Video-based Network-wide Speed and Speeding Analysis to Support Vision Zero in Bellevue (WA) United States

Speeding Report | July 2020

Contents

Key Terms

Dilemma Zone
The area at which road users at a signalized intersection must decide whether to stop or cross the intersection upon encountering a yellow traffic light

Driver
A legacy term for what is now more formally known as a motorized road user. In reality traffic data acquisition is performed on vehicular-shaped objects of various (FHWA-compliant) classifications (passenger cars, pickups, single-unit trucks, etc.) which usually (but not always) have at least one operator (the now more formal definition of "driver") and which may or may not have other occupants on board. The traffic data acquisition system does not observe vehicle operators/drivers directly, nor does it count onboard passengers, and therefore cannot distinguish between vehicles operating in autonomous mode and manual mode, if that vehicle model supports CAV functionality. Any and all references to "drivers" in text are made with the assumption that the number of motorized road users operating in autonomous mode is insignificant at the time of data collection and therefore does not skew human behavior analysis results.

Excessive Speed
The median speed of the road user's speed while they are speeding

High Injury Network (HIN)
A specific subset of the roadway network in Bellevue used to prioritize for proactive education, enforcement, engineering, and engagement for the benefits of all modes. The HIN was created weighing killed or severely injured collisions more heavily than less-severe collisions.

Road User
A road user is any entity moving along the road. The video analytics detects and tracks all motorized vehicles (cars, buses, pickup trucks, work vans, single-unit trucks, articulated trucks, and motorcyclists), bicyclists, and pedestrians

Scenario
An event involving two different road movements

Speed
The video analytics platform used defines a road user's speed as the median speed of the road user while they are in motion

Speeding
A road user is speeding when they are traveling above the posted speed limit for more than 20-percent of their moving trajectory

Speeding Incidence Rate
The proportion of the speeding road users from all the roads. In this report, speeding incidence rates are given per 10,000 road users

Speeding Rate
The percentage of the individual road user's trajectory for which they are speeding

Trajectory
A road user's path

Video Analytics
Automatic video content analysis using machine learning to provide temporal and spatial information about traffic events

Executive Summary

As part of the City of Bellevue's Vision Zero goal to eliminate traffic deaths and serious injuries by 2030, the City has partnered with Together for Safer Roads and Transoft Solutions (ITS) Inc., formerly Brisk Synergies, on a network-wide traffic conflict screening using video analytics. This project leverages video footage from existing traffic cameras to obtain useful data that can be searched, managed, and used to provide traffic management centers with detailed information on traffic volumes, speeds, and other conditions, and allow a more rapid response to traffic incidents. This report looks at driver speeds and speeding occurrence throughout the network and is one of three reports published through this partnership. The other two reports are on network screening and conflict analysis (Video-based Network-wide Conflict Analysis to Support Vision Zero in Bellevue (WA) United States) and on a correlation between conflicts and collisions (Video-based Conflict, Speeding, and Crash Correlation in Bellevue (WA) United States).

For this project, video footage was obtained for 40 intersections. These intersections were chosen based on their location on the High Injury Network, varying land use, and urban density, amongst other variables. The footage was recorded daily (16 hours per day) during the months of August and September daily, resulting in just under 40,000 hours of footage. Using video analytics, median driver speed values were obtained (while the road user was in motion), and speeding incidences were detected. Results from the entirety of the footage were used to gain insight; however, the data presented in this report is from a full week in September (4,500 hours). The general summary statistics that were obtained and the two models used for speed analysis are from September 13th to September 19th. The analysis period was reduced to ensure uniformity in data and to account for some technical difficulties faced in obtaining the footage.

Key findings

- Throughout the network, 870,000 speeding events were observed, indicating that approximately 10.8-percent of drivers were speeding.
- Driver speeds and speeding were observed to be higher at intersections in residential areas as compared to intersections in commercial areas.
- Intersections not on the High Injury Network experienced higher speeds and speeding incidence rates, as the majority of these intersections were residential.
- On average, higher driver speeds were observed in locations outside of downtown compared to locations in downtown; however, speeding was more prevalent in downtown.
- As expected, locations with higher posted speed limits had higher speeds on average; however, posted speed limits had no effect on speeding incidence rates.
- Speeds and speeding were constant throughout the weekday with the exception of a decrease around peak hours due to an increase in volumes.
- A statistical analysis showed that non-peak hours, weekends, through driver movements, increased lane width and motorcyclists, particularly, were correlated with an increased speeds.

- The factors listed above, as well as the proximity to a school, were correlated to increased excessive speeds.
- Based on network screening, the intersection of Bel-Red Rd and NE 30th St was the intersection most prone to driver speeding. An in-depth look at this intersection suggests that this may be due to driver overconfidence. Northbound through and Southbound through drivers observe a lower frequency of interactions with road users due to the lower side street volumes and prohibition of certain movements. Additionally, the southbound through speeding behavior was observed to occur to catch the yellow/green traffic lights.

1 Introduction

1.1 Project Motivation and Objectives

As pedestrian and bicycle fatalities continue to rise nationwide, there is a need for improved data driven approaches to achieve our collective goal of Vision Zero – eliminating traffic fatalities and serious injuries to ensure that everyone can safely move around in our communities. Between 2009 and 2018, 66-percent of all fatal and serious-injury collisions in the City of Bellevue, Washington, United States occurred along just 9-percent of streets (Breiland, C., Weissman, D., Saviskas, S., & Wasserman, D., 2019). Vulnerable road users (pedestrians and cyclists) made up 5-percent of all collisions during this time but comprised 46-percent of all serious injuries and fatalities. An analysis of the collisions indicates that the following five road user behaviors contributed to 70-percent of all fatal and serious injuries: driver's failure to yield to a pedestrian, failure to grant right-of-way to a motorist, driver distraction, intoxication, and speeding.

In response to these road safety concerns, the City of Bellevue passed a Vision Zero resolution in 2015 to strive to eliminate traffic fatalities and serious injuries by 2030. In 2018, the City of Bellevue partnered with Transoft Solutions (ITS) Inc., formerly Brisk Synergies to conduct a citywide network screening analysis to better understand the factors that impact the safety of its transportation system and leverage this insight to identify improvements and evaluate outcomes. BriskLUMINA, a product of Transoft Solutions (ITS) Inc., uses computer vision and artificial intelligence to analyze traffic video. Camera footage is analyzed to obtain data about surrogate safety indicators including road user speeds and near-misses. Results are often used to validate road improvements, determine high-risk locations, and determine the most severe conflicts and interactions at an intersection, roundabout, or road segment.

The objective of this Report is to use video analytics and existing traffic camera footage to perform a network-wide screening of roads and intersections in the city of Bellevue. This screening provides the City with data on which locations experience high motorized and vulnerable road user volumes, and the frequency and severity of near-misses. This data can be correlated with location, land use, and urban density. All of this information can be used by the City in safety diagnosis, risk factor identification, and treatment assessment. This report will focus on speeding.

1.2 Speeding

Speeding is a major concern to many cities around the world. According to the National Highway Traffic Safety Administration[1] , driver speeding was a contributing factor in more than 26-percent of all traffic fatalities in the United States. For vehicle to vehicle crashes, the likelihood of fatality increases as speed increases[2] , therefore it is important to assess safety with respect to speed. Speeding is defined as traveling too fast for conditions or in excess of the posted speed limits[2]. The motorist must take into consideration vehicle capability, roadway features, environmental conditions, surrounding context, presence of other road users, and most importantly, the speed limit[2]. Even though any type of driver is susceptible to speeding, more common offenders have been

[1] (2019, December 12). Speeding. Retrieved from https://nhtsa.gov/risky-driving/speeding
[2] Speed as a Safety Problem. (n.d.). Retrieved from https://www.ite.org/technical-resources/topics/speed-management-for-safety/speed-as-a-safety-problem/

found to be young, male drivers; Collision-involved teens have been found to be less likely to obey the speed limit, and generally more likely to take part in risky driving behavior[3].

The City of Bellevue has several existing programs managed by Neighborhood Traffic Safety Services that help with speed management. One of the existing programs is the installation of permanent (stationary) radar feedback signs that tell drivers how fast they are going. Additionally, to manage driver speeds and speeding around schools, the City has installed flashing speed zone signs around schools. In another program, residents can request temporary radar signs or police speed enforcement. The City plans on expanding these efforts as part of its Vision Zero Action Plan.

1.3 Project Overview

For this project, 40 of the City of Bellevue's approximately 200 signalized intersections were selected based off of the High Injury Network (HIN)[4] and whether there was a traffic camera present. Thirty-one of the intersections were along the HIN and nine were not. The majority of the intersections (31) were not in the downtown area, defined here as the area bordered by Main St. & NE 12 and 100th Ave & 112th Ave. In addition, 28 intersections were located in commercial areas as opposed to residential areas and 28 intersections were in medium density locations (suburbs, big-box stores, and/or factories) while the rest were in high density locations (multi-story dwellings and/or businesses). Figure 1.1 depicts the location of these study intersections. All intersections are signalized and 34 are four-legged intersections, 5 are three-legged, and 1 is five-legged. Table 1 in the appendix lists the intersections and other variables pertaining to them, including land use, urban density, etc.

Traffic cameras, at the intersections shown in Figure 1.1, recorded daily for 16 hours, from 6 AM to 10 PM, for the months of August and September in 2019, resulting in just under 1,000 hours of footage for each intersection.

1.4 Methodology

After camera selection, the network cameras were tapped into and the video footage was recorded. Footage for five other intersections was also recorded for precautionary measures (unintended camera movement or disconnection). The footage was then calibrated on an intersection basis, after which it was processed using BriskLUMINA. Lastly, the data was quality controlled, extracted, and analyzed.

[3] The Traffic Injury Research Foundation. The Road Safety Monitor: Excessive Speeding. (2007). Retrieved from https://tirf.ca/wp-content/uploads/2017/02/rsm_speeding-2007-final.pdf

[4] Breiland, C., Weissman, D., Saviskas, S., Wasserman, D., (2019). Task 3A – Value Added Research Findings. Fehr and Peers Memorandum.

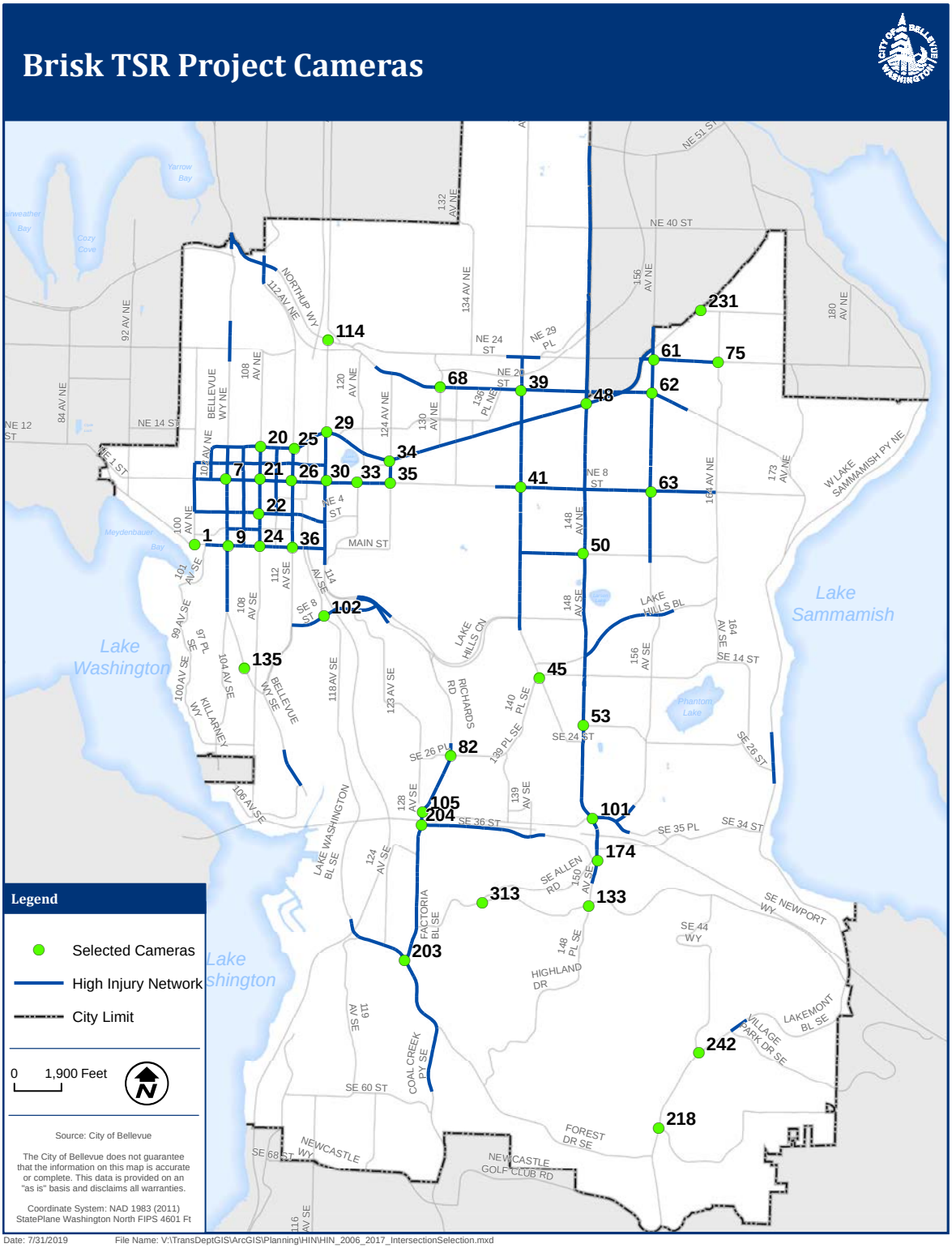

Figure 1.1 - 40 intersections analyzed in project

2
Network Traffic Data

In this section, data on road user counts, speeds, and conflicts is summarized. The following analysis was completed for seven consecutive days of footage from September 13th to 19th, 2019. This amounted to 112 hours for each intersection, just under 4,500 hours of footage in total. One week of footage was used as some cameras disconnected or had inconsistent frame rates at times.

