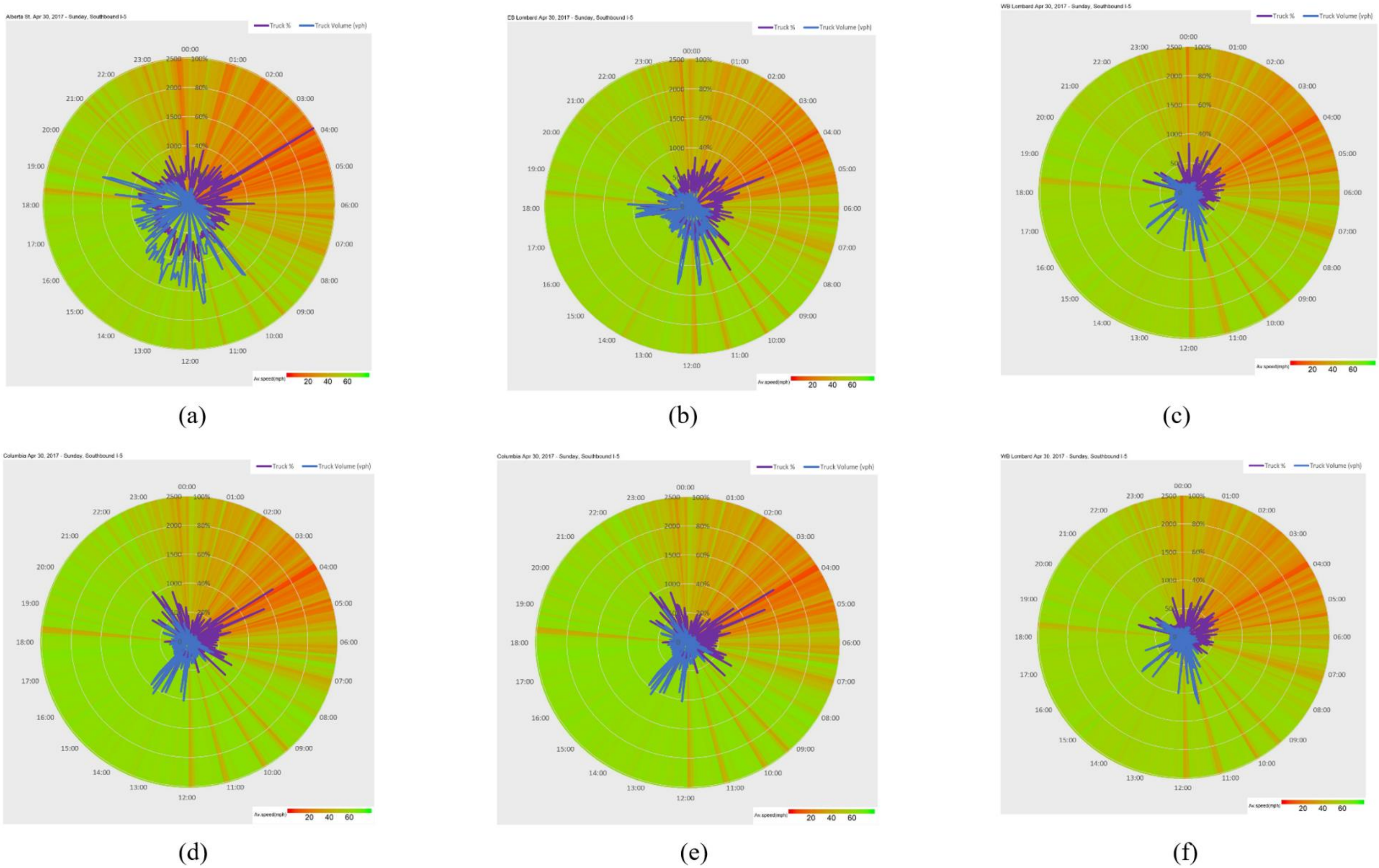
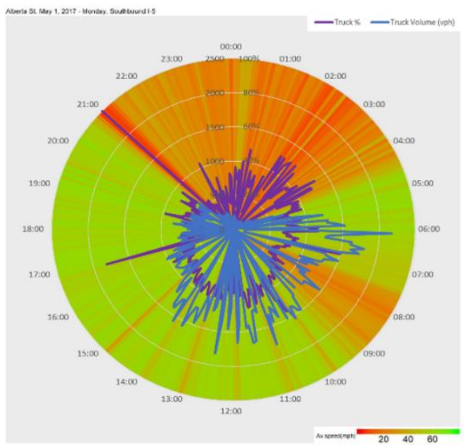


Figure B.7: 5-min combo plots for April 30, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.



