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Characterization of the Coronavirus Pandemic on Signalized Intersections Using Probe Vehicle Data

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ABSTRACT

The Coronavirus (COVID-19) pandemic presents a unique opportunity to establish a baseline for studying transportation performance metrics before, during, and the eventual transition to normalcy using probe vehicle data. Probe vehicle speed data are already being used to evaluate traffic congestion characteristics, resiliency, and network response at local, corridor, and regional levels. A better understanding of changes in traffic characteristics, 24-hours a day, 7 days a week, can be realized through the analysis of spatially located, temporal speed data. This paper explores the use of probe vehicle data sets to establish the baseline traffic conditions under the unique conditions resulting from COVID-19. The preliminary research analysed about 500,000 speed records over a 21-week period at two intersections in Northern New Jersey to numerically and visually characterize the speed patterns through the COVID-19 progression. Although further research and statistical analysis is necessary to evaluate the data as it relates to the New Jersey State pandemic and emergency management policies, the preliminary results indicate school closures and the stay-at-home order have significantly impacted normal traffic and thus present a unique research opportunity to study baseline, non-congested conditions.

Keywords: roads & highways, traffic management, infrastructure planning, COVID-19, travel speed

1. INTRODUCTION

Under the Operations Performance Measurement Program [*1*] of the United States Department of Transportation (USDOT), federal, state, and local agencies have been increasingly using the National Performance Management Research Data Set (NPMRDS) to evaluate road performance as well as external factors that impact roadway performance [*2*]. Probe Vehicle Data (PVD), which is part of the NPMRDS, has been applied to the development of a number of visually intuitive, quantifiable performance measures [*3, 4, 5,* 6, *7*]. Other studies have incorporated PVD into congestion performance indices used in national reports [*8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18*]. This research applies a baseline performance metric and visualization technique to quantify the Coronavirus (COVID-19) pandemic's impact on traffic operations and verify the decrease in speed variability near signalized intersections. The pandemic resulted in the closure of New Jersey State schools and offices on March 18, 2020 [*19*] followed soon after by a stay at home order starting March 21, 2020 [*20*]. The response to these closures was expected to decrease traffic congestion and speed variability, thus providing a unique opportunity to evaluate signal performance under non-congested conditions. Without traffic volumes at the study sites, the variations in speed provide the only means to characterize how traffic is moving through the system and can be used as a means to understand congestion conditions immediately following an unplanned, sustained emergency event. Preliminary results defined by Rick Schuman of INRIX [*21*], indicate that personal travel in NJ is down by 36% between March 1 and May 29, the second highest decrease for all states, with a peak reduction of 60%.

This study entails the aggregation of approximately 495,208 speed records for analysis. The visual analysis defined in this paper provides a way to chronical evolving disruption and eventual return to normalcy in traffic patterns resulting from a sustained event. This research is conducted in preparation for a more in-depth state-wide analysis requiring the development of additional performance metrics evaluating billions of speed records against the baseline COVID-19 conditions.

2. DATA AND TEST BED

The evaluation of anonymous probe vehicle speed data requires a cross-reference between spatially defined Traffic Message Channels (TMC) and temporal speed datasets collected in one minute increments. The speed data associated with each TMC was provided by a commercial provider and available on the Regional Integrated Transportation Information System (RITIS) website [*22*]. Two study sites, US Route 9 and Schanck Road, and US Route 22 and Rock Avenue (Figure 1) were used to evaluate the main approach speed data over a 150-day study period starting January 1, 2020. In Figure 1, the TMC distances as well as the proximity to the study sites are shown. For this paper the time prior to the start of March 18, 2020 is referred to as Before-COVID (BC) and time after as During-COVID (DC).