2.1 Speeds

The speed for all the road users was obtained on a road user-basis and was aggregated for a network-wide analysis by road user type and movement type. The road user speed output of the traffic safety analytics is the median speed of the road user while in motion (excluding zero speed values). In the following section, speed information will be provided for motorized road users. Figure 2.1 plots the speed distribution of all through motorized road users along the entire network.

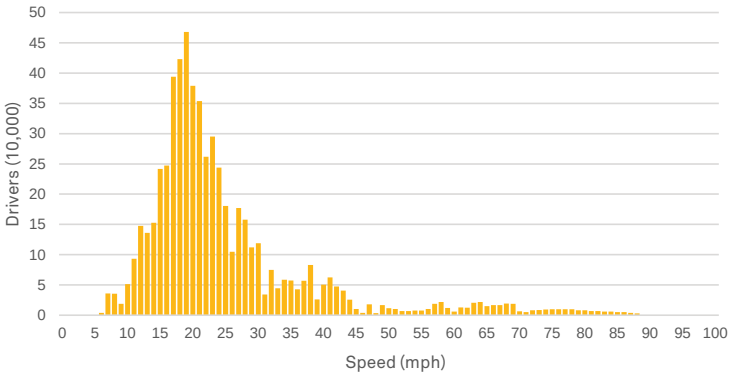

Figure 2.1 – Through Driver Speed distribution

For drivers, on average, the median speed in residential locations was found to be higher than in commercial locations. In addition, median speeds were found to be higher at intersections outside of the downtown. Table 2.1 provides the speed values, with the standard deviation, on a movement basis. Table 2 of the appendix has the average speed of each intersection by turning movement.

Table 2.1 - Average Driver Speeds (mph) at Intersections with Different Locations and Land Use				
		Left Turn Speed	**Through Speed**	**Right Turn Speed**
Land Use	**Commercial**	12.3 (1.9)	23.6 (6.9)	11.9 (2.8)
	Residential	13.7 (5.1)	35.0 (11.2)	13.2 (4.4)
Location	**Downtown**	11.3 (1.6)	16.6 (7.4)	11.7 (2.2)
	Non-Downtown	12.9 (3.7)	23.3 (9.2)	12.4 (3.3)
	Median	12.5 (3.4)	20.5 (8.9)	12.4 (3.1)

Figure 2.2 shows the weekday hourly through speeds for through movements across the network, for residential and commercial locations. On a network-wide basis, through movement speeds were relatively constant throughout the day. Slight fluctuations in speeds were observed for commercial locations, particularly during the peak hours. Drivers at residential locations had the highest speeds. It should be noted that many of the study intersection in areas of residential land use were on major arterials, such as 148th Ave SE and Richards Rd. Residential areas experienced the most fluctuations throughout the day; Two peaks were observed, with one at 10 AM and one between 6 and 8 PM.

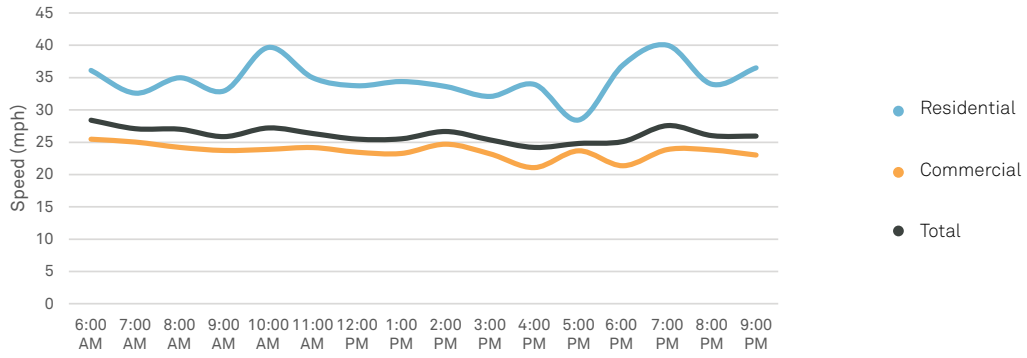

Figure 2.2 – Temporal through driver speed by land use

Figure 2.3 shows the temporal variation of through driver speeds by posted speed limit. All study intersections had a posted speed limit of either 30 or 35 mph; except for one intersection Bel-Red Rd and NE 30th St, which had a speed limit of 40 mph. This intersection was excluded from the graph. As would be expected, speeds were lower at intersections with posted speed limits of 30 mph compared to intersections with posted speed limits of 35 mph. Fluctuations in speeds throughout the day were slight and do not appear to have a clear correlation with the time of day.

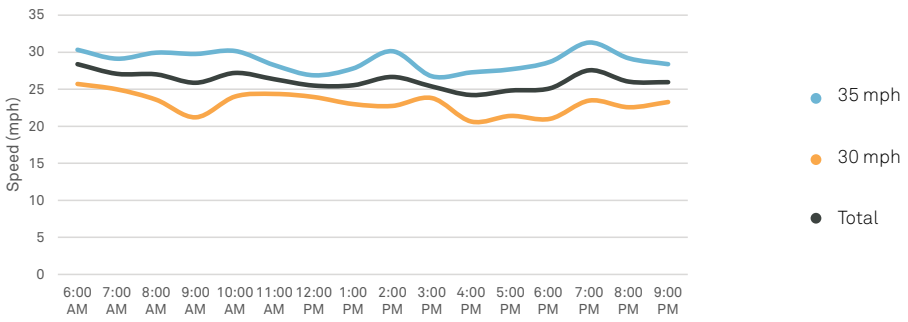

Figure 2.3 – Temporal through driver speed by posted speed limit

Figure 2.4 shows the temporal variation of through driver speeds according to the HIN. Speeds along the HIN were observed to be lower than speeds not on the HIN. This is due to speeds and speeding limits being higher at residential land use (Figure 2.2) and two-thirds of the selected locations not on the HIN were in residential areas.

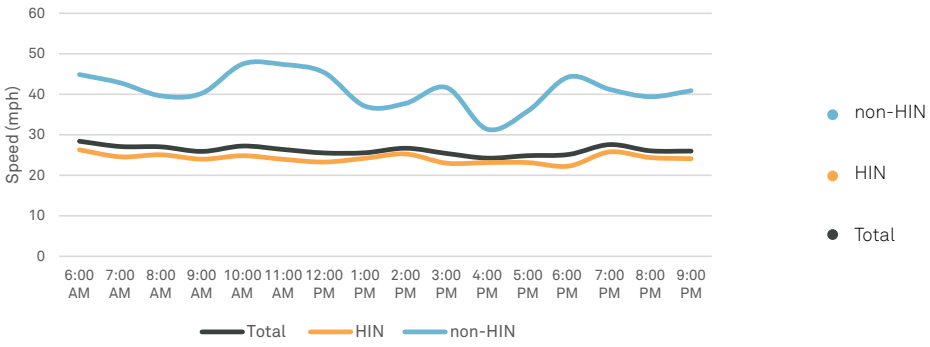

Figure 2.4 – Temporal through driver speed by High Injury Network

2.2 Speeding Violations

A driver speeding violation, as defined by the traffic video analytics output, occurs when a road user is traveling above the posted speed limit for more than 20-percent of their moving trajectory. This 20-percent is defined as the 'speeding rate' by the video analytics software used. A vehicle's trajectory is bound by the field of view of the camera. Depending on the intersection, it extends between 0 to 30-feet from the stop line of each approach. Speeding is limited to motorized road users and uses the speed limits of through movements as the assigned

speed limit for the intersection. Any driver driving above the speed limit will have an excessive speed value, defined as the median speed value of the driver's speeding trajectory. Figure 2.5 shows a speeding heatmap throughout the network with speed limits noted.

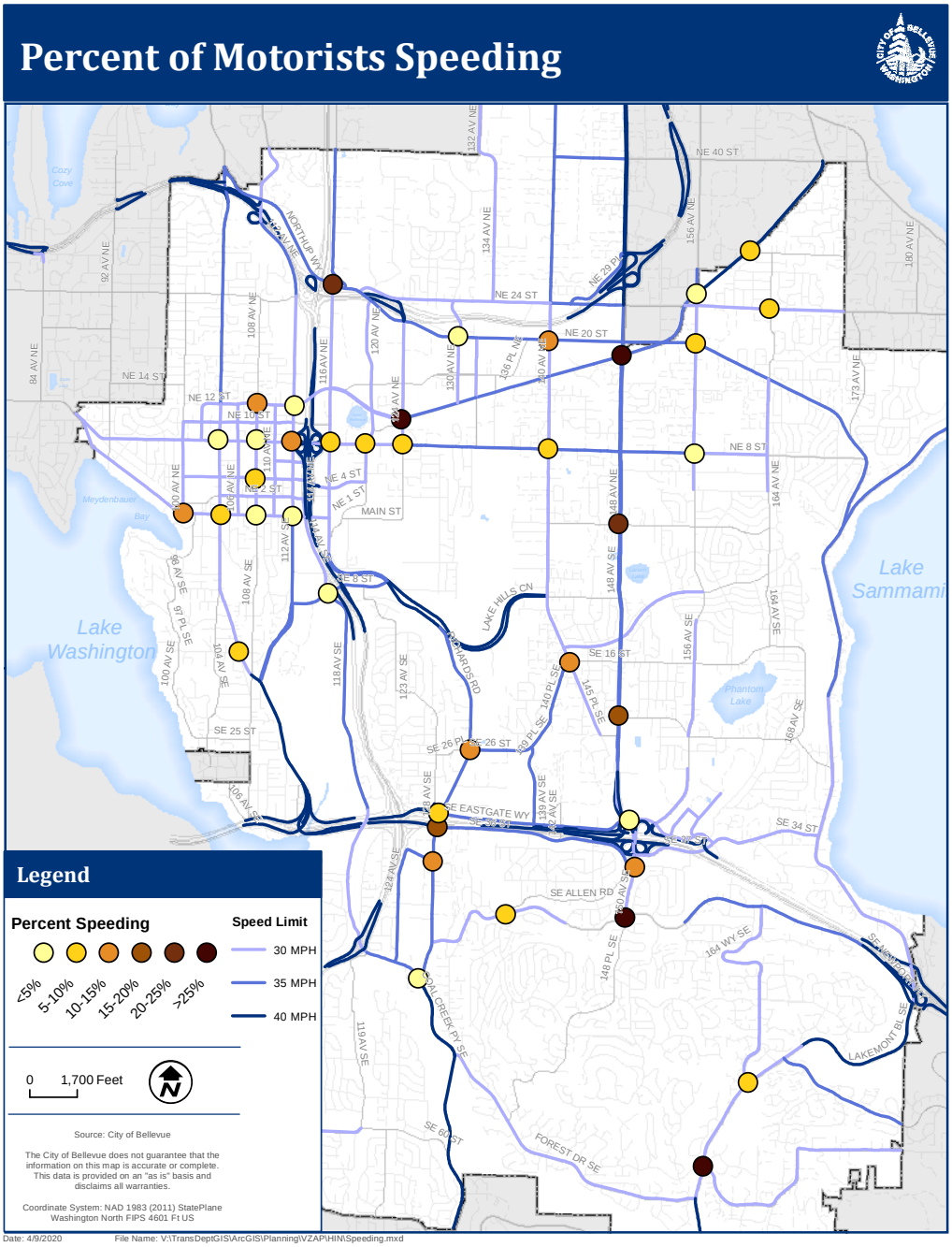

Figure 2.5 – Percent of Motorist Speeding

Throughout the network, 870,000 speeding events were observed, indicating that approximately 10.8-percent of drivers were speeding. Figure 2.6 plots the speeding rates of all speeding motorized road users throughout the network. This figure shows that the majority of the speeding drivers were speeding for only a small portion of their trajectory. This is expected to be the case at intersections as the drivers are not at free-flow conditions. Table 3 of the appendix shows the speeding rate at every intersection. Table 2.2 provides additional information on the speed distribution of speeding driver's excessive speeds.