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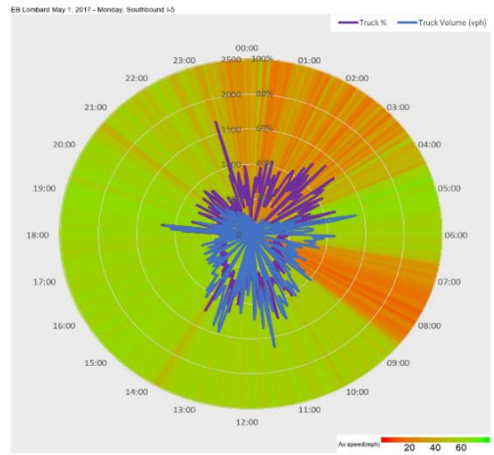

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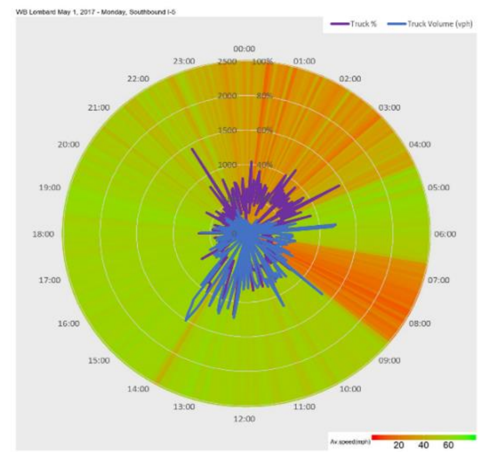

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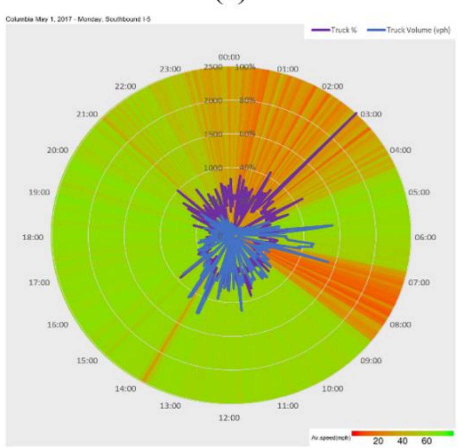

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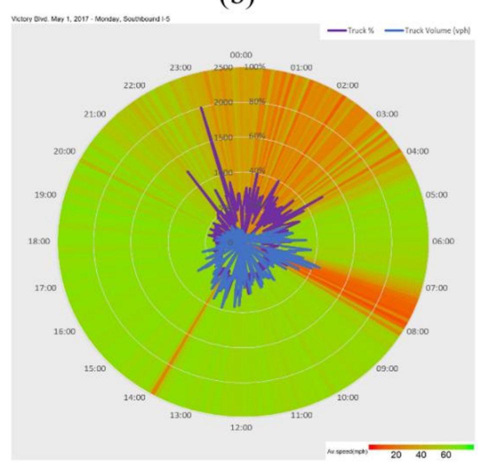

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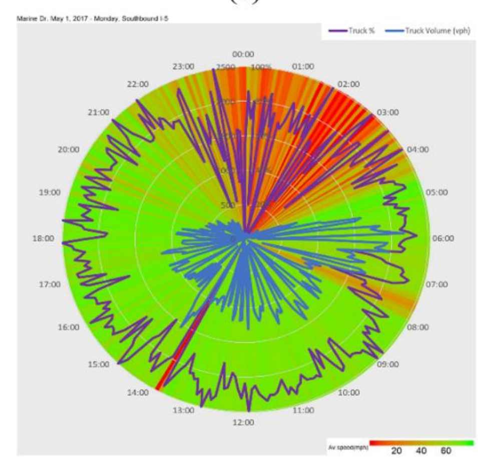


(f)

Figure B.8: 5-min combo plots for May 1, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.