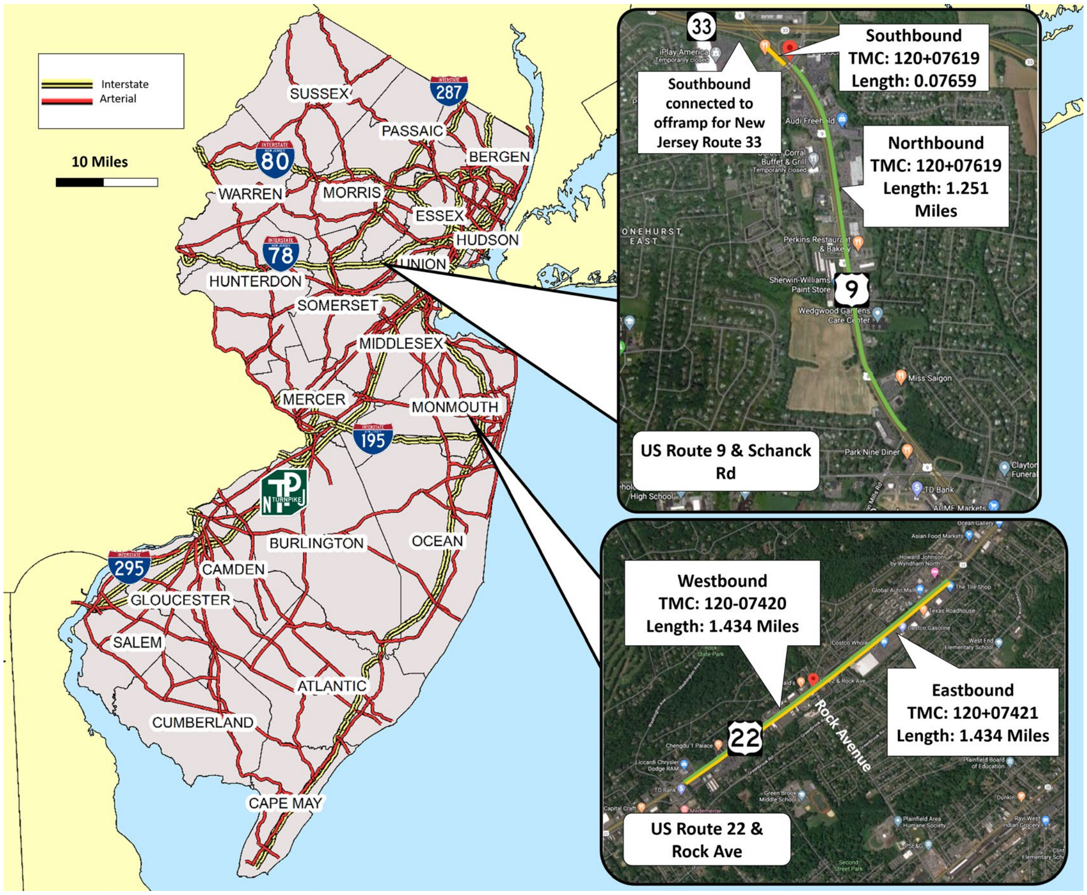


Figure 1. United States Route 9 and Route 22 study sites

3. MEASURES OF CONGESTION

Previous research using commercially available PVD had aggregated the data in 15-minute bins [*13*]. As part of the current research, three different bin sizes were compared to determine if a more granular data aggregation was necessary. The average speed for each TMC was determined by calculating the average speed of all available data in 15-, 10-, and 1-minute bins. The average speed (AvgSpeed) for each bin is calculated using the following:

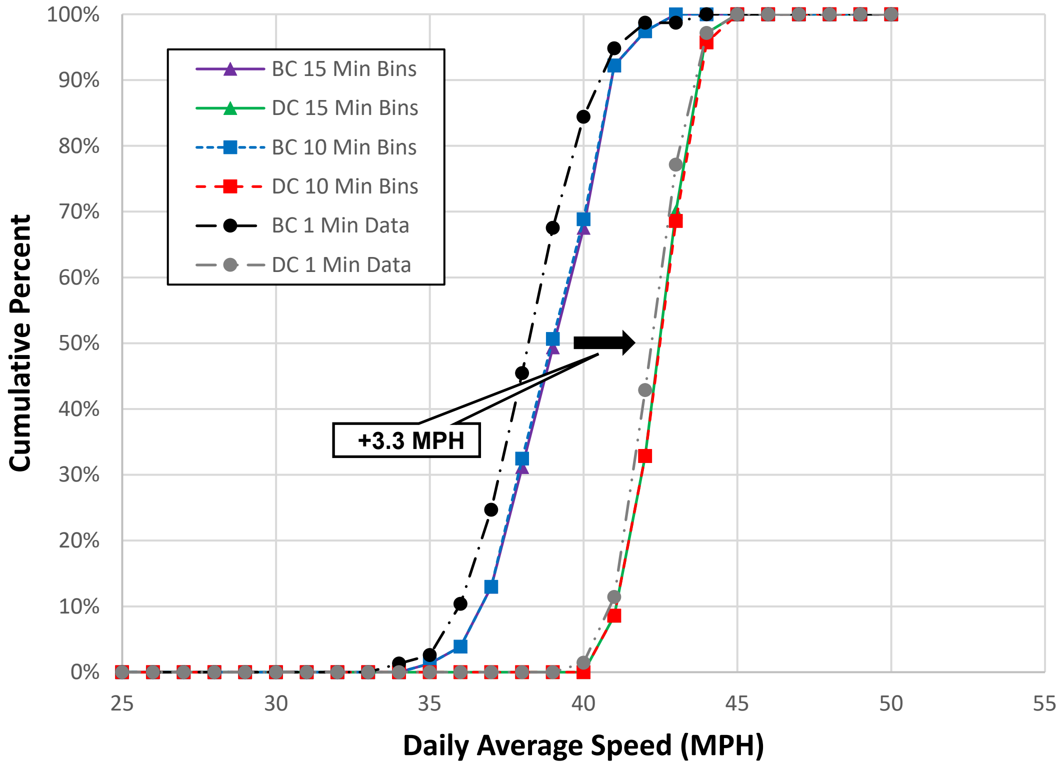
$$AvgSpeed_i = \frac{1}{n_j} \sum_{j \in F} v_{ij} \tag{1}$$