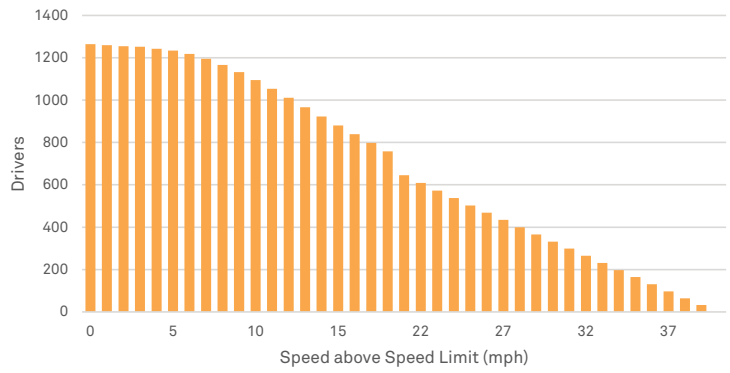

Figure 2.6 – Excessive speed distribution across the network

Table 2.2 – Additional information on speeding distribution

Percentile	mph Above Speed Limit
5th	1.1
15th	3.1
50th	11.4
85th	23.8
95th	26.9

Figure 2.7 depicts the excessive speed distribution based on the HIN. As with speeds, speeding incidence rates (speeding infractions rates) and excessive speeds were higher along intersections not on the HIN.

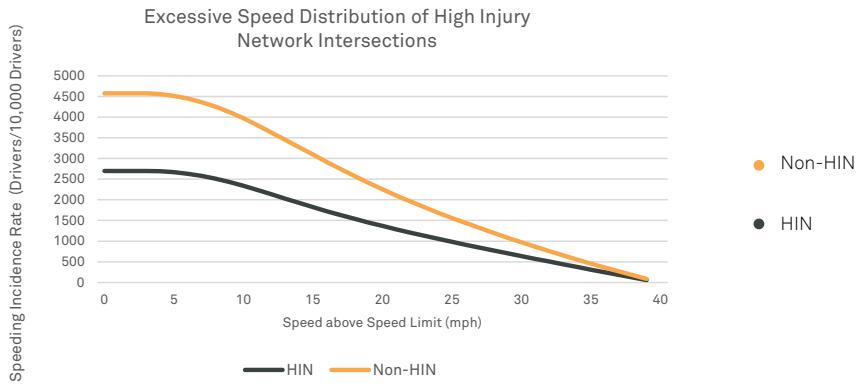

Figure 2.7 – Excessive speed distribution by HIN

Driver speeding incidence was higher downtown with 15-percent of the drivers speeding compared to the areas outside of downtown where 10.5-percent of the drivers were speeding. However, speeding was more prevalent in residential areas, with 14-percent of drivers speeding compared to commercial areas where 10.6-percent of drivers were observed speeding. Figure 2.8 depicts hourly speeding incidence rates on weekdays by land use. Speeding incidence rates appear to be lowest during the peak hours between 3 and 6 PM.

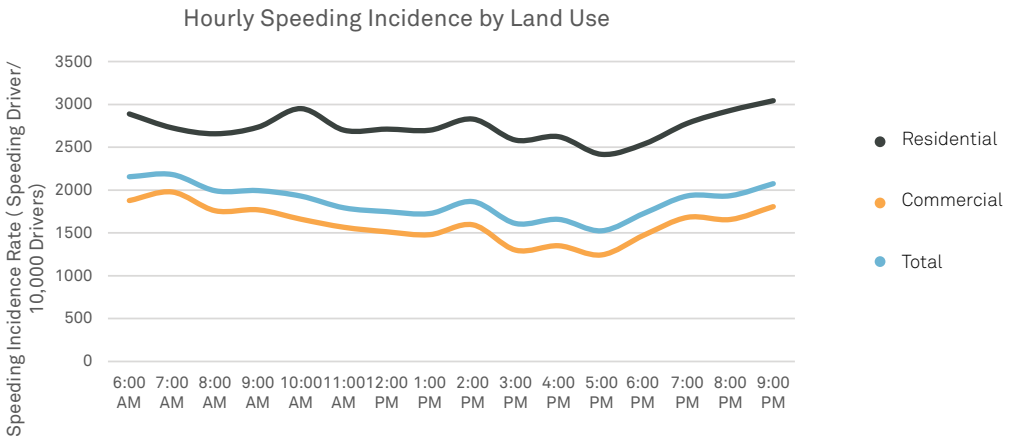

Figure 2.8 – Temporal variation of speeding incidence by Speed Limit

In terms of speeding at locations with different speed limits, speeding incidence rates do not appear to be more prevalent at either location. Looking at the temporal variation in Figure 2.9, speed incidence rates are slightly higher at locations with speed limits of 35 mph in the morning; however, later in the afternoon, speeding incidence rates are slightly higher at locations with speed limits of 30 mph.

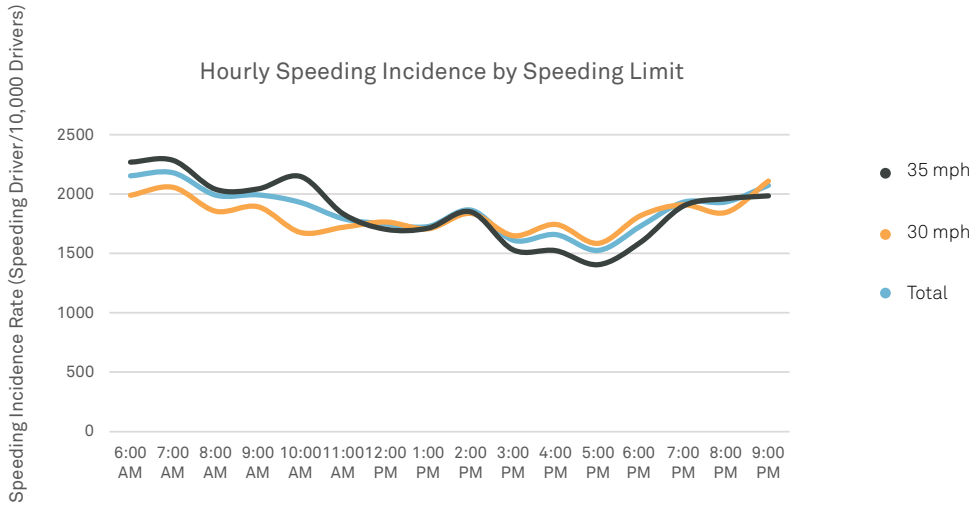

Figure 2.9 – Temporal variation of speeding incidence by Speed Limit

Figure 2.10 depicts hourly speeding distribution across the entire network. A volume trendline is added to the graph. The trendline only depicts the change in volume pattern and does not correspond to the actual network volume. The figure shows that speeding incidence is lowest during peak hours, closer to 5 PM.

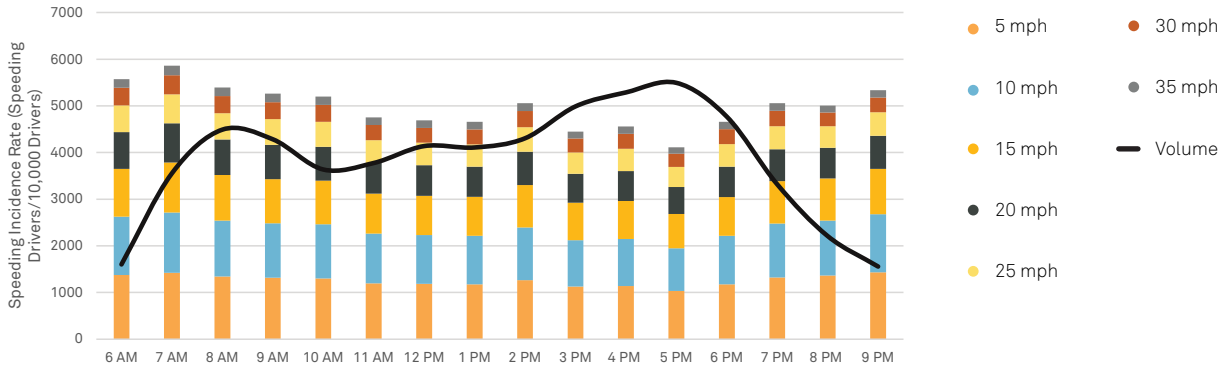

Figure 2.10 – Weekday hourly speed distribution

3
Statistical Approach

Two statistical models were conducted based on this data. A linear regression model was used to perform a network-wide analysis while a multilevel mixed-effects linear regression model was estimated for the hotspot analysis. Multiple geometric and non-geometric variables were considered when creating these models. These initial variables, which were eventually filtered, include urban density (high or medium), land use (commercial or residential), whether not a school is present within less than 0.125 miles from the intersection, road user types (car driver, bus or truck operator, motorcyclist), road user movement (through, left turn, or right turn), vehicular traffic phasing (protected vs non-protected left turns), pedestrian traffic phasing, number of lanes, lane width, crosswalk width, presence of bike infrastructure (dedicated bike path, shared bike path, both, or neither), time of the day, and days of the week.

3.1 Networkwide Analysis

A linear regression analysis was estimated with intersection fixed effects using the speed of the speeding event (the independent variables) as a surrogate safety measure.

$$y_i=\beta_0+\beta_1\ x_{i1}+\beta_2\ x_{i2}+\cdots+\beta_p\ x_{ip}+\alpha Zi+\varepsilon_i, \qquad i=1, 2,.....,n$$

Where:
y_i- surrogate safety measure (speed), for all infractions
$\mathbf{x}$ - the vector of explanatory variables (in this case driver speeding rate, maximum speed, peak hours, user type, road user type, and weekday)
Z_i - intersection fixed effects
β – vector of unknown parameters
ε – random error of the regression estimate

The geometry factors for each site were not considered in the above model. They were replaced with a site-specific fixed effect parameter. This was done to determine which sites cause an increase in speeding for site-specific parameters.

3.1.1 Network-Wide Analysis Results

The outputs of the model can be found in Table 4 of the Appendix. The explanatory variables (driver speeding rate, maximum speed, time of day, weekday vs. weekend, user type, and road user type) were found to be statistically significant at 99-percent except for the weekend at 94-percent significance. Driver speeding rates were found to cause an increase in speed by 0.23 mph for every 1-percent increase in speeding rate. Peak hours, between 3 PM and 6 PM, led to a small, but statistically significant decrease in speed by 0.15 mph compared to

non-peak hours. Motorcyclists were found to be the fastest motorized road users, with speeds 0.97 mph higher compared to drivers, and the slowest motorized road users were bus operators, with speeds 0.69 mph lower compared to drivers. Through driver movements were found to be the fastest; Right turning and left turning movements were found to have lower speeds by 4.82 mph and 4.27 mph, respectively. Weekends caused only a very minor reduction in driver speed.
The result of the model indicated that the fastest driver speeds were observed at Bel-Red Rd & NE 30th St followed by 148th Ave SE & SE 22nd St. The slowest speeds were observed at 108th Ave & Main St and 164th Ave NE & NE 24th St. A detailed breakdown of the results can be found in Table 5 of the appendix.

3.2 Hotspot Analysis

To identify salient factors associated with each of the surrogate measures, a multilevel mixed-effects linear regression model was estimated, using intersection-level random effects and an independent covariance structure. Data consists of all driver speeding incidences per road user. The two surrogate safety indicators used are the driver speed, and the excessive driver speed, which corresponds to the speed of the road user exclusively during speeding instances.

$$y_{ij}=\beta_0+\beta_1 x_{ij1}+\beta_2 x_{ij2}+\cdots+\beta_p x_{ijp}+\alpha_j+\varepsilon_{ij}$$

Where:
y_{ij} - surrogate safety indicators (driver speed and excessive speed)
x_{ijk} - vector of explanatory variables (road user, peak hour, night-time, traffic volume, site type, etc...)
β_p - vector of unknown regression parameters
α_j - fixed effects error term for each site j
ε_{ij} - error random term of the regression

The outcome measures include the volumes, time of day, weekday vs weekend, speed limit, road user type, movement type, and the average lane width. For the purpose of this study, higher values of the safety indicators, driver speed, and excessive speed, are more critical.

3.2.1 Hotspot Analysis Results

The two intersections identified for faster speeds, Bel-Red Rd & NE 30th St and 148th Ave SE & SE 22nd St, were used to generate the multilevel mixed-effects linear regression model. The results of the driver speed and excessive speed models can be found in Tables 6 and 7 of the appendix. Both sites have the same land use (residential), urban density (medium), and are not in the downtown; therefore, variation in land use, urban density, and downtown/non-downtown could not be compared. In addition, both intersections have a protected-permissive left turn signal phasing on the major street and a permissive left turn along their minor street. For Bel-Red Rd & NE 30th St, the minor street through movement is prohibited. Other notable features of the intersections are summarized in Table 3.1.

Table 3.1 - Site Characteristics

		Bel-Red & NE 30th	148th Ave & SE 22nd
Average Weekday Hourly	Drivers	1,091	3,161
	Pedestrian	23	18
	Cyclists	2	0
	Posted Speed Limit (mph)	40	35
	Speeding Incidence	7.8%	13.3%

Both models show that an increase in driver speeding rate is accompanied by an increase in speed and excessive speed. For each 1-percent increase in distance over which speeding occurred, speeds increase by 0.27 mph and excessive speeds increase by 0.03 mph. Peak hours (between 3 PM and 6 PM), as opposed to nonpeak hours, were found to decrease the speed by 0.7 mph and the excessive speed by 0.9 mph. Motorcyclists were again observed to be the fastest road users followed by bus operators, truck operators, and then drivers (different from the network-wide analysis). Speeds were larger on the weekends by 0.85 mph for the speed and 0.8 for the excessive speed model.