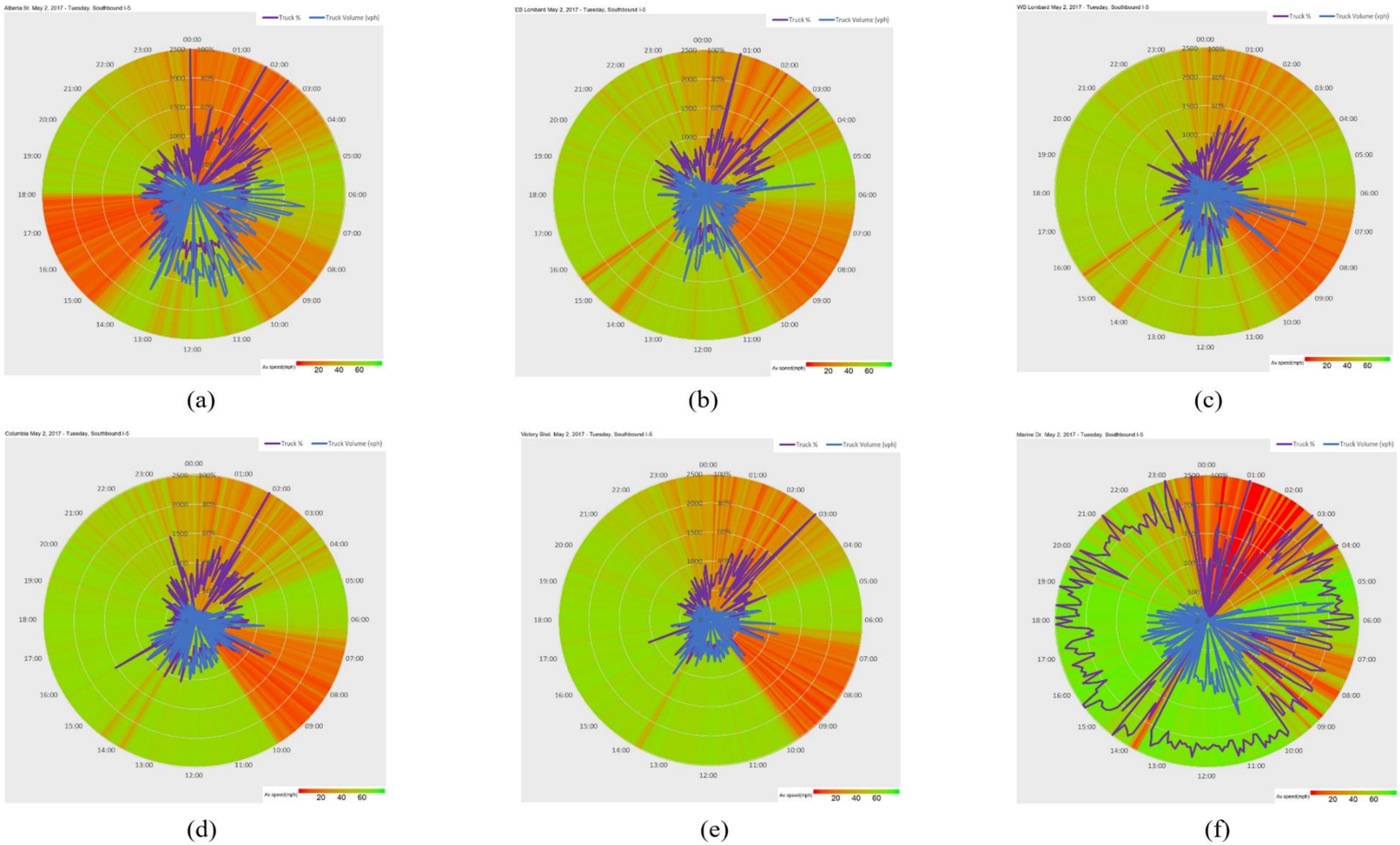


Figure B.9: 5-min combo plots for May 2, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.