Where,

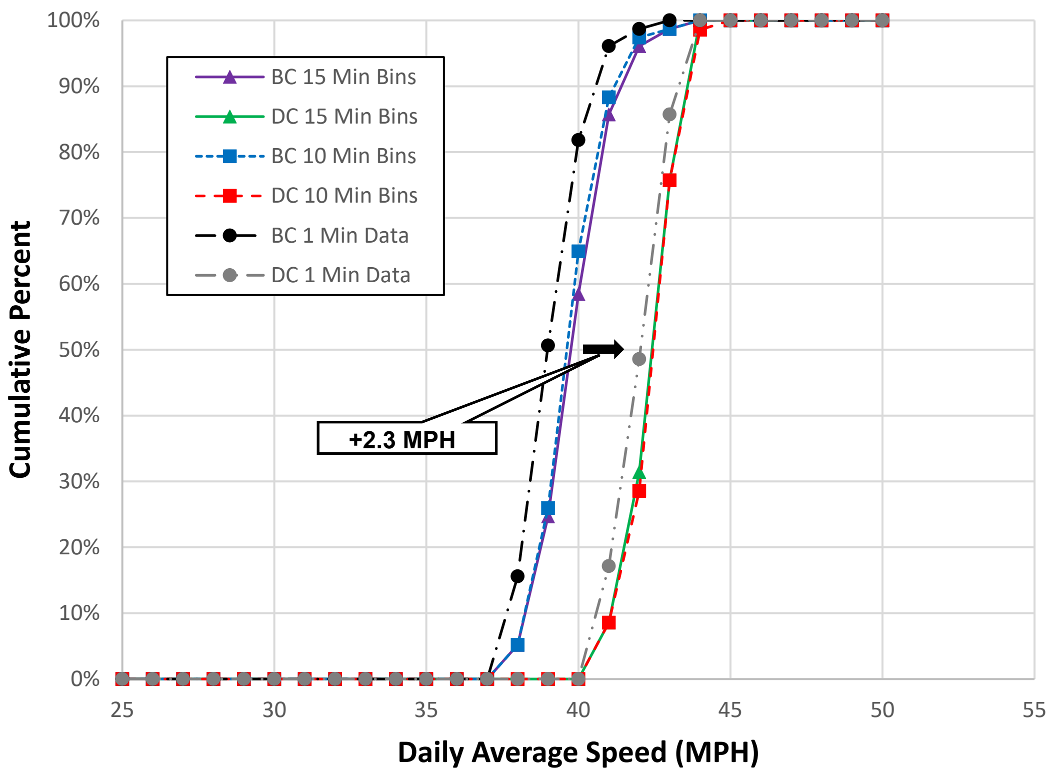
AvgSpeed is the average speed threshold for TMC i; v_{ij} are speed records for TMC i for the respective interval j; n_j is the total count of the binned intervals within study interval F, which is defined as all the bin periods (96 for 15-minute bins, 144 for 10-minute, and 1,440 for the raw 1-minute data) for each day of the study period. Only commercially available INRIX data with a high confidence score of 30 and a greater than 85% probability of reflecting current traffic conditions was used [*22*].

3.1 Comparison of Bin Sizes

A visual analysis of the cumulative distribution function (CDF) for all data collected is shown in Figure 2 and Figure 3. The figures illustrate the average BC and DC speeds for the 15-, 10-, and 1-minute bins. It is noted that no commercial data was available between March 28, 2020 through April 1, 2020. The CDF BC and DC median shifts for all the speed bins are reflected in the figures. Although all the shifts are relatively similar, the biggest shift occurred in Figure 3b, where southbound velocity increased by around 4 mph DC. It is also noted that the low average speed at this intersection is most likely due to the proximity to an off ramp from State Route 33. Although further research is needed to statistically evaluate different bin sizes, peak travel times, and the eventual return of the expected speeds, a simple analysis of the speed data appears to show that the three bin sizes provide similar results. In all cases there is an increase in speed, a result of COVID-19. A day-by-day breakdown of the data is shown in Figure 4 and Figure 5, where similar shifts in average speed can be seen for all direction in US-22 and US-9. Baseline speeds for these figures can be found in Table 1 and Table 2, where high variance can be seen in US-9 southbound. This may because of its short length, and connection to an offramp from NJ-33.