The presence of a school within 0.125 miles reduced the driver speed by 5 mph but increased the excessive speed by 0.6 mph. The number of lanes had a significant effect on speed as having an extra lane (2 lanes compared to 1 lane) increased speed by 4.4 mph but reduced the excessive speed by 0.7 mph. A 3.28 ft (1 meter) increase in lane width was found to have a slight effect of decreasing both the speed and the excessive speed.

4
In-Depth Analysis

As Bel-Red Rd and NE 30th St was the site most prone to driver speeding according to the model, a more in-depth analysis was completed to help diagnose safety issues. Speed and speeding patterns will be assessed in this section.

4.1 General Intersection Characteristics

Figure 4.1 depicts an aerial image of the intersection. This intersection was the only intersection to have a speed limit of 40 mph for one of its corridors, Bel-Red Rd, the North-South corridor. Notable features of the intersection include a small traffic island (circled in red) separating the westbound right turning movements, originating from NE 30th St, and another island (circled in green) for southbound left turning drivers (originating from Bel-Red Rd).

Figure 4.1 - Bel-Red Rd and NE 30th St

Figure 4.2 depicts the road user trajectories at this intersection. Note that there are no northbound left turning, eastbound left turning, eastbound through, and westbound through movements.

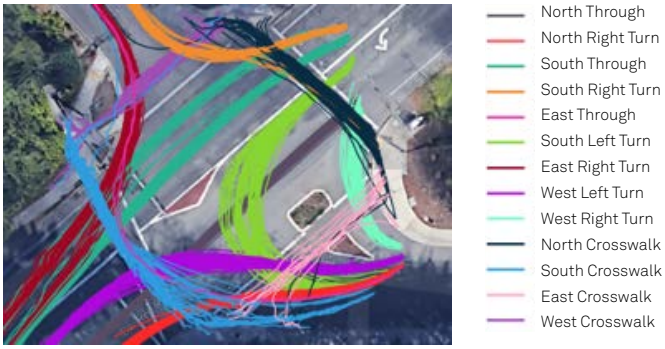

Figure 4.2 – Road user trajectories at Bel-Red Rd and NE 30th St

Table 4.1 displays the average hourly weekday (Tuesday, Wednesday and Thursday) volumes for each movement. These volumes are also graphically presented in Figure 4.3, where the arrow width and color correlate to volumes. The northbound through and southbound through movements comprise the majority of the driver volumes, between three and six times other individual movements. Pedestrian volumes are also extremely low at this intersection. The full temporal breakdown of volumes observed at this intersection can be found in Table 8 of the appendix.

Table 4.1 – Average Hourly Weekday Volumes

Northbound			Eastbound			Southbound			Westbound			Crosswalks			
LT	Thru	RT	LT	Thru	RT	LT	Thru	RT	LT	Thru	RT	N	E	S	W
-1	185	56	-	-	51	55	161	32	49	-	57	5	0	3	11

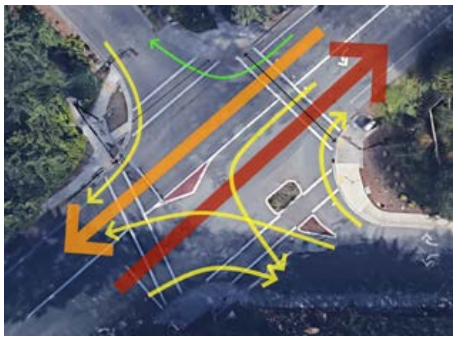

Figure 4.3 – Pictorial depiction of road user volumes at Bel-Red Rd and NE 30th St

4.2 Intersection Speed Profile

Even though this intersection has 4 approaches, only 8 driver movements are allowed (as opposed to the standard 12). Of these 8 movements, two movements are through movements, two are left turning movements, and four are right turning movements. Generally, the two through movements experience the highest speeds, followed by the left turning movements, and lastly, the right turning movements. Figures 4.4 and 4.5 show temporal speed variation by movement on an hourly and daily basis, respectively, where similar movements have the same dash type. The full temporal breakdown of average speeds can be found in Table 9 of the appendix.

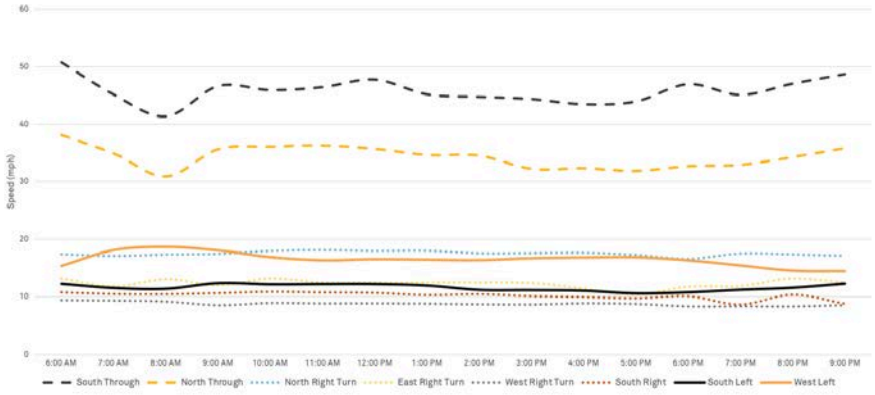

Figure 4.4 – Hourly speed variation by movement at Bel-Red Rd and NE 30th St

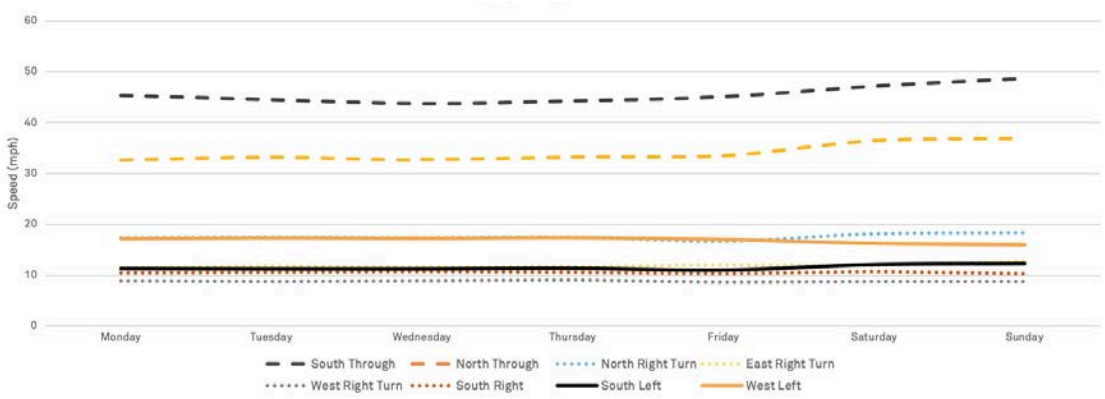

Figure 4.5 – Daily speed variation by movement at Bel-Red Rd and NE 30th St

The graphs indicate that variation in turning movement speed is very slight throughout the day and that there is a noticeable decease in through movement speeds at 8 AM (around a 10 mph decrease). Speeds are constant throughout the week with the exception of a slight increase in through movement speeds during the weekend (around 2-3 mph). Additionally, the graphs show that the average speed for the southbound through movement is on average 10 mph higher than the northbound through movement. The westbound left turning movement is on average 5 mph faster than the northbound left turn. All right turning movements have very similar speeds with the exception of the northbound right turning movement. This can be attributed to the wider turning radius available for this movement compared to the other right turning movements. The speed heatmap generated by the video analytics for this intersection is shown in Figure 4.6

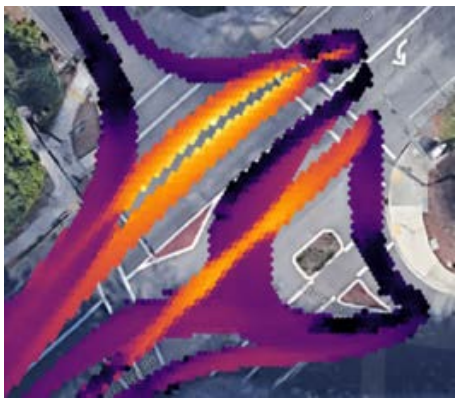

Figure 4.6 – Speed heatmap at Bel-Red Rd and NE 30th St

4.3 Intersection Speeding Profile for Bel-Red Rd and NE 30th St

Two indicators for speeding are offered by the video analytics to provide information on speeding drivers, the speeding rate and the excessive speed. A driver is identified as speeding if they are driving above the speed limit for more than 20-percent of their trajectory. The speeding rate is the percentage of the driver's trajectory at which the driver is speeding. Lower speeding rates mean that a driver only sped for a small portion of their

path and may be indicative of drivers entering the dilemma zone and speeding to catch the yellow traffic light. Higher speeding rates may be more indicative of careless driver behavior due to overconfidence, impatience, or other factors. Figures 4.7 (a), (b), and (c) show the distribution of the speeding rate for all the speeding road users along the intersection, as a whole and specifically for the northbound through and southbound through movements, the two movements with observed speeding. Table 10 in the appendix breaks down these values. Note that the video analytics flags drivers as speeding only if they have been speeding for more than 20-percent of their trajectory.

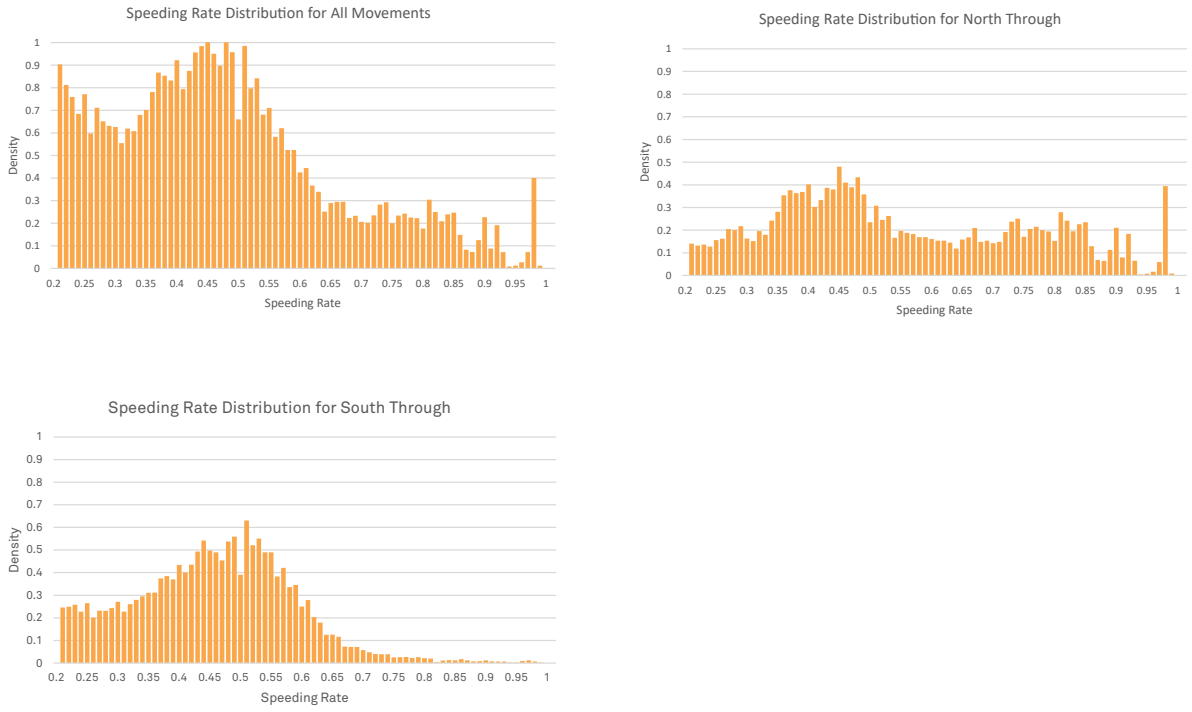

Figure 4.7 – Speeding rate by movement

The above figures show that southbound drivers are more susceptible to speeding at lower rates compared to northbound through drivers. One such incidence is captured in Figure 4.8 where a driver is speeding as they have encountered a red light while trying to cross the intersection.

Figure 4.8 – Driver speeding to cross red light

The video analytics also provides a speed value for speeding drivers denoted as the excessive speed. Excessive speed is the median speed only for the speeding driver's speeding trajectory. Figure 4.9 shows the distribution of excessive speeds based on rates, the values of which around found in Table 11 of the appendix.

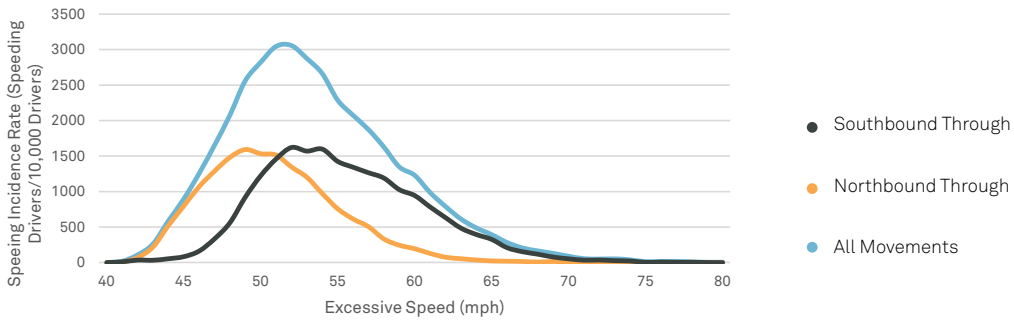

Figure 4.9 – Excessive speed distribution at Bel-Red Rd and NE 30th St

Figures 4.10 (a), (b), and (c) show the daily variation in speeding incidence rate. A trendline was placed on the graph to provide more context about speeding with respect to volumes. Figure 4.10b shows that northbound speeding incidence rates were lower than southbound speeding incidence rates. They also predominantly exceeded the speed limit by 10 mph or less and were higher on the weekends compared to the other days of the week. In addition to being higher, southbound speeding incidence rates had a wider excessive speed range and did not vary across the weekdays regardless of changes in volume.