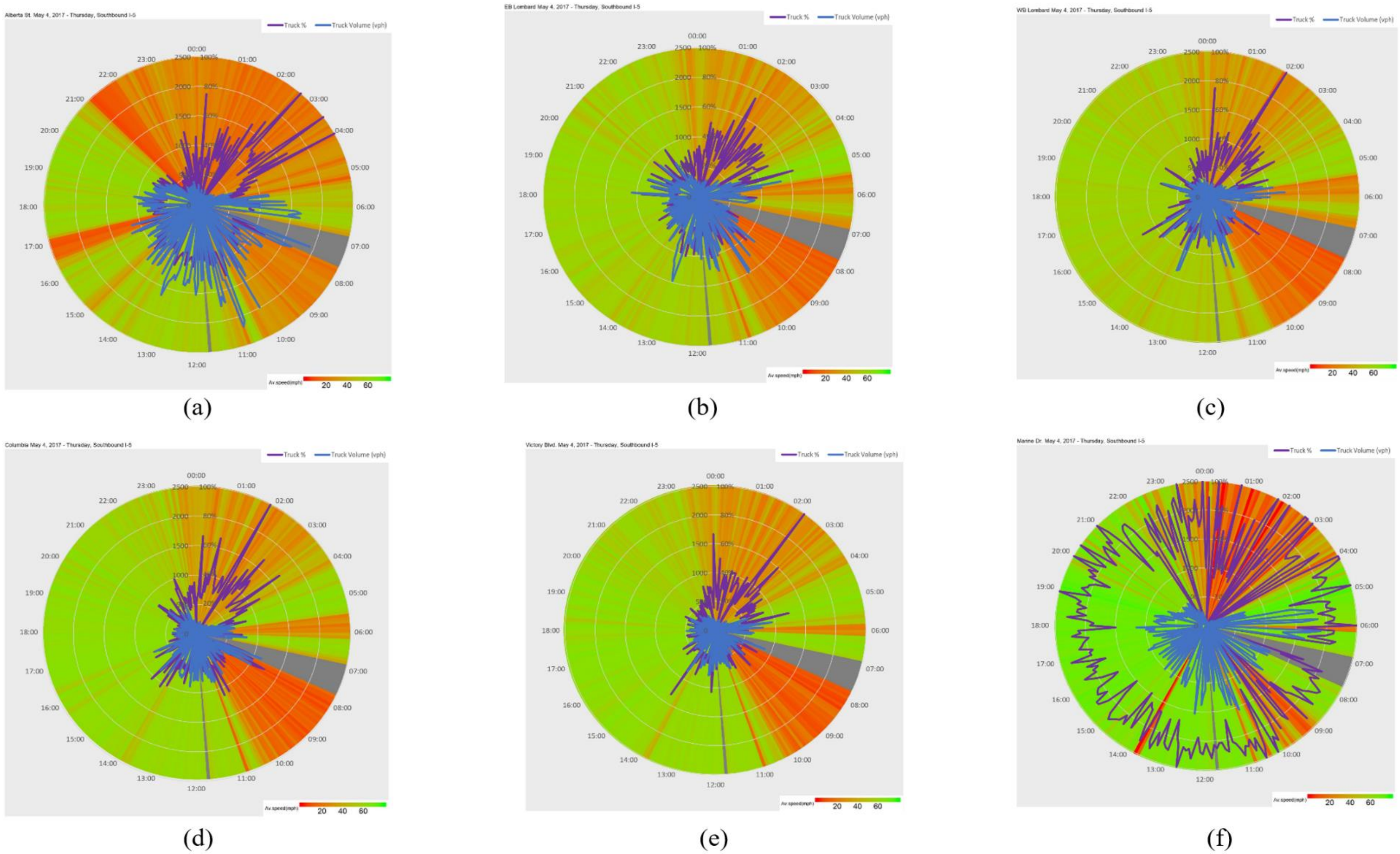
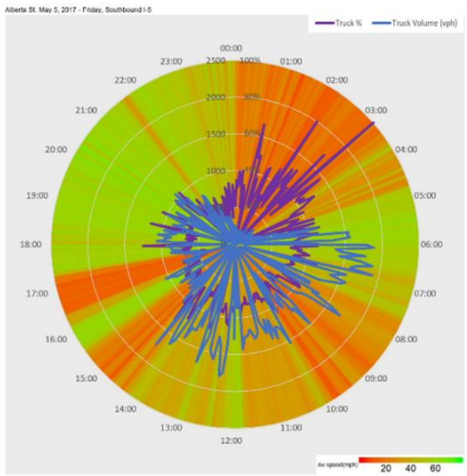


Figure B.10: 5-min combo plots for May 4, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.