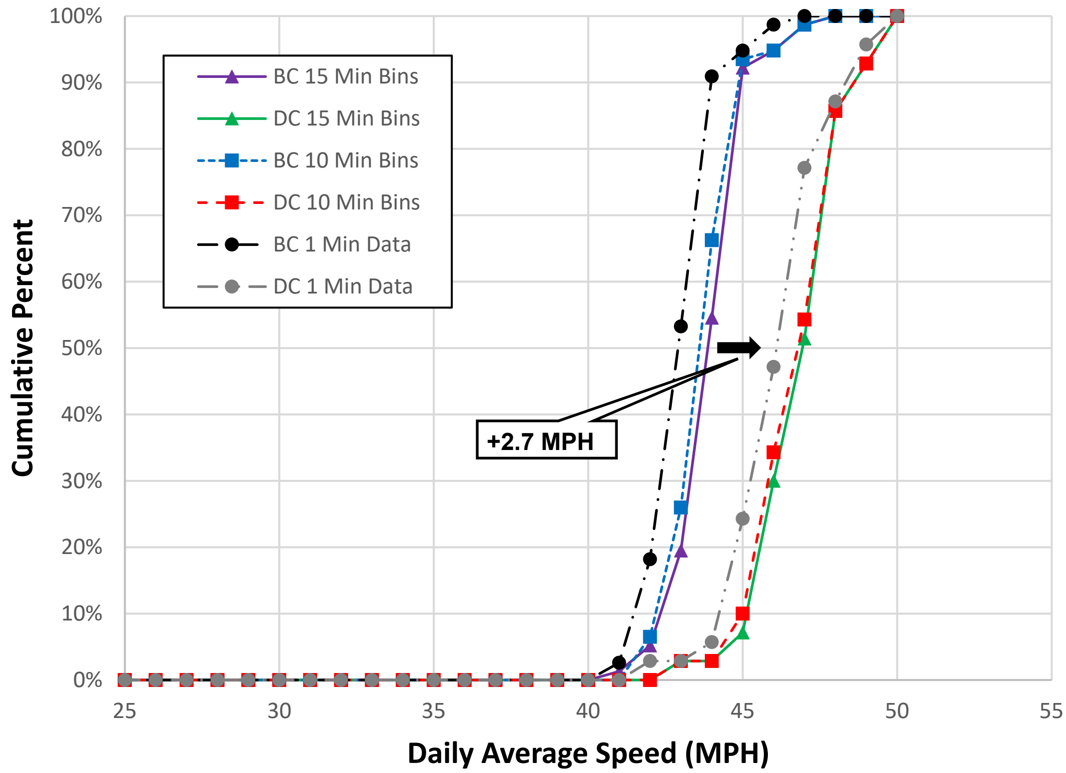


a. Eastbound

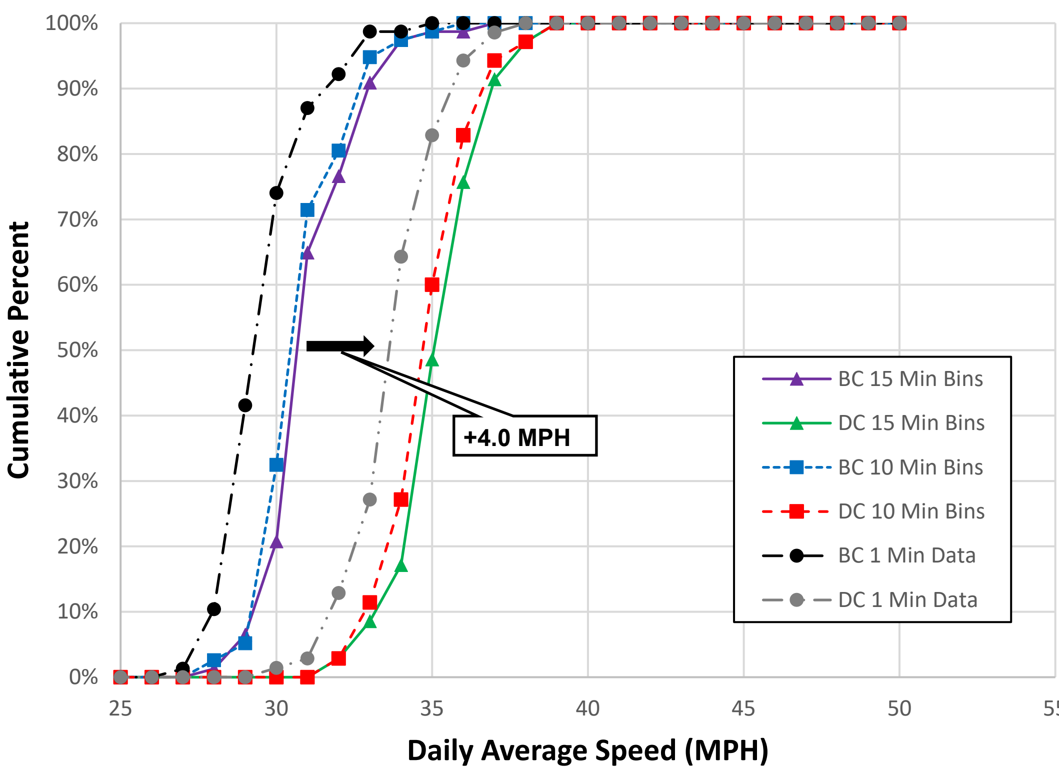


b. Westbound

Figure 2. US-22, Speeds for Varying Bin Sizes Before and After March 18, 2020 (Posted Speed 50 MPH)

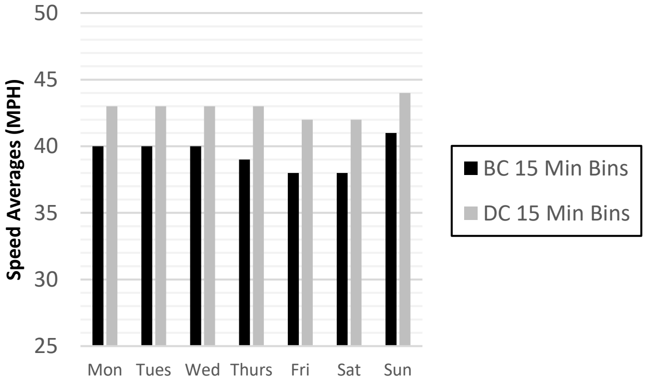


a. **Northbound**

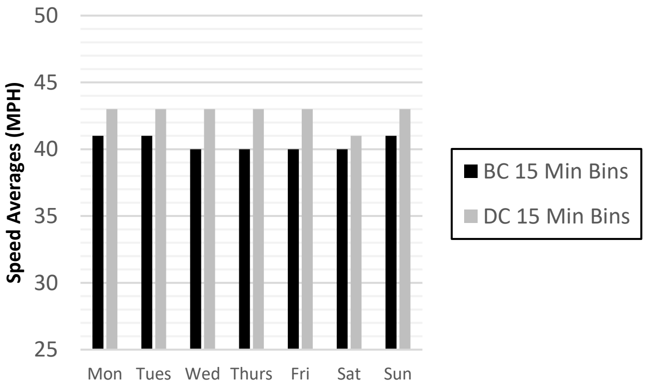


b. **Southbound**

Figure 3. US-9, Speeds for Varying Bin Sizes Before and After March 18, 2020 (Posted Speed 50 MPH)

