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A Comparative Analysis of Arterial Characteristics to Evaluate Potential Lane Reduction

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ABSTRACT

Major roadways across the United States (US) have spurred commercial, retail, industrial, and residential developments along their routes. These roadways have been constructed as a reliable means to link cities and towns. Over the years, towns centers and residential housing have developed along these routes changing the characteristics from a roadway that provides mobility into a roadway that provides accessibility to the local population. Consequently, the roadway infrastructure has not always evolved to meet the demands of the population living closest to the road, instead serving others located outside the town. Road diets, or lane reductions, have been introduced to help mitigate crash incidents, while creating a corridor that can provide greater accessibility to pedestrians and bicyclists. This research compares the characteristics of two parallel corridors, 4-lane Route 31 (NJ-31) and 2-lane Route 206 (US-206), located in Mercer County, New Jersey (NJ), US. Both roads traverse residential areas and are in close proximity to a college campus. NJ-31 has the potential to be reduced from 4-lanes to 2-lanes, but information is needed to support this reduction. An analysis of the two corridors including crashes, congestion, volume, demographics, and entrance types are quantified and compared. Although similar in traffic volume, the NJ-31 experiences a higher rate of traffic crashes per mile, while US-206 experiences more congestion. This research demonstrates a foundation in establishing metrics to determine long term impacts of a dieted roadway, and to quantify an increase of congestion as compared to a reduction in crash incidents.

Keywords: traffic calming, pedestrian access, lane reduction

1. BACKGROUND INFO

The U.S. Department of Transportation (US DOT) has put forth an ambitions Equity Action Plan [1] for building a transportation system that works for all people, with equity and safety as one of the 2022-2026 Strategic Goals [2]. There have been several initiatives like Complete Streets and LEED Neighborhoods that have promoted alternative designs. 'Safe Routes to School' [3] is another initiative that promotes studies concerning children's safety and health as well as the broader impact of walking and biking to school. Transit Oriented Development (TOD) is another example to foster livable and walkable communities with mixed land use development in conjunction with connectivity to transit systems [4],[5]. While the impacts of all these initiatives are reviewed in the context of making roadway improvements to ultimately improve a neighborhood, the greater understanding of the potential impacts are still not fully assessed as part of the roadway system enhancement.

Despite the development of several guidelines by federal and State DOTs for the safe implementation of complete street type initiatives, there remains ample legal, technological, socioeconomic, and political issues to be resolved. This study aims to compare and characterize some of the variables to be considered when evaluating the need for a roadway lane reduction, also known as a road diet, that supports long term planning goals at the local level. With certain agencies dominating the decision process, it is important to identify variables that support the need for a road diet, that will allow a road to evolve from a roadway that predominately provides mobility into a street that provides access and supports the community while improving safety. By utilizing the infrastructure in a manner that improves the community, the safety and socioeconomic vitality of the area, all parts of infrastructure can be systematically improved.

Probe vehicle speed data is a way to quantifying congestion along arterial roads. Once quantified, it can be used to compare congestion to transportation equity measures, crash incidents, and local demographics. Predefined spatially located roadway segments known as traffic message channels (TMCs) are linked to commercially available, temporal anonymous probe vehicle speed data. The availability of speed data for a specific segment or time is based on the presence of a telemetrically tracked vehicle being observed over the length of the TMC segment during a specific time period. In New Jersey alone there are over 16,000 TMCs. For this study, congestion data is one data set used to compare two roadway segments in Ewing Township, New Jersey.

2. STUDY SITE

This research was conducted on two arterial roadways located in Mercer County, NJ, close to the I-295 corridor. Route 31 (NJ-31) is a 4-lane state highway that traverses north to south along the western portion of New Jersey. The portion of NJ-31 (Figure 1) within the study site includes the segment that runs from North Olden Avenue to the intersection of Ewingville Road and Upper Ferry Road which is comprised for a TMC in each direction. It directly passes the campus of The College of New Jersey (TCNJ) in Ewing Township. There are currently 6,790 full-time enrolled students at TCNJ, of which 54% live in off-campus housing who must commute to school via personal or public transportation methods [6]. The current posted speed limit along the study area of NJ-31 is 40 mph, essentially bisecting Ewing Township disconnecting the local neighborhoods.