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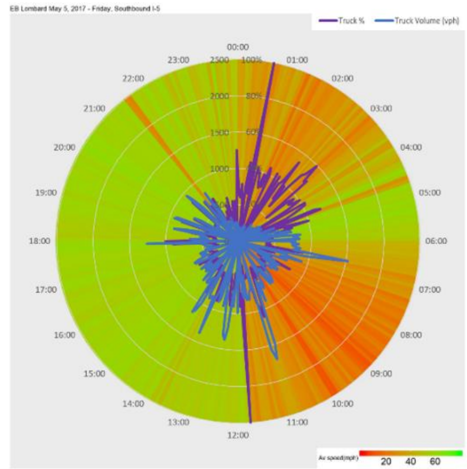

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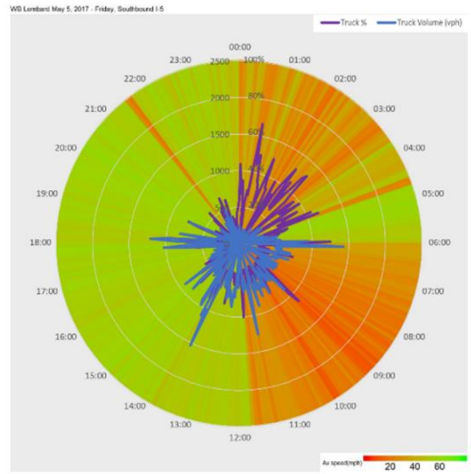

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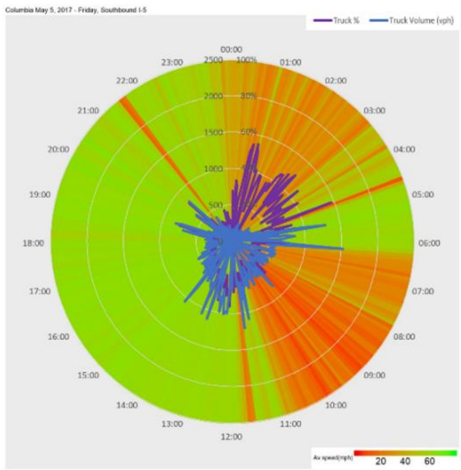

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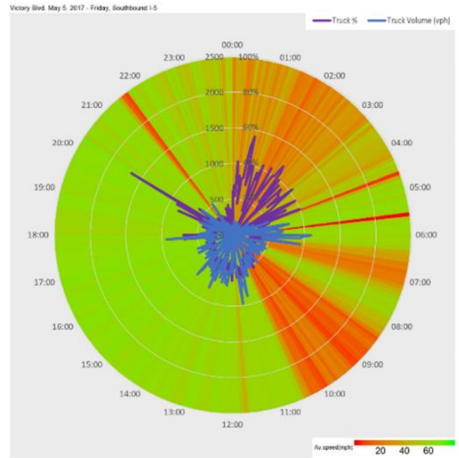

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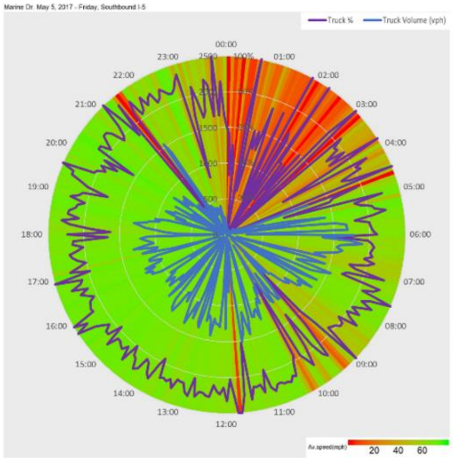

(f)

Figure B.11: 5-min combo plots for May 5, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.