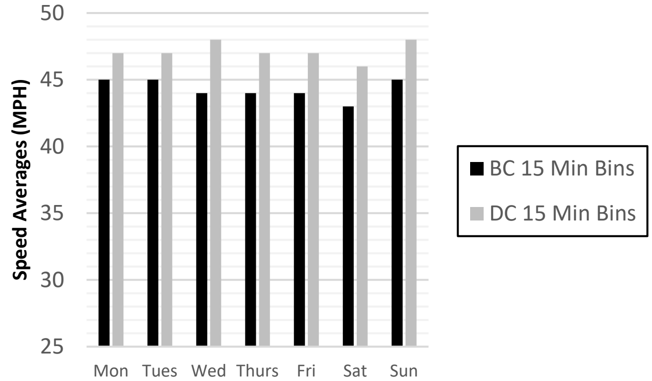


a. Eastbound

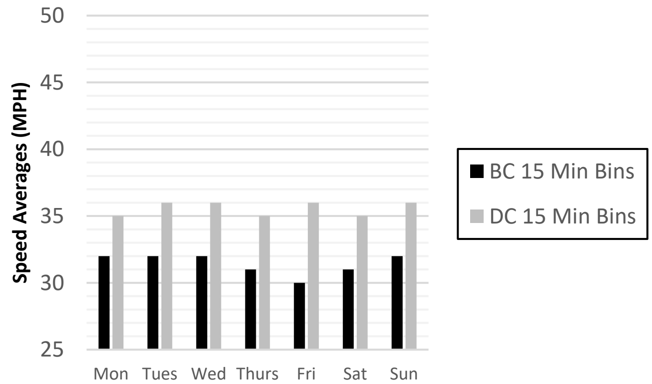


b. Westbound

Figure 4. Average Daily 15-Minute Speeds BC, DC for US Route 22 Intersection



a. Northbound



b. Southbound

Figure 5. Average Daily 15-Minute Speeds BC, DC for US Route 9 Intersection

Table 1. Before Covid Closings Weekday (Mon-Fri) Statistics Based on 1 Min. Data

Road/Direction	Avg(MPH)	Variance	St Dev.
US22 Eastbound	38.6	35.6	6.0
US22 Westbound	39.5	31.7	5.6
US9 Northbound	43.5	25.3	5.0
US9 Southbound	29.8	93.9	9.7

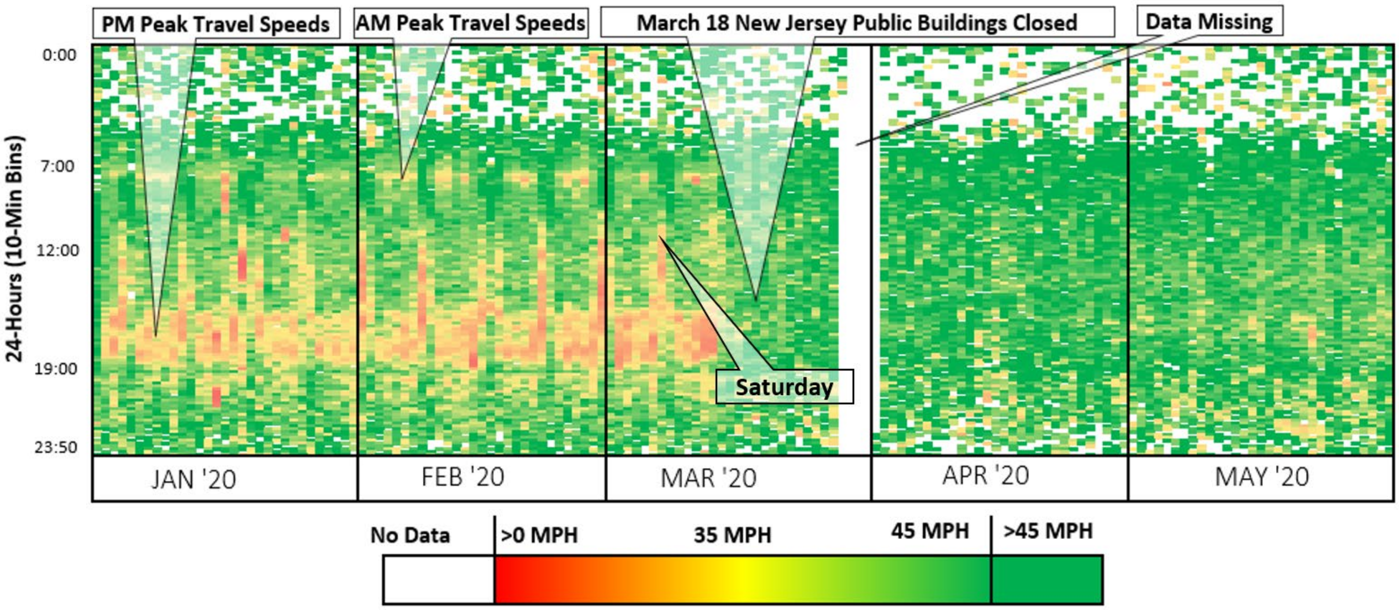
Table 2. During Covid Closings Weekday (Mon-Fri) Statistics Based on 1 Min. Data