The second roadway in the study area is US Route 206 (US-206), which is a major route that also runs in the north and south directions (Figure 1). The segment of US-206 defined in the study area is located between the intersection of Eggert Crossing Road and the I-295 interchange. The segment is two lanes with a posted speed limit of 35 mph and is adjacent to Rider University, a private university with a total undergraduate enrollment of 3,200 students [7]. According to the U.S. Census Bureau data, the two selected sites demonstrate contrasting socioeconomic features. For instance, the census tract that includes NJ-31 from the study site shows almost three times higher rate of economically disadvantaged population percent compared to the site close to US-206 [8]. In addition, the area surrounding Route 31 is classified as Historically Disadvantaged Community per USDOT Equitable Transportation Community Explorer [9]

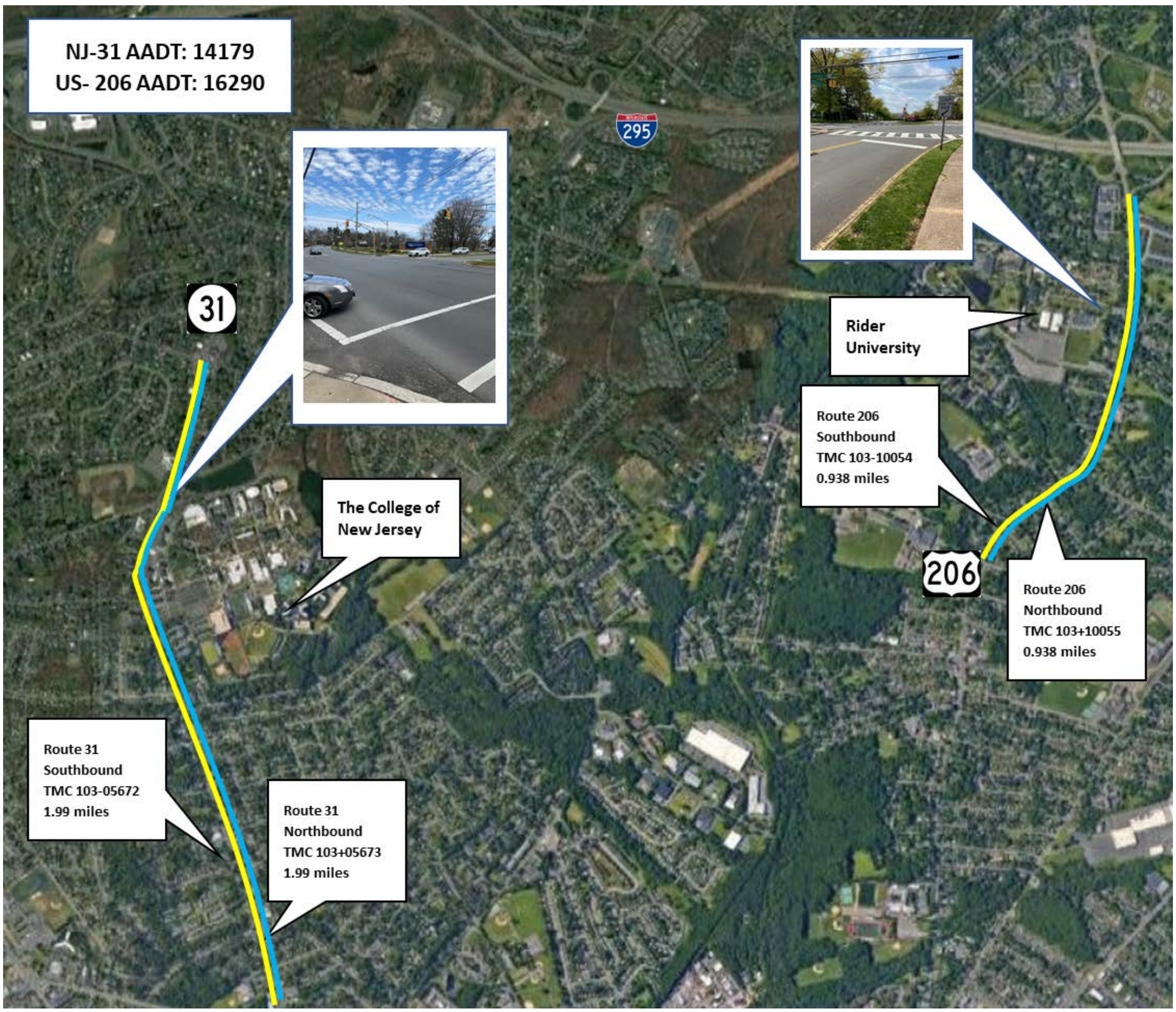

Figure 1. NJ Route 31 and United States Route 206 study sites.