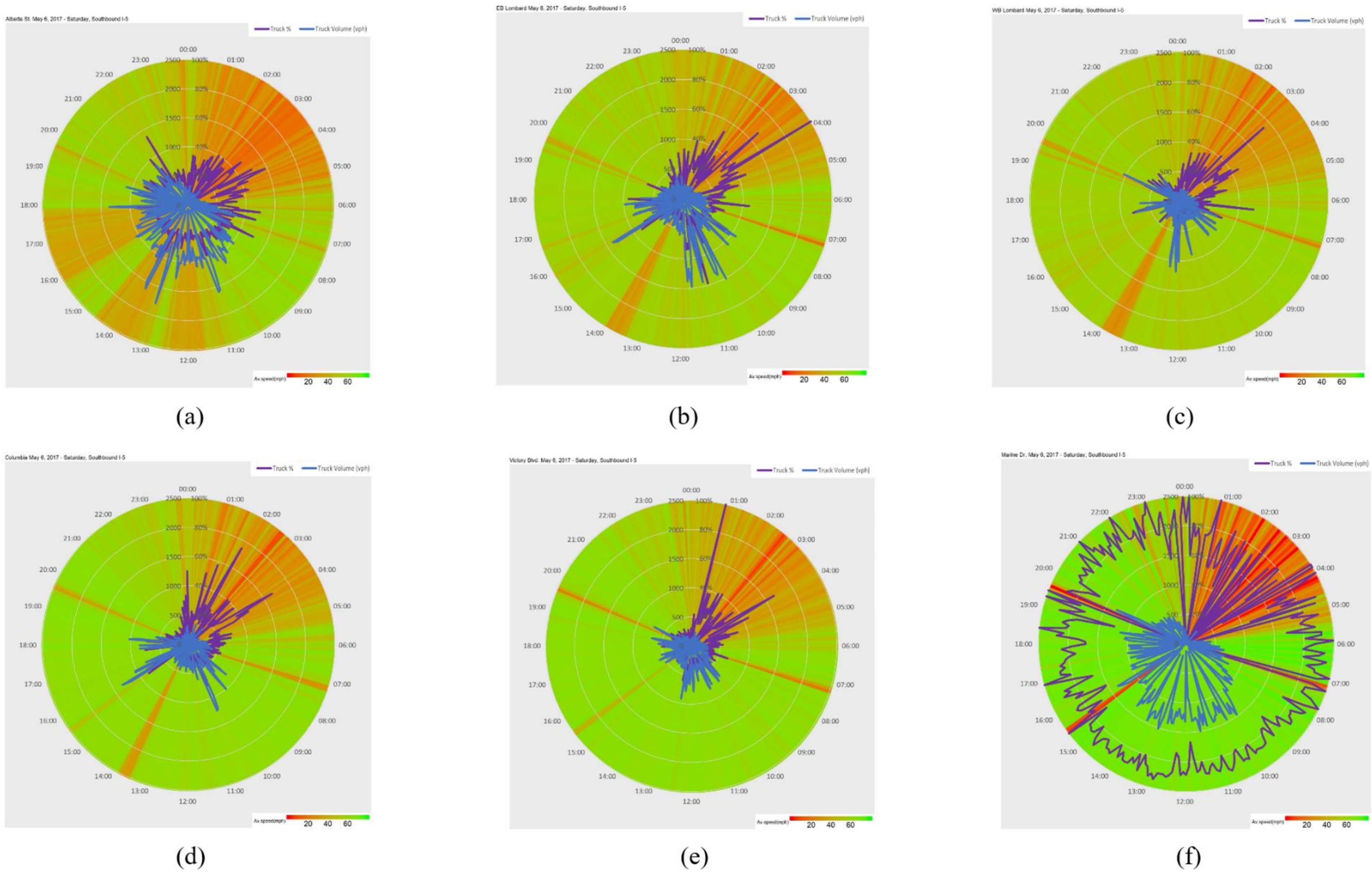

Figure B.12: 5-min combo plots for May 6, 2017 – southbound (a) Alberta St., (b) EB Lombard, (c) WB Lombard, (d) Columbia, (e) Victory Blvd., (f) Marine Dr.

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LeEtta Schmidt, lmschmidt@usf.edu and Drew Smith dsmith@usf.edu
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Class or Project: Master Thesis

Title of Copyrighted Work: Multimodal Data Set Clean-up for Portland Oregon Metropolitan Region/Data Set Description and Dictionary/Freeway Data

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Class or Project: Master Thesis

Title of Copyrighted Work: Exploring Length-Based Vehicle Count Data

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