Road/Direction	Avg(MPH)	Variance	St Dev.
US22 Eastbound	42.6	17.3	4.2
US22 Westbound	42.7	24.5	4.9
US9 Northbound	46.6	30.9	5.6
US9 Southbound	33.9	120.8	11.0

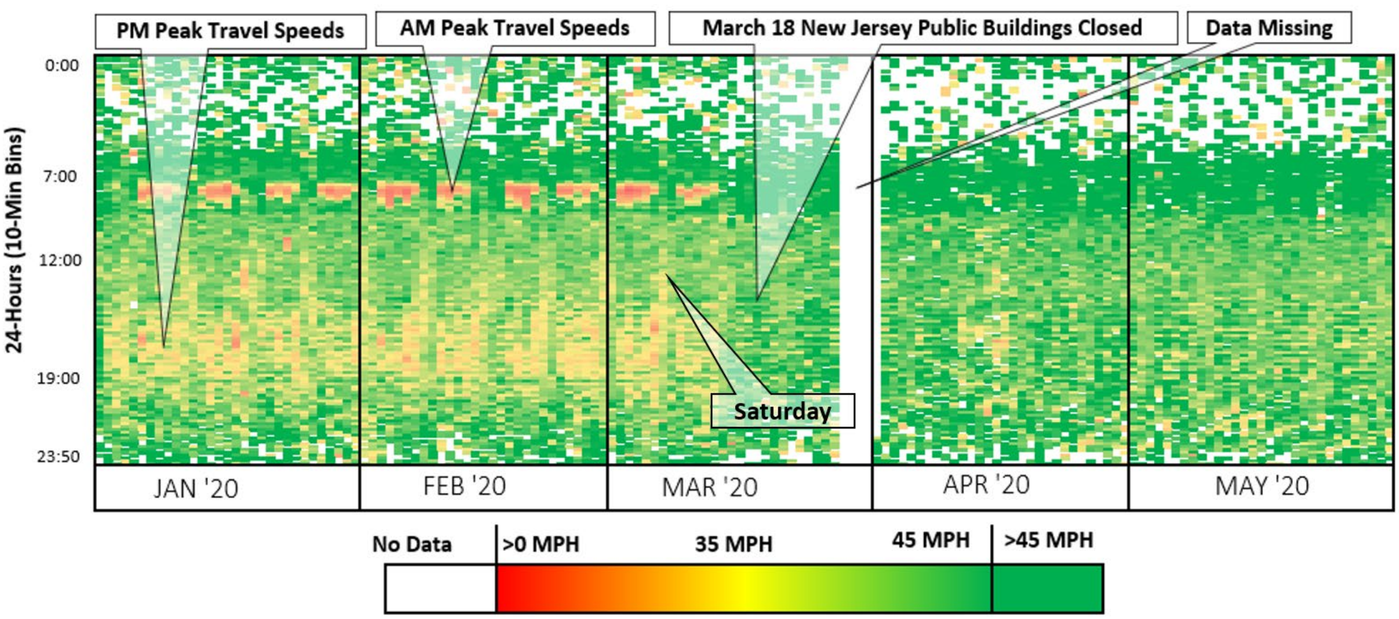
3.2 Average Speed Visualized

The US-22 study site was used to illustrate the juxtaposed average speeds per day in a heat map type format. For the eastbound and northbound approaches for US-22, both the 10-minute (Figure 6) and 15-minute (Figure 7) bins were used, where the y-axis is the respective bin period and the x-axis is the day of the year. Each cell reflects the AvgSpeed for their bin, which is used to characterize the speed near the intersection. These heat maps present a visualization of steady patterns, and deviations from those patterns. Traffic speed deviations emerge slightly earlier then March 18, beginning around Monday March 16. This may be due to the order going out March 16 [*19*]. In the figures, the transition from BC and DC is readily apparent. Also apparent are the BC AM and PM Peak times, weekend travel BC as well as the absence of both AM and PM Peak times DC. When comparing the two bin sizes, Figure 6 and Figure 7, it is apparent that there is not an immediately recognizable difference between the two.

The variance in speeds for BC and DC in Table 1 and Table 2, are visually represented in Figure 7 and Figure 8. For US22 the varience decreases as speeds become consistently faster, but with minimal peaks. US9 however sees its variances increase DC. This is apparent southbound, where peak travel times appear twice, once at 1300 and again at 2000, as compared to the more continuous flow BC. For US9 northbound the peak during the 1300 is more abrupt, as compared to BC when the congestion occurred throughout the day. It was expected that both intersections would have a decrease in varience, with a smoother flow. What was interesting about US9 is that the varience increased because the congestion that normally appears throughout the day became more confined to traditional peak times.