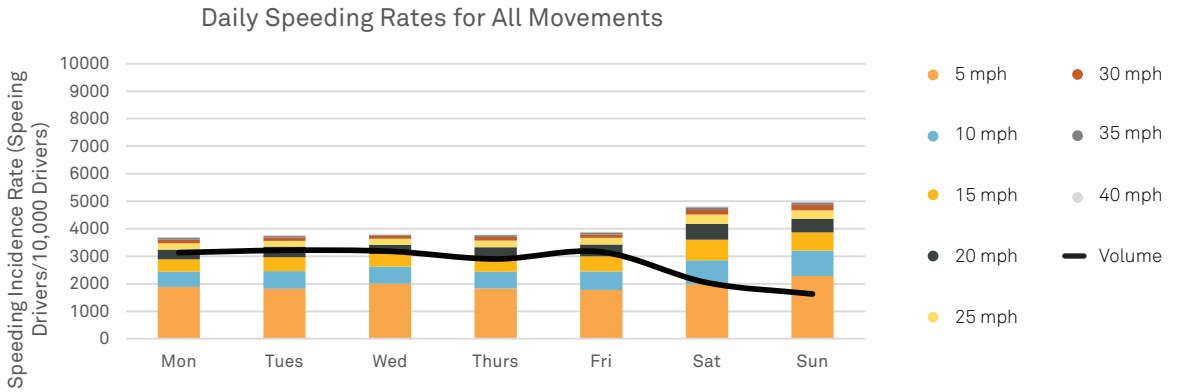

Figure 4.10a - Daily speeding incidence rates for all movements

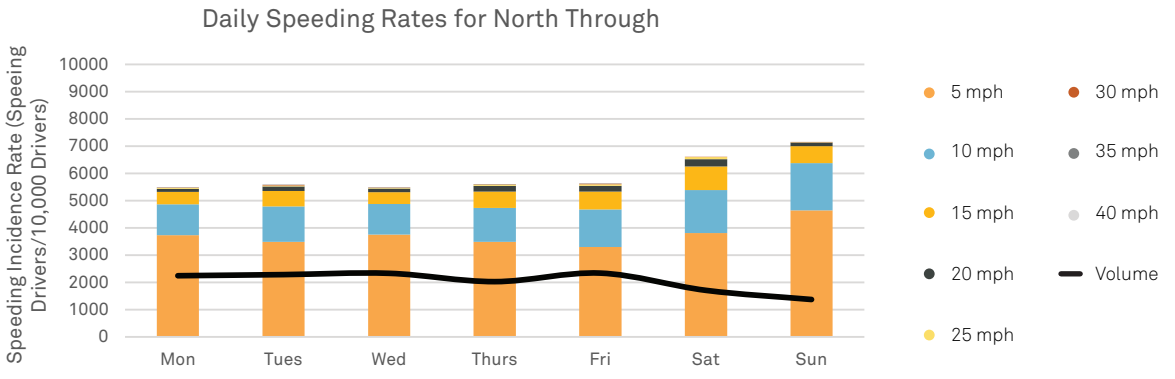

Figure 4.10b - Daily speeding incidence rates for northbound through

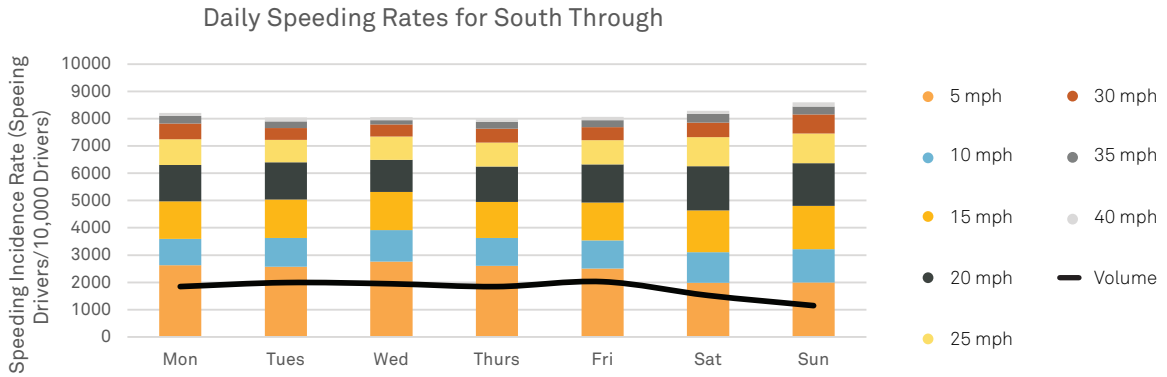

Figure 4.10c - Daily speeding incidence rates for southbound through

Figures 4.11 (a), (b), and (c) show the hourly variation in speeding incidence rate on the weekdays and Figures 4.12 (a), (b), and (c) show the hourly variation in speeding incidence on the weekends. The same traffic volume trend line is present. Again, northbound excessive speeds were predominantly lower than 10 mph above the speed limit. On weekdays, speeding incidence rates decreased with increases in volumes. On weekends, rates were more constant; however, incidence rates were significantly lower at 6 AM. Southbound excessive speeds experience a wider excessive speed range. Incidence rate was constant throughout the day on both weekdays and weekends, with the exception of 6 AM on weekends. All temporal speeding incidence rate values are provided in Tables 12 and 13 of the appendix.