3. DATA

Speed, crash, volume, and geometric data was used to characterize the two corridors. Commercially available Anonymous Probe Vehicle (APV) speeds associated with each TMC were obtained from the Regional Integrated Transportation Information System (RITIS) website [10] for the northbound and southbound directions of each of the study corridors. A little more than 142,000 APV speed samples were aggregated into 15-minute bins for the month of April 2022. This data was used to evaluate both the speed and traffic congestion along the corridors. Crash data was extracted and mapped with the NJDOT Safety Voyager [11] crash map tool to display the crashes and their corresponding locations along the study routes. In addition, the Average Annual Daily Traffic (AADT) was obtained from the NJDOT interactive traffic map where the latest count for NJ-31 [12] and US-206 [13] where used respectively in 2019 and 2013. The crash incidents along NJ-31 (Figure 2) and NJ-206 (Figure 3) indicate that there are areas along the route that incur more incidents than others, with a total of 294 incidents along NJ-31 and 63 along US-206.

The fixed entities per mile data summation is shown in Table 1, where the number of each fixed entity (e.g. pedestrians crossings) is normalized based on the number of miles for each corridor. In general, the two corridors appear to be similar, with some noted exceptions. NJ-31 has a greater number of residential and commercial entrances per mile, and while the AADT along NJ-31 is lower than US-206, the number of crashes per AADT is 2.5 greater along NJ-31 despite the lower volume.

Table 1. Entrances on NJ Route 31 and US Route 206

Fixed Entities Per Mile	Route 31	Route 206
Pedestrian Crossing	12.0	7.1
Intersecting Roads	14.5	12.2
Residential Driveways	49.7	34.6
Commercial Entrances	9.5	2.0
School Entrances	2.0	3.0
Church Entrances	1.5	1.0
Crashes	147.5	64.0
AADT	14179	16290
crash/AADT	0.0104	0.0039
Lanes	4	2

Figure 2. NJ Rt. 31 Crash Data for 2018-2021

Figure 3. US-206 Crash Data for 2018-2021

The crash data was collected for the years 2018-2021 for each roadway. On Route 31, the peak crashes occurred at the southern intersection with North Olden Avenue and the Northern intersection with Upper Ferry Road. There were also above average crashes at the entrance of TCNJ. At Route 206, a crash peak of 18 occurred at mile marker 47.8, which is located at the entrance to Rider University. When crash severity was reviewed, NJ-31 shows 1 fatal and 5 serious injury crashes while no fatal nor serious injury crash was observed along US-206. For the Minor injury crash level, still NJ-31 shows higher rate compared to that of US-206 for the same time-period.

The speed data for all four road segments are displayed in **Error! Reference source not found.**. From the comparison of speeds over the month of April, there was little difference between the posted and actual speeds at the 85th Percentile, where the speeds are about 37.5 mph. This indicates that both roads have about the same speeds in each direction throughout the day. It is noted that although the speeds are similar, US-206 was found to have higher AADT with less travel lanes when compared to SR-31.

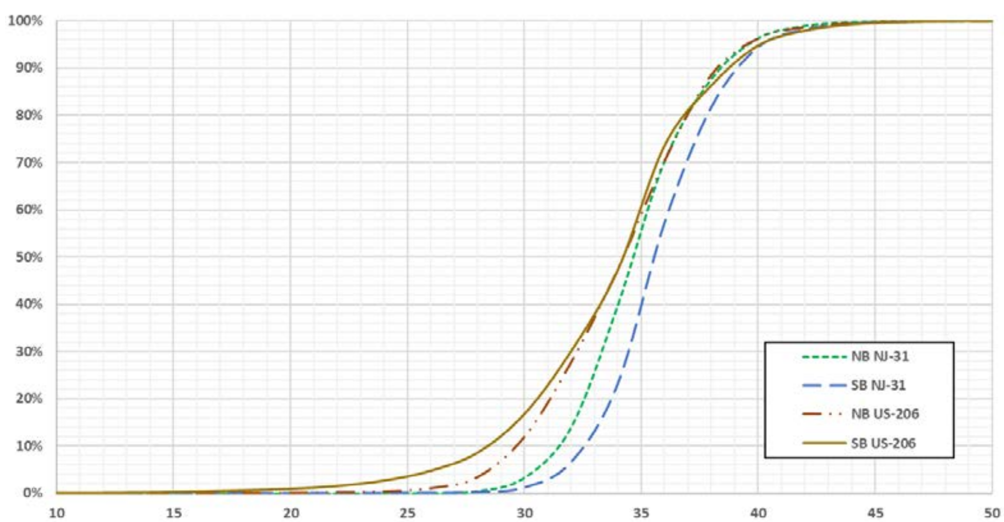

Figure 4. NJ Route 31 and US Route 206 Speed Data, April 2022.