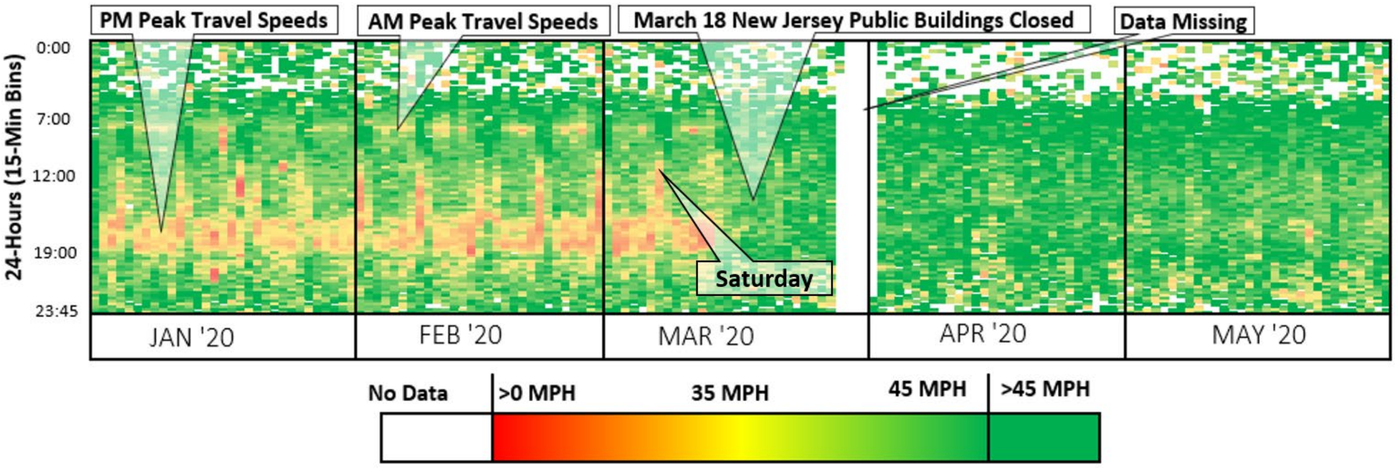


a. Eastbound

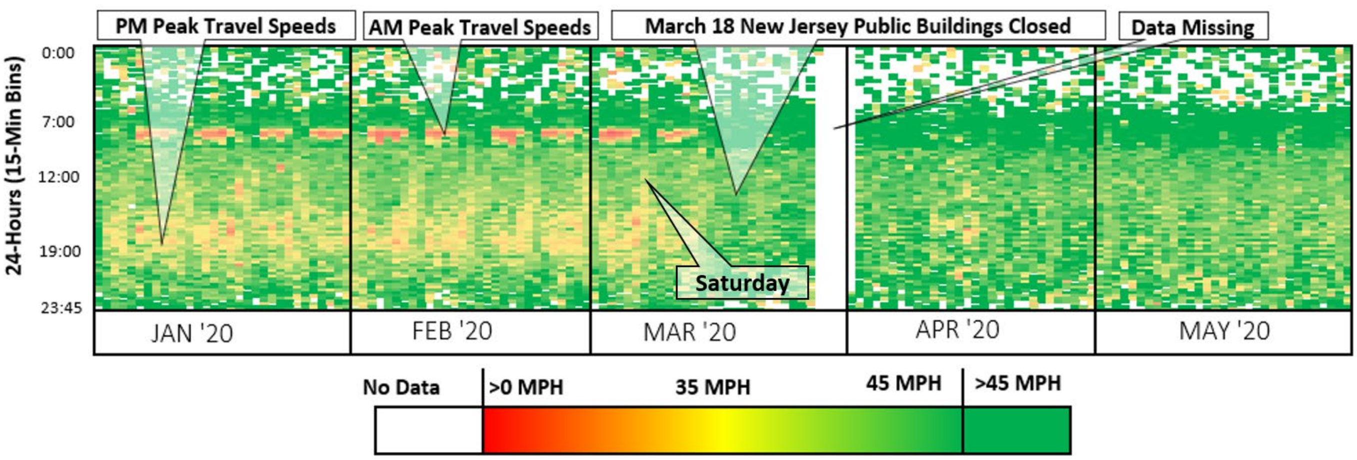


b. Westbound

Figure 6. 10-minute Bin Speed Distribution for US-22, 2020



a. Eastbound



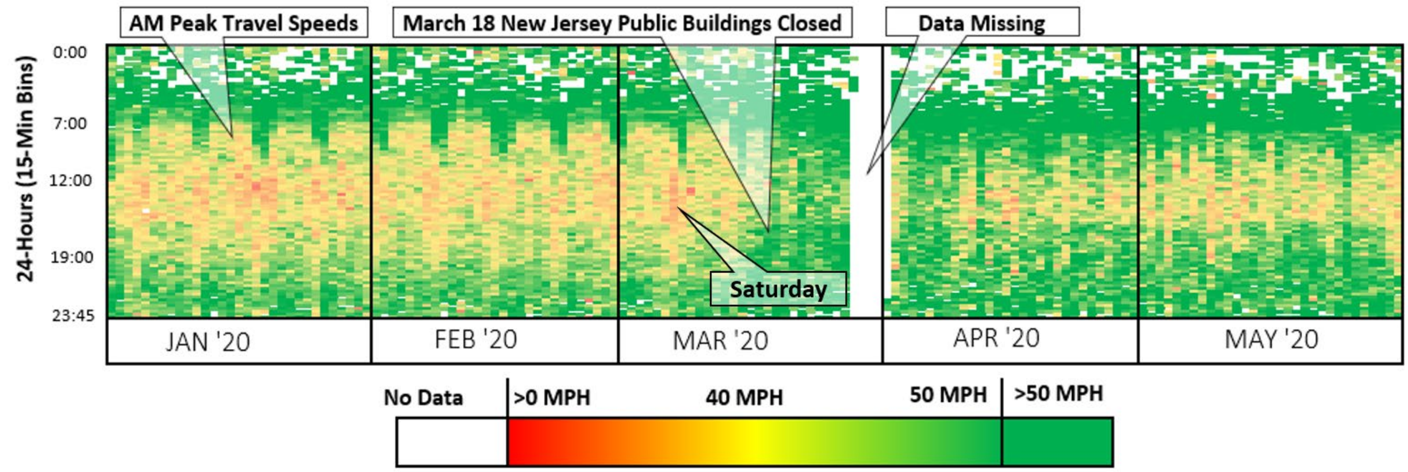
b. Westbound

Figure 7. 15-minute Bin Speed Distribution for US-22, 2020

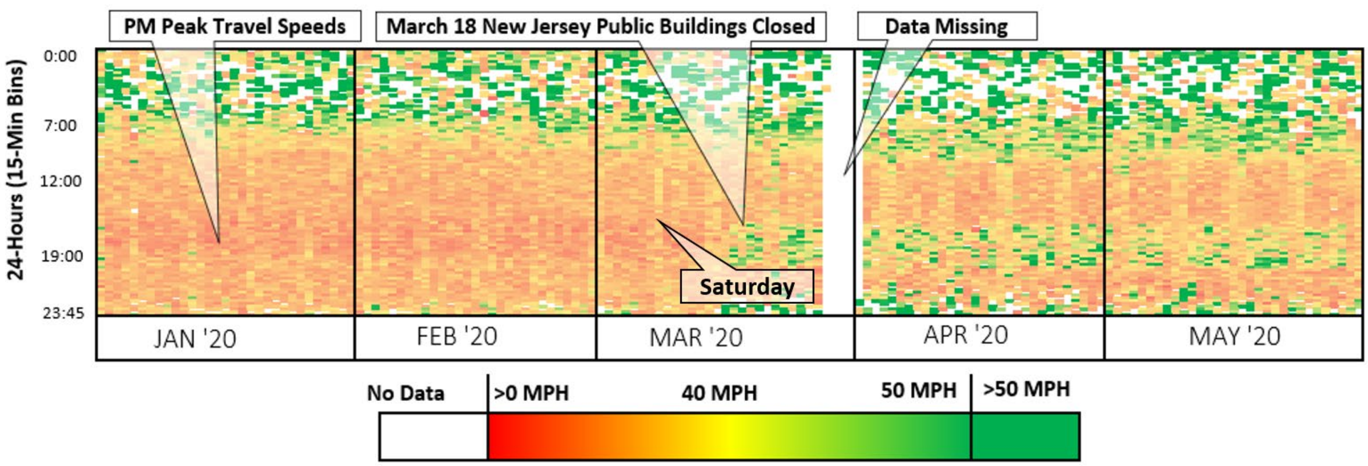
4. CONCLUSIONS

Due to the COVID-19 pandemic, a New Jersey executive order was made on March 16, 2020 to close schools starting March 18, 2020. This study was developed as a preliminary evaluation to determine how much of an impact this pandemic has on travel speeds, and speed variations through the use of visualizations and varying bin sizes. Ultimately this research will be expanded state-wide with more evolved performance metrics, but for this paper changes in average travel speed is measured at two intersections, US Route 22 and Rock Avenue, and US Route 9 and Schanck Road. The results of the analysis showed that there was definitive changes in travel speeds whose increase ranged from 2.3 to 4.0 MPH. A cumulative distribution frequency diagram demonstrated that the three different average speed bins (15-, 10-, and 1-minute) were relatively close, confirming that either the 15- or 10-minute bin would adequately characterize traffic speeds. Additional analysis indicated a decrease in speed variance for US Route 22, and an increase for US Route 9. It was expected that both intersections would have a decrease in variance, thus indicating smoother flow. For US 22, after reviewing the heatmap it became apparent that US 22 had defined peak travel times BC, which were gone DC. However, US 9 had a single Peak Travel time BC, but in DC it had two peak travel times, an indication that although traffic got less congested, the improvement of the traffic flow caused more variance in speed.

Based on these preliminary results, it appears that COVID-19 has had a significant impact on the motoring public of New Jersey. This was not unexpected. However, the unfortunate pandemic has presented a unique opportunity to study traffic patterns under smoother traffic flows under non-congested, at least partially non-congested conditions. The results support the need to extend this research across the region to better understand how the traffic system responded not only to the shut down, but to the eventual recovery. This data can also be used to better understand the traffic signalization and how retiming might improve traffic flow. Further research is underway to quantify the pandemic's disruption of state traffic patterns, tolling, and recovery process, as well as evaluating how to incorporate similar data revolving around COVID-19 [*23*].



a. Northbound



b. Southbound

Figure 8. 15-minute Bin Speed Distribution for US-9, 2020

5. ACKNOWLEDGMENTS

The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the sponsoring organizations. These contents do not constitute a standard, specification, or regulation. The speed data and segment information used in this report was obtained from INRIX Inc.

The authors confirm contribution to all parts of the paper. All authors reviewed the results and approved the final version of the manuscript.

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