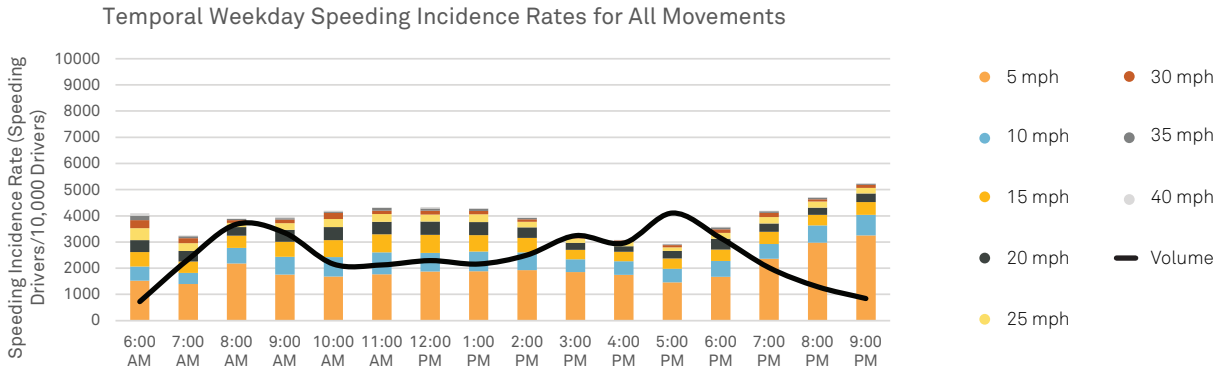

Figure 4.11a – Hourly weekday speeding incidence rates for all movements

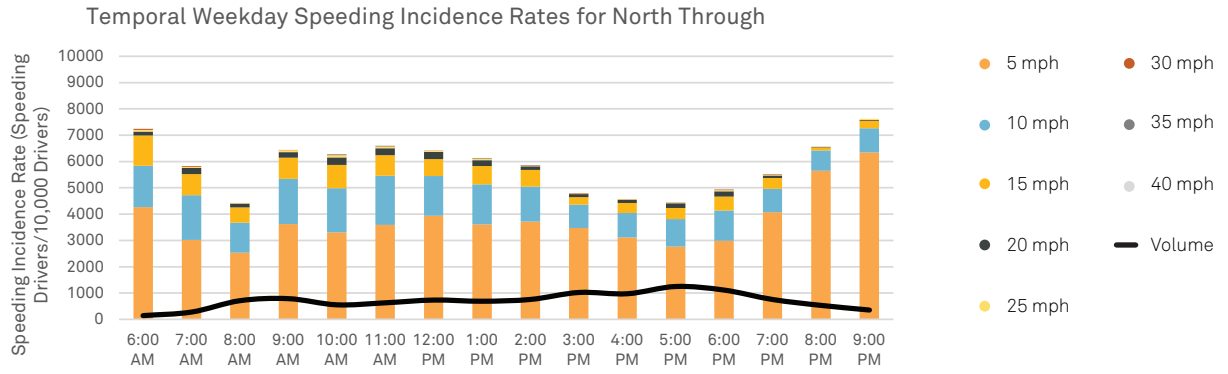

Figure 4.11b – Hourly weekday speeding incidence rates for northbound through

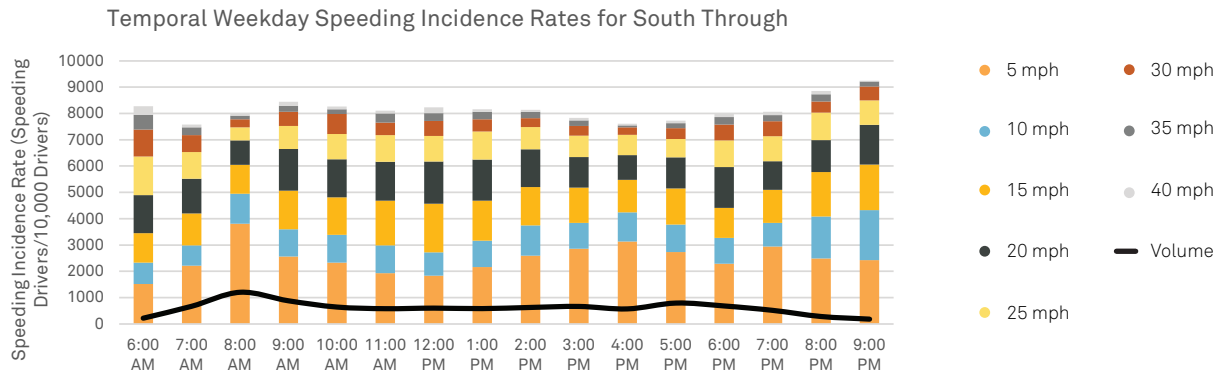

Figure 4.11c – Hourly weekday speeding incidence rates for southbound through

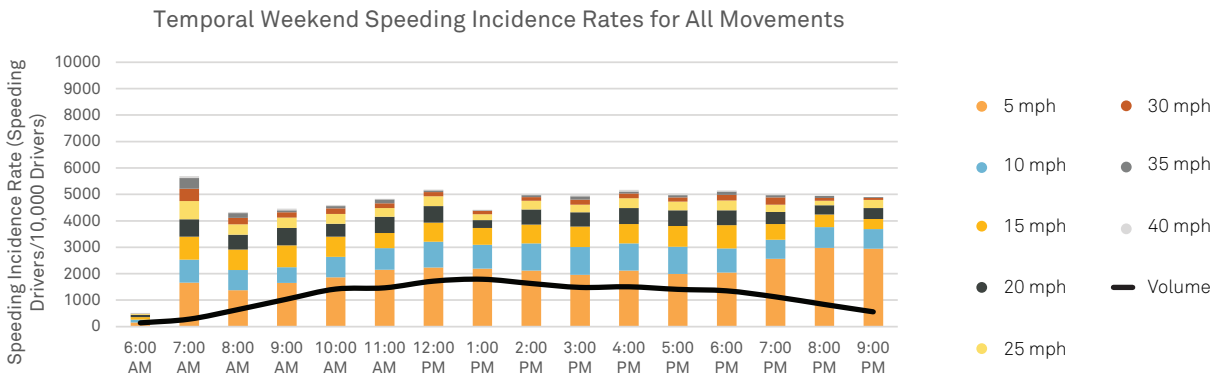

Figure 4.12a – Hourly weekend speeding incidence rates for all movements

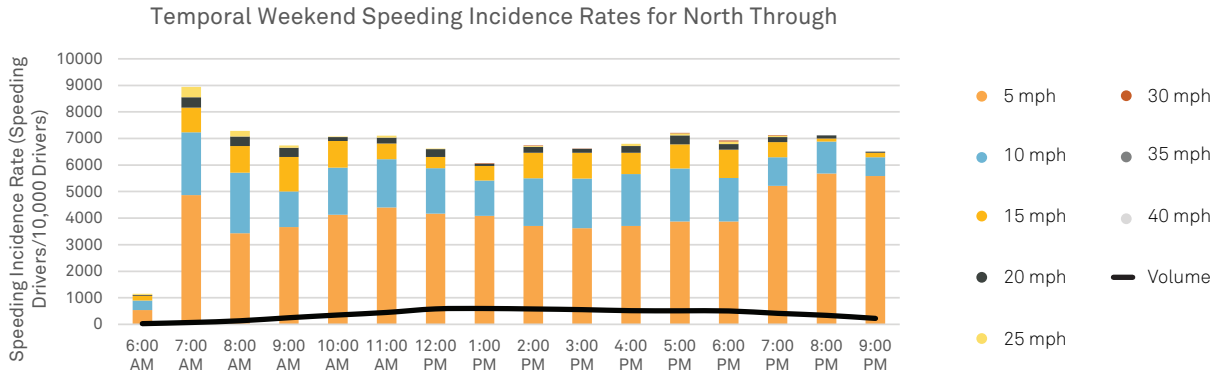

Figure 4.12b – Hourly weekend speeding incidence rates for northbound through

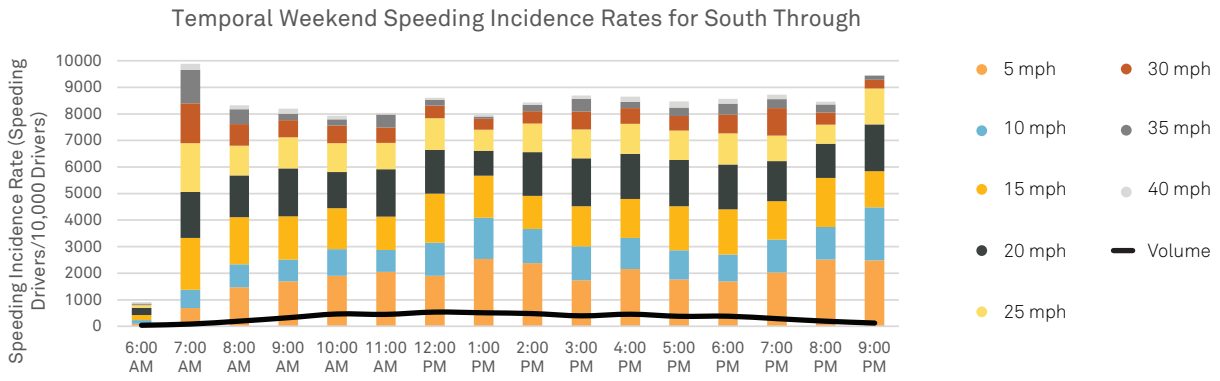

Figure 4.12c – Hourly weekend speeding incidence rates for southbound through

4.4 Intersection Speeding Diagnosis

The information provided by the video analytics indicates that Bel Red Rd and NE 30th St is prone to high speeding incidence rates for multiple reasons. Only two through movements are allowed at this intersection, which are along the North-South corridor, and they have significantly higher traffic volumes than all other movements. Additionally, only one left turn is permissible along this corridor and is protected by a traffic island. These factors create an environment whereby the northbound through and southbound through drivers may be more comfortable driving at a higher speed due to the low amount of interactions involving other movements. Speeding behavior was found to be different between southbound through and northbound through movements. The northbound through speeding incidence rate was found to be lower; however, drivers were more likely to speed for longer and at faster speeds. There was little variation in northbound through speeding with respect to volume except for a decrease when volumes increased on weekdays. Southbound through driver were more likely to commit speeding infractions but for a shorter time and at lower speeds. There was no evident correlation between speeding incidence and traffic volumes for this movement. Video evidence indicates that this was likely to be due to red light traffic light infractions.

5
Conclusion

This work introduces a unique application of a large-scale network screening using video data from traffic surveillance cameras and BriskLUMINA, a specialized automated-road-safety platform. Over 4,000 hours of video footage from 40 intersections with varied urban densities and land uses were analyzed across the City of Bellevue.

Summary statistics show that average speeds were higher on arterials in residential land use areas and in non-downtown locations as opposed to in commercial and downtown locations, respectively. Speeds were found to be higher at intersections not on the HIN as the majority of them were residential. Instances of speeding were more prevalent in residential areas as opposed to commercial areas; however, speeding was more prevalent in the downtown intersections as opposed to the non-downtown intersections. Speeding incidence rate was not affected by the posted speed limit at an intersection and was observed to be higher at locations not on the HIN. Weekday hourly speeds and speeding incidence rates were constant with the exception of a decrease around peak hours.

A network-wide analysis was conducted on driver speeding incidence and a hotspot analysis was conducted on speeds and excessive speeds. The results showed a decrease in speeds and speeding during peak hours. Furthermore, driver speeds were higher on roads with wider lanes. Near schools (within a 0.125-mile radius), speeds were lower, but excessive speeds were found to be higher.

The intersection that was most susceptible to driver speeding was Bel-Red Rd & NE 30th St. High speeding incidence rates were observed along the northbound through and southbound through movements along Bel-Red Rd. Speeding behavior differed for both movements, however. Northbound through speeding incidence rate was found to be lower but occurred at higher speeds and for longer. Southbound through speeding incidence rate was found to be higher but occurred for a shorter time and at lower speeds. Speeding at this intersection can be attributed to the excessive confidence of drivers because of the lower volumes of surrounding movements and the prohibition of several other movements. The speeding behavior is similar to that of drivers increasing their speeds to catch the end of a green or yellow traffic light. This information was also evident in the speeding conflict clips generated.

This analysis demonstrates the scalability of the platform. By taking advantage of existing infrastructure, this analytics solution can support Vision Zero programs.

5.1 Lessons Learned

This joint project between the City of Bellevue, Together for Safer Roads, and Transoft Solutions (ITS) Inc. is the first of its kind. Tens of thousands of hours of footage were collected and tens of millions of road users were detected. Due to the extensive amount of data, video processing (and reprocessing) was lengthy and costly. To

reduce the cost and time, less hours of footage can be processed, either for a shorter duration or using less hours of footage a day. Additionally, as this study relies on video analytics, the quality of the video footage is extremely important. The network cameras used by the city were of extremely high quality and were located at a height so as to capture the entire intersection and movements clearly. However, issues were encountered as some cameras moved slowly over time resulting in missing data within some regions of the camera's field of view, and delays from recalibrating. Additionally, a few of the cameras had inconsistent frame rates which meant additional quality control was required to delete false positive results. Lastly weather conditions led to the obstruction of parts of the camera lens due to snow or rain drops. Similar projects in the future will place greater emphasis on the site selection based on the camera's field of view alongside weather conditions and the data collection period.

5.2 Future Work

The data used in this report is part of a bigger project with the City of Bellevue, Together for Safer Roads, and Transoft Solutions (ITS) Inc. Two additional reports have been produced on network screening and conflict analysis and another one to gain a better understanding of conflicts and collisions.

5.3 Acknowledgements

We would like to thank Dr. Yinhai Wang – director of the Smart Transportation Applications and Research Laboratory (STAR Lab) at the University of Washington (UW) and director for Pacific Northwest Transportation Consortium (PacTrans), USDOT University Transportation Center for Federal Region 10 – for helping in the definition of this project and in the revision of the final report.

Appendix

Appendix | Table 1. Intersection Characteristics

Table 1: Intersection Characteristics

Intersection		Speed Limit	Land Use	Urban Density	Downtown Core	# of Crosswalks	HIN	Presense of Bike Path	
NS Corridor	EW Corridor							NS Corridor	EW Corridor
100th Ave	Main St	30	Comercial	High	Yes	4	No	No	No
108th Ave	Main St	30	Comercial	High	Yes	4	Yes	Yes	No
108th Ave NE	NE 4th St	30	Comercial	High	Yes	4	Y	Yes	No
108th Ave NE	NE 8th St	30	Comercial	High	Yes	4	Y	Yes	No
108th Ave NE	NE 12th St	30	Comercial	High	Yes	4	Y	Yes	Shared
112th Ave	Main St	35	Comercial	High	No	4	Y	No	No
112th Ave NE	NE 12th St	30	Comercial	High	Yes	4	Y	No	No
112th Ave NE	NE 8th St	30	Comercial	High	Yes	3	Y	Yes	No
116th Ave NE	Northup Wy	35	Comercial	Medium	No	2	No	Yes	Yes
116th Ave NE	NE 8th St	30	Comercial	High	No	3	Yes	No	No
118th Ave SE	SE 8th St	35	Residential	Medium	No	2	Yes	No	No
120th Ave NE	NE 8th St	30	Comercial	High	No	4	Yes	Shared	Shared
124th Ave NE	Bel-Red Rd	35	Comercial	Medium	No	3	Yes	No	No
124th Ave NE	NE 8th St	35	Comercial	Medium	No	4	Yes	No	Yes
130th Ave NE	Northup Wy	35	Comercial	Medium	No	4	Yes	No	No
140th Ave NE	NE 8th St	35	Comercial	Medium	No	4	Yes	Shared	Shared
140th Ave NE	NE 20th St	35	Comercial	Medium	No	4	Yes	Yes	Shared
145th Pl SE	SE 16th St	35	Residential	Medium	No	4	No	Yes	Yes
148th Ave	Main St	35	Comercial	Medium	No	4	Yes	Shared	Yes
148th Ave NE	Bel-Red Rd	35	Comercial	Medium	No	4	Yes	Shared	Shared
148th Ave SE	SE 22nd St	35	Residential	Medium	No	4	Yes	No	No
150th Ave SE	SE Eastgate Wy	30	Comercial	Medium	No	1	Yes	No	Yes
150th Ave SE	SE Newport Wy	30	Residential	Medium	No	4	No	Shared	Shared
150th Ave SE	SE 38th St	35	Comercial	Medium	No	4	Yes	No	No
156th Ave NE	NE 8th St	35	Comercial	Medium	No	4	Yes	Shared	Shared
156th Ave NE	Northup Wy	35	Comercial	Medium	No	4	Yes	No	No
156th Ave NE	Bel-Red Rd	35	Comercial	Medium	No	4	Yes	No	No
164th Ave NE	NE 24th St	30	Residential	Medium	No	4	Yes	Yes	Shared
164th Ave SE	Lakemont Blvd	30	Residential	Medium	No	3	No	Yes	Yes
Allen Rd	Newport Way SE	30	Residential	Medium	No	4	No	Yes	Yes
Bel-Red Rd	NE 30th St	40	Residential	Medium	No	4	No	No	Yes
Bellevue Wy	Main St	30	Comercial	High	Yes	4	Yes	Shared	Shared
Bellevue Wy NE	NE 8th St	30	Comercial	High	Yes	4	Yes	No	No
Bellevue Wy SE	SE 16th St	30	Comercial	Medium	No	4	No	No	No
Factoria Blvd SE	SE 36th St	35	Comercial	Medium	No	3	Yes	Shared	Shared
Factoria Blvd SE	Coal Creek Pkwy	35	Residential	Medium	No	2	Yes	Yes	Yes
Factoria Blvd SE	SE 38th St	35	Comercial	Medium	No	4	Yes	No	No
Lakemont Blvd SE	Cougar Mt Way	30	Residential	Medium	No	4	No	Yes	Yes
Richards Rd	SE 26th St	35	Residential	Medium	No	4	Yes	Yes	Shared
Richards rd	SE Eastgate Wy	35	Residential	Medium	No	3	Yes	Shared	Yes

Appendix | Table 2: Average Speed by Movement at All Intersections

Table 2: Average Speed by Movement at All Intersections

Intersection		Speed		
NS Corridor	**EW Corridor**	**Through**	**Right Turn**	**Left Turn**
100th Ave	Main St	12.5	14.8	12.7
108th Ave	Main St	11.6	8.1	7.9
108th Ave NE	NE 4th St	35.2	12.6	12.7
108th Ave NE	NE 8th St	15.3	9.3	10.6
108th Ave NE	NE 12th St	20.8	11.7	11.3
112th Ave	Main St	18.7	10.5	11.4
112th Ave NE	NE 12th St	25.6	12.9	12
112th Ave NE	NE 8th St	16.6	11.9	13.2
116th Ave NE	Northup Wy	7.6	10.9	7.3
116th Ave NE	NE 8th St	21	12.9	11.7
118th Ave SE	SE 8th St	18.4	13.5	15.9
120th Ave NE	NE 8th St	24.1	14.4	12.9
124th Ave NE	Bel-Red Rd	29	13.5	14.4
124th Ave NE	NE 8th St	26.5	9.5	10.6
130th Ave NE	Northup Wy	13.3	7	7.7
140th Ave NE	NE 8th St	25.3	12	12.4
140th Ave NE	NE 20th St	19.1	12.5	12.3
145th Pl SE	SE 16th St	35.8	10.8	10.2
148th Ave	Main St	23.3	11.9	12.6
148th Ave NE	Bel-Red Rd	19.1	13.7	13.4
148th Ave SE	SE 22nd St	41.3	12.4	13
150th Ave SE	SE Eastgate Wy	25.7	14.2	14.6
150th Ave SE	SE Newport Wy	26.6	14.7	16.4
150th Ave SE	SE 38th St	20	11	12.3
156th Ave NE	NE 8th St	18.4	11.2	11.8
156th Ave NE	Northup Wy	24	13.8	13.6
156th Ave NE	Bel-Red Rd	16.5	16	13
164th Ave NE	NE 24th St	10.6	8.7	7.5
164th Ave SE	Lakemont Blvd	31.4	13	12.3
Allen Rd	Newport Way SE	31.5	20.2	14.6
Bellevue Wy	Main St	16.5	9.7	10.4
Bellevue Wy NE	NE 8th St	18.3	8.7	11
Bellevue Wy SE	SE 16th St	38.9	11.1	14.8
Bel-Red Rd	NE 30th St	40.1	12	14.1
Factoria Blvd SE	SE 36th St	12.3	9.4	13.8
Factoria Blvd SE	Coal Creek Pkwy	19.3	14.2	13.8
Factoria Blvd SE	SE 38th St	25.7	12.4	11.3
Lakemont Blvd SE	Cougar Mt Way	39	14.2	21.3
Richards Rd	SE 26th St	13.8	9.8	9.7
Richards rd	SE Eastgate Wy	20.1	12.4	13.7