4. MEASURES OF CONGESTION

Previous research using commercially available APV had aggregated the data in 15-minute bins [14],[15], and the same application was made in this paper where the average speed for each Traffic Message Channel (TMC) was determined by calculating the average speed of all available data in 15-minute bins. The average speed (AvgSpeed) for each bin is calculated using the following:

$$AvgSpeed_i = \frac{1}{n_j}\sum_{j \in F} v_{ij} \qquad (1)$$

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) 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 [15].

The same AvgSpeed formula was applied to calculate the free flow speed (FFS) of the corridor, were the average speed during the hours of 0100 and 0600 to determine the free flow speed along the corridor.

Congestion Hours

The following equation characterizes the total number of congestion hours (CHs) for a segment along a corridor where the Space Mean Speed (SMS) falls under 28 mph during a 15-minute bin:

$$CH_s = 0.25 * \sum N_s\,;[\,v_s < 28\,mph], (3)$$

Where CH_s is simply the count of the 15-minute bins (N_s) for a particular segment 's', where SMS falls below 28 mph for the 15-minute analysis period. The 0.25 constant corresponds to the faction of hour that is analyzed (15-minute bins). This calculation can be used to compare segment congestion conditions and help identify "hot spots." By tabulating each interstate segment's accumulated congestion hours, a table or graphic can be constructed that characterizes the location and magnitude of congestion along a route. The 28-mph speed limit is an arbitrary number and other speeds can be selected by the user.

5. ROAD DIET COMPARISON METRIC

A straightforward measure was put together to assess if a roadway might be good candidate for a road diet. For this study only two roads were compared, but in the future a collection of completed road diets along with potential roadways to compare will be conducted. For this measure it is assumed that the roadway carries less than 20,000 AADT, which per FHWA are good candidates for a lane reduction(s), [16]. Using the collected data, all crossings and entrances per mile are summed and multiplied by the number of crashes per AADT as show in the following formula:

$$RD_r = \frac{Crashes_r}{AADT_r}\sum PC_r + IR_r + RD_r + CE_r + SE_r + ChE_r \qquad (2)$$

Where,

RDr is the Road Diet Metric for road *r;* when comparing the two roadways a higher RDr will indicate a better candidate to make changes that improve the corridor. PC_r is the number of pedestrian crossing per mile, IR_r is the number of intersecting roads, RD_r is the number of residential driveways, CE_r is the number of commercial entrances, SE_r is the number of school entrances, and ChE_r is the number of church entrances. It is noted that the building sizes and number of parking spaces will impact these values, but for this initial study the specific buildings are assumed to be similar in size.

All the necessary geometric information can be readily gathered from an aerial map. A higher *RD* number, when compared to a similar roadway will give a measure on how the two relate to each other based on Equation 2. Speed is not accounted for, because even at high speed there may be many crossing and entrances. For this study SR-31 was found to have an RD of 1.88 compared to US-206 which had an RD of 0.23. These numbers will require further analysis, but for this study they indicate a higher value for SR-31.

6. CONGESTION RESULTS

The speed data collected is meant to begin a method to quantify differences between the two roads, and how might a road diet might perform on SR-31 as compared to the existing US-206 corridor. For both roads, a congestion measure was applied to determine roadway performance throughout the date. Any road is considered to be congested for any 15-minute interval, independent of posted speed, when the average 15-minute SMS fell below 28 mph. Therefore, for speeds lower than 28 mph, an aggregated number of 15-minute bins found to be congested was converted to hours. The total congestion hours for the month of April are pictured in Figure 5. For US-206, the road was congested about 15% of the time, while for SR-31 that number is 3%. This was calculated by taking the total number of hours of congested and dividing it by the total hours in April. Following that procedure, the congestion was then organized by the days of the week, allowing for a closer analysis of how the two routes compare. The average NB and SB congestion by day