Appendix | Table 3: Speeding Incidence Rate by Intersection

Table 3: Speeding Incidence Rate by Intersection

Intersection		Speeding Incidence
NS Corridor	**EW Corridor**	**Rate**
100th Ave	Main St	11.2%
108th Ave	Main St	4.5%
108th Ave NE	NE 4th St	12.0%
108th Ave NE	NE 8th St	9.5%
108th Ave NE	NE 12th St	3.2%
112th Ave	Main St	1.0%
112th Ave NE	NE 12th St	0.4%
112th Ave NE	NE 8th St	14.3%
116th Ave NE	Northup Wy	21.1%
116th Ave NE	NE 8th St	8.3%
118th Ave SE	SE 8th St	1.8%
120th Ave NE	NE 8th St	8.6%
124th Ave NE	Bel-Red Rd	26.8%
124th Ave NE	NE 8th St	7.7%
130th Ave NE	Northup Wy	1.6%
140th Ave NE	NE 8th St	5.8%
140th Ave NE	NE 20th St	14.8%
145th Pl SE	SE 16th St	13.3%
148th Ave	Main St	20.3%
148th Ave NE	Bel-Red Rd	34.3%
148th Ave SE	SE 22nd St	15.2%
150th Ave SE	SE Eastgate Wy	28.6%
150th Ave SE	SE Newport Wy	13.9%
150th Ave SE	SE 38th St	4.2%
156th Ave NE	NE 8th St	0.5%
156th Ave NE	Northup Wy	5.9%
156th Ave NE	Bel-Red Rd	3.8%
164th Ave NE	NE 24th St	9.7%
164th Ave SE	Lakemont Blvd	8.0%
Allen Rd	Newport Way SE	8.8%
Bellevue Wy	Main St	8.7%
Bellevue Wy NE	NE 8th St	1.8%
Bellevue Wy SE	SE 16th St	5.0%
Bel-Red Rd	NE 30th St	7.8%
Factoria Blvd SE	SE 36th St	1.4%
Factoria Blvd SE	Coal Creek Pkwy	18.9%
Factoria Blvd SE	SE 38th St	11.9%
Lakemont Blvd SE	Cougar Mt Way	39.0%
Richards Rd	SE 26th St	10.7%
Richards rd	SE Eastgate Wy	9.8%

Appendix | Table 4: Output of Speeding Network-wide Analysis Model

Table 4: Output of Speeding Network-wide Analysis Model

Parameter		Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Speeding Rate		0.3711564	0.0003101	1196.84	0	0.3705486	0.3717643
Maximum Speed		0.0208937	0.0005413	38.6	0	0.0198327	0.0219546
Peak Hour	**0**	0	(base)				
	1	-0.2486776	0.0151619	-16.4	0	-0.2783944	-0.2189608
RU Type	**Car**	0	(base)				
	Motorcycle	1.559729	0.1433763	10.88	0	1.278716	1.840741
	Bus	-1.100266	0.0885833	-12.42	0	-1.273886	-0.9266453
	Truck	0.4414118	0.0563655	7.83	0	0.3309374	0.5518862
Movement	**Through**	0	(base)				
	Right Turn	-7.755395	0.040891	-189.66	0	-7.83554	-7.67525
	Left Turn	-6.868976	0.0466074	-147.38	0	-6.960324	-6.777627
Day of Week	**Weekday**	0	(base)				
	Weekend	-0.0288064	0.014868	-1.94	0.053	-0.0579472	0.0003345

Appendix | Table 5: Output of Speeding Network-wide Analysis Model by Intersection

Table 5: Output of Speeding Network-wide Analysis Model by Intersection

Intersection		Coef.	Std. Err.	t	P>t	95% Conf.	Interval]
NS Corridor	EW Corridor						
100th Ave	Main St	-10.6054	0.0444357	-238.67	0	-10.69249	-10.5183
108th Ave	Main St	-8.005249	0.0664184	-120.53	0	-8.135427	-7.875072
108th Ave NE	NE 4th St	-20.93771	0.0565783	-370.07	0	-21.0486	-20.82682
108th Ave NE	NE 8th St	-7.06541	0.0404022	-174.88	0	-7.144597	-6.986223
108th Ave NE	NE 12th St	-3.598561	0.0912461	-39.44	0	-3.777401	-3.419722
112th Ave	Main St	-6.478755	0.1717621	-37.72	0	-6.815403	-6.142107
112th Ave NE	NE 12th St	-9.989616	0.3665164	-27.26	0	-10.70798	-9.271256
112th Ave NE	NE 8th St	-5.605951	0.0366771	-152.85	0	-5.677837	-5.534065
116th Ave NE	Northup Wy	-0.1580306	0.0383121	-4.12	0	-0.2331211	-0.0829401
116th Ave NE	NE 8th St	-7.130634	0.0458089	-155.66	0	-7.220418	-7.04085
118th Ave SE	SE 8th St	1.948674	0.0934839	20.85	0	1.765449	2.131899
120th Ave NE	NE 8th St	-8.916585	0.0465093	-191.72	0	-9.007742	-8.825428
124th Ave NE	Bel-Red Rd	0	(base)				
124th Ave NE	NE 8th St	-10.43219	0.0807641	-129.17	0	-10.59049	-10.2739
130th Ave NE	Northup Wy	-5.707395	0.1009051	-56.56	0	-5.905166	-5.509624
140th Ave NE	NE 8th St	-6.844752	0.056256	-121.67	0	-6.955011	-6.734492
140th Ave NE	NE 20th St	0.2642112	0.0394885	6.69	0	0.1868151	0.3416074
145th Pl SE	SE 16th St	2.471313	0.0396628	62.31	0	2.393575	2.54905
148th Ave	Main St	-6.801694	0.0373105	-182.3	0	-6.874821	-6.728566
148th Ave NE	Bel-Red Rd	-10.16183	0.0477	-213.04	0	-10.25532	-10.06833
148th Ave SE	SE 22nd St	-4.144965	0.0425476	-97.42	0	-4.228357	-4.061573
150th Ave SE	SE Eastgate Wy	-5.605652	0.038275	-146.46	0	-5.68067	-5.530634
150th Ave SE	SE Newport Wy	-5.870182	0.0426977	-137.48	0	-5.953868	-5.786496
150th Ave SE	SE 38th St	1.410934	0.0677303	20.83	0	1.278185	1.543684
156th Ave NE	NE 8th St	-10.79355	0.2971124	-36.33	0	-11.37589	-10.21122
156th Ave NE	Northup Wy	-18.77997	0.0849847	-220.98	0	-18.94654	-18.61341
156th Ave NE	Bel-Red Rd	-0.5377843	0.0780074	-6.89	0	-0.6906762	-0.3848924
164th Ave NE	NE 24th St	-6.483026	0.0448036	-144.7	0	-6.57084	-6.395213
164th Ave SE	Lakemont Blvd	-6.455217	0.0807781	-79.91	0	-6.613539	-6.296894
Allen Rd	Newport Way SE	-0.8028048	0.0533794	-15.04	0	-0.9074266	-0.698183
Bellevue Wy	Main St	-7.875384	0.0490641	-160.51	0	-7.971548	-7.77922
Bellevue Wy NE	NE 8th St	-7.125257	0.1044499	-68.22	0	-7.329975	-6.920538
Bellevue Wy SE	SE 16th St	-8.162076	0.0668684	-122.06	0	-8.293135	-8.031016
Bel-Red Rd	NE 30th St	10.30321	0.0760336	135.51	0	10.15419	10.45223
Constant	35.74924						
Factoria Blvd SE	SE 36th St	-4.881272	0.0985723	-49.52	0	-5.07447	-4.688073
Factoria Blvd SE	Coal Creek Pkwy	-4.482148	0.0470518	-95.26	0	-4.574368	-4.389928
Factoria Blvd SE	SE 38th St	-0.1752751	0.0414881	-4.22	0	-0.2565903	-0.0939599
Lakemont Blvd SE	Cougar Mt Way	-2.374348	0.0348649	-68.1	0	-2.442682	-2.306014
Richards Rd	SE 26th St	-5.931257	0.0719513	-82.43	0	-6.072279	-5.790234
Richards rd	SE Eastgate Wy	-1.136001	0.0425069	-26.73	0	-1.219313	-1.052689

Appendix | Table 6: Output of Speed Hotspot Analysis Model

Table 6: Output of Speed Hotspot Analysis Model

Parameter		Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Speeding Rate		0.4439248	0.0013453	329.99	0	0.4412882	0.4465615
Maximum Speed		0.1460696	0.0027485	53.14	0	0.1406825	0.1514566
Peak Hour	0	0	(base)				
	1	-1.16168	0.0681317	-17.05	0	-1.295215	-1.028144
RU Type	Car	0	(base)				
	Motorcycle	2.239936	0.4544536	4.93	0	1.349223	3.130648
	Bus	1.540675	0.7145518	2.16	0.031	0.1401787	2.94117
	Truck	1.059076	0.1792347	5.91	0	0.7077827	1.41037
Movement	Through	0	(base)				
	Right Turn	4.221185	0.1676046	25.19	0	3.892686	4.549684
	Left Turn	0.5979373	0.5188417	1.15	0.249	-0.4189738	1.614848
Day of Week	Weekday	0	(base)				
	Weekend	1.372845	0.0867964	15.82	0	1.202727	1.542963
Proximity to School	No school within 0.125 mi	0	(base)				
	School within 0.125 mi	-8.187802	0.4748525	-17.24	0	-9.118496	-7.257109
Number of Lanes	1	0	(base)				
	2	7.16323	0.4814167	14.88	0	6.219671	8.10679
Lane Width		-0.1947244	0.0295568	-6.59	0	-0.2526546	-0.1367942
Constant		27.67799	0.6705525	41.28	0	26.36373	28.99224

Appendix | Table 6: Output of Excessive Speed Hotspot Analysis Modelw

Table 6: Output of Excessive Speed Hotspot Analysis Model

Parameter		Coef.	Std. Err.	t	P>t	[95% Conf	Interval]
Speeding Rate		0.0405103	0.0012588	32.18	0	0.0380431	0.0429774
Maximum Speed		0.3993297	0.0025718	155.27	0	0.394289	0.4043704
Peak Hour	0	0	(base)				
	1	-1.4789	0.0637513	-23.2	0	-1.603851	-1.35395
RU Type	Car	0	(base)				
	Motorcycle	3.109436	0.4252354	7.31	0	2.27599	3.942882
	Bus	2.082086	0.6686111	3.11	0.002	0.7716325	3.39254
	Truck	1.273939	0.1677112	7.6	0	0.945231	1.602647
Movement	Through	0	(base)				
	Right Turn	1.165762	0.1568288	7.43	0	0.8583828	1.47314
	Left Turn	-4.263965	0.4854838	-8.78	0	-5.215496	-3.312434
Day of Week	Weekday	0	(base)				
	Weekend	1.299101	0.081216	16	0	1.139921	1.458282
Proximity to School	No school within 0.125 mi	0	(base)				
	School within 0.125 mi	1.907077	0.4443229	4.29	0	1.03622	2.777934
Number of Lanes	1	0	(base)				
	2	-1.116487	0.450465	-2.48	0.013	-1.999382	-0.233592
Lane Width		-1.407761	0.0276565	-50.9	0	-1.461967	-1.353555
Constant		68.85036	0.6274407	109.73	0	67.62059	70.08012

Appendix | Table 8: Temporal Breakdown of Motorized Volumes Bel-Red Rd. & NE 30th St.

Table 8: Temporal Breakdown of Motorized Volumes Bel-Red Rd. & NE 30th St.

	Week Day						
Time	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**
6:00 AM	280	284	301	301	280	83	52
7:00 AM	934	963	936	949	893	183	93
8:00 AM	1470	1475	1471	1509	1441	410	229
9:00 AM	1425	1389	1408	1263	1215	590	444
10:00 AM	869	926	771	937	816	770	646
11:00 AM	824	810	841	903	874	806	656
12:00 PM	802	871	1009	924	978	921	794
1:00 PM	785	860	901	853	924	974	813
2:00 PM	994	983	928	991	1114	913	713
3:00 PM	1281	1336	1223	1269	1381	861	617
4:00 PM	1487	1527	1466	0	1443	815	686
5:00 PM	1714	1668	1638	1675	1524	715	689
6:00 PM	1366	1261	1297	1244	1142	709	639
7:00 PM	691	860	838	852	802	623	497
8:00 PM	484	513	533	515	544	477	355
9:00 PM	255	353	344	315	417	351	202
Total	15661	16079	15905	14500	15788	10201	8125

Appendix | Table 9: Temporal Breakdown of Speed by movement Bel-Red Rd. & NE 30th St.

Table 9: Temporal Breakdown of Speed by movement Bel-Red Rd. & NE 30th St.

		Movement							
		South Through	North Through	North Right Turn	East Right Turn	West Right Turn	South Right	South Left	West Left
Time	6:00 AM	51	38	17	13	9	11	12	15
	7:00 AM	45	35	17	12	9	10	12	18
	8:00 AM	41	31	17	13	9	10	11	19
	9:00 AM	47	36	17	12	8	11	12	18
	10:00 AM	46	36	18	13	9	11	12	17
	11:00 AM	46	36	18	12	9	11	12	16
	12:00 PM	48	36	18	12	9	11	12	17
	1:00 PM	45	35	18	13	9	10	12	16
	2:00 PM	45	35	18	13	9	10	11	16
	3:00 PM	44	32	18	12	9	10	11	17
	4:00 PM	43	32	18	11	9	10	11	17
	5:00 PM	44	32	17	10	9	10	11	17
	6:00 PM	47	33	17	12	8	10	11	16
	7:00 PM	45	33	18	12	8	9	11	15
	8:00 PM	47	34	17	13	8	10	12	15
	9:00 PM	49	36	17	12	9	9	12	14
Day	Monday	45	33	17	12	9	10	11	17
	Tuesday	45	33	17	12	9	11	11	17
	Wednesday	44	33	17	12	9	11	11	17
	Thursday	44	33	17	12	9	11	11	17
	Friday	45	34	17	12	9	10	11	17
	Saturday	47	36	18	12	9	11	12	16
	Sunday	49	37	18	13	9	10	12	16

Appendix | Table 10: Speeding Rate by Movement Bel-Red Rd. & NE 30th St.

Table 10: Speeding Rate by Movement Bel-Red Rd. & NE 30th St.

Rate	Movement		
	All Movements	Norhtbound Through	Southbound Through
20%	0	0	0
21%	0.903	0.141	0.246
22%	0.812	0.132	0.249
23%	0.759	0.136	0.258
24%	0.684	0.128	0.228
25%	0.771	0.156	0.265
26%	0.597	0.162	0.201
27%	0.711	0.205	0.232
28%	0.651	0.200	0.231
29%	0.631	0.218	0.243
30%	0.626	0.163	0.271
31%	0.555	0.152	0.228
32%	0.619	0.196	0.261
33%	0.608	0.180	0.280
34%	0.680	0.242	0.295
35%	0.702	0.281	0.311
36%	0.781	0.354	0.312
37%	0.867	0.376	0.374
38%	0.853	0.363	0.385
39%	0.832	0.368	0.370
40%	0.922	0.402	0.434
41%	0.794	0.303	0.400
42%	0.875	0.333	0.435
43%	0.956	0.387	0.493
44%	0.984	0.380	0.542
45%	1.048	0.480	0.498
46%	0.950	0.410	0.490
47%	0.897	0.389	0.454
48%	1.022	0.433	0.538
49%	0.957	0.358	0.559
50%	0.660	0.235	0.391
51%	0.985	0.308	0.631
52%	0.797	0.245	0.521
53%	0.842	0.263	0.551
54%	0.681	0.167	0.490
55%	0.710	0.197	0.490
56%	0.583	0.188	0.383
57%	0.621	0.183	0.421
58%	0.524	0.169	0.336
59%	0.524	0.169	0.346
60%	0.425	0.161	0.250
61%	0.444	0.154	0.279
62%	0.367	0.154	0.203
63%	0.339	0.145	0.179
64%	0.251	0.119	0.125
65%	0.290	0.159	0.126
66%	0.295	0.168	0.116
67%	0.295	0.210	0.073
68%	0.224	0.148	0.071
69%	0.233	0.154	0.071
70%	0.206	0.142	0.057
71%	0.203	0.148	0.048
72%	0.235	0.192	0.040
73%	0.283	0.238	0.039
74%	0.293	0.251	0.039
75%	0.200	0.171	0.025
76%	0.234	0.206	0.026
77%	0.243	0.215	0.027
78%	0.225	0.200	0.023
79%	0.223	0.194	0.026
80%	0.177	0.153	0.022
81%	0.304	0.279	0.020
82%	0.250	0.242	0.004
83%	0.209	0.195	0.011
84%	0.239	0.226	0.013
85%	0.247	0.235	0.012
86%	0.149	0.129	0.017
87%	0.083	0.069	0.012
88%	0.073	0.064	0.008
89%	0.125	0.113	0.009
90%	0.227	0.211	0.012
91%	0.088	0.080	0.008
92%	0.191	0.184	0.007
93%	0.072	0.065	0.007
94%	0.009	0.005	0.003
95%	0.012	0.008	0.003
96%	0.027	0.017	0.010
97%	0.072	0.059	0.012
98%	0.401	0.394	0.007
99%	0.012	0.009	0.003
100%	0	0	0

Appendix | Table 11: Speed Distribution of Speeding Drivers by Movement Bel-Red Rd. & NE 30th St.

Table 11: Speed Distribution of Speeding Drivers by Movement Bel-Red Rd. & NE 30th St.

Speed (mph)	Movement		
	All Movements	Northbound Through	Southbound Through
40	0	0	0
41	17	6	11
42	107	71	35
43	261	220	33
44	585	522	54
45	894	797	83
46	1255	1071	162
47	1653	1289	334
48	2077	1483	561
49	2563	1593	922
50	2822	1534	1224
51	3046	1515	1460
52	3058	1348	1622
53	2875	1203	1571
54	2662	974	1599
55	2288	759	1426
56	2075	615	1344
57	1874	507	1266
58	1628	334	1191
59	1348	246	1028
60	1229	197	945
61	987	130	784
62	790	77	634
63	614	56	486
64	488	38	396
65	393	25	327
66	282	21	210
67	205	17	153
68	164	8	118
69	128	17	78
70	89	8	53
71	54	4	34
72	49	0	36
73	52	1	27
74	38	1	22
75	12	1	3
76	16	0	7
77	15	1	4
78	9	0	5
79	4	0	1
80	4	0	0

Appendix | Table 12: Daily Speeding Distribution by Movement Bel-Red Rd. & NE 30th St.

Table 12: Daily Speeding Distribution by Movement Bel-Red Rd. & NE 30th St.

	Speed Above Speed Limit (mph)	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
All Movements	5 mph	1885	1824	2010	1834	1779	1991	2284
	10 mph	552	631	612	606	672	864	928
	15 mph	455	509	468	505	548	747	660
	20 mph	345	384	328	388	426	572	491
	25 mph	231	213	214	238	244	345	311
	30 mph	141	114	111	132	128	164	199
	35 mph	68	62	39	63	67	95	82
	40 mph	25	34	26	26	30	33	46
	Total	3701	3771	3807	3792	3892	4810	5002
Northbound Through	5 mph	3734	3484	3758	3490	3299	3805	4643
	10 mph	1125	1306	1119	1240	1378	1583	1726
	15 mph	461	560	427	599	650	860	623
	20 mph	114	171	139	210	218	266	142
	25 mph	27	35	17	52	58	82	11
	30 mph	16	15	6	10	17	12	11
	35 mph	7	4	4	5	4	0	0
	40 mph	0	0	0	0	0	0	0
	Total	5484	5575	5471	5605	5624	6608	7156
Southbound Through	5 mph	2627	2576	2763	2604	2506	1986	1997
	10 mph	973	1051	1157	1020	1028	1118	1218
	15 mph	1369	1415	1401	1327	1387	1538	1588
	20 mph	1328	1357	1175	1297	1409	1614	1567
	25 mph	946	819	853	879	885	1065	1088
	30 mph	580	442	445	510	479	536	692
	35 mph	279	244	154	241	255	319	292
	40 mph	106	138	105	100	116	112	161
	Total	8208	8042	8052	7979	8065	8287	8603

Appendix | Table 13: Hourly Speeding Distribution by Movement at Bel-Red Rd. & NE 30th St.

Table 13: Hourly Speeding Distribution by Movement at Bel-Red Rd. & NE 30th St.

		Speed Above Speed Limit (mph)	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM
Weekday	All Movements	5 mph	1521	1397	2180	1761	1688	1771	1878	1885	1922	1855	1746	1465	1669	2367	2974	3248
		10 mph	546	419	592	673	739	835	711	754	685	481	518	520	613	557	657	790
		15 mph	553	441	468	572	648	689	685	629	553	361	361	392	434	470	409	487
		20 mph	456	404	327	464	500	480	506	488	401	274	218	281	404	312	270	333
		25 mph	450	293	167	246	306	294	271	305	214	169	155	142	231	252	232	214
		30 mph	311	188	103	140	229	132	151	127	90	82	59	80	139	153	93	113
		35 mph	166	83	45	58	60	101	76	79	62	42	14	38	67	59	58	42
		40 mph	97	32	22	43	30	26	59	25	20	20	12	18	29	30	27	6
		Total	4101	3258	3904	3958	4200	4327	4337	4293	3946	3284	3083	2936	3586	4200	4720	5232
	Northbound Through	5 mph	4265	3024	2534	3627	3303	3594	3943	3615	3720	3474	3115	2764	2991	4076	5653	6344
		10 mph	1577	1694	1146	1714	1683	1869	1506	1516	1326	888	932	1051	1144	884	767	925
		15 mph	1147	801	580	803	883	775	643	700	630	280	376	417	532	412	114	284
		20 mph	143	237	127	217	291	272	274	219	139	118	118	181	203	93	19	28
		25 mph	72	36	28	70	82	64	48	58	13	15	21	24	36	33	19	43
		30 mph	36	36	7	6	18	8	7	7	20	15	10	8	27	20	0	0
		35 mph	0	0	0	0	27	16	0	15	7	0	0	0	14	0	0	0
		40 mph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	7240	5829	4423	6437	6288	6597	6420	6130	5855	4789	4573	4444	4946	5519	6572	7624
	Southbound Through	5 mph	1515	2217	3807	2563	2334	1934	1839	2157	2596	2855	3131	2728	2288	2946	2491	2430
		10 mph	816	772	1141	1039	1049	1049	886	1009	1146	989	1108	1044	979	898	1595	1899
		15 mph	1119	1213	1095	1467	1433	1700	1839	1519	1458	1337	1240	1380	1148	1249	1685	1732
		20 mph	1445	1318	929	1581	1441	1474	1605	1562	1442	1163	932	1177	1545	1093	1219	1508
		25 mph	1469	1011	496	879	963	1015	978	1070	841	808	774	703	1015	946	1039	922
		30 mph	1026	644	312	531	760	477	569	466	337	378	290	405	603	576	430	531
		35 mph	559	292	137	223	180	356	293	276	240	204	70	196	287	234	269	196
		40 mph	326	112	67	166	102	95	226	95	80	98	62	95	132	117	125	28
		Total	8275	7581	7984	8447	8262	8101	8236	8154	8141	7832	7608	7728	7999	8059	8853	9246
Weekend	All Movements	5 mph	152	1667	1377	1654	1864	2148	2233	2194	2122	1962	2119	1994	2047	2563	2981	2948
		10 mph	111	870	767	590	777	814	974	895	1021	1049	1033	1026	905	723	781	741
		15 mph	90	870	767	832	763	575	729	638	713	771	726	783	883	589	481	380
		20 mph	90	652	563	658	487	622	618	297	572	541	606	598	564	464	349	416
		25 mph	35	688	391	387	367	328	379	229	332	291	373	328	371	268	168	307
		30 mph	7	471	250	203	219	178	152	123	141	189	180	157	215	277	108	72
		35 mph	14	399	172	77	78	150	70	22	74	129	73	85	119	89	72	36
		40 mph	14	72	47	58	42	21	23	22	25	34	60	64	52	45	24	0
		Total	512	5688	4335	4458	4597	4836	5178	4421	5000	4966	5170	5036	5156	5018	4964	4901
	Northbound Through	5 mph	538	4868	3429	3661	4129	4403	4171	4083	3711	3627	3707	3879	3878	5215	5685	5590
		10 mph	358	2368	2286	1339	1770	1814	1709	1333	1787	1867	1950	1988	1634	1077	1195	699
		15 mph	179	921	1000	1299	1011	597	427	550	962	969	811	916	1063	574	117	175
		20 mph	36	395	357	354	140	221	291	83	223	144	251	331	217	191	117	44
		25 mph	36	395	214	79	28	66	17	0	34	0	77	78	98	48	0	0
		30 mph	0	0	0	0	0	0	0	17	17	18	0	19	39	24	0	0
		35 mph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		40 mph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	1147	8947	7286	6732	7079	7102	6615	6067	6735	6625	6795	7212	6929	7129	7114	6507
	Southbound Through	5 mph	93	690	1472	1687	1902	2053	1907	2534	2381	1734	2157	1763	1693	2027	2513	2480
		10 mph	140	690	863	828	1004	817	1241	1559	1284	1281	1176	1105	1016	1237	1231	2000
		15 mph	186	1954	1777	1626	1538	1258	1852	1579	1242	1508	1460	1658	1693	1443	1846	1360
		20 mph	280	1724	1574	1810	1368	1788	1648	936	1656	1809	1699	1737	1693	1512	1282	1760
		25 mph	93	1839	1117	1166	1090	993	1185	799	1077	1080	1133	1105	1172	962	718	1360
		30 mph	23	1494	812	644	662	574	481	409	455	678	588	553	703	1031	462	320
		35 mph	47	1264	558	245	235	486	222	78	248	477	240	316	417	344	308	160
		40 mph	47	230	152	184	128	66	74	78	83	126	196	237	182	172	103	0
		Total	909	9885	8325	8190	7927	8035	8611	7973	8427	8693	8649	8474	8568	8729	8462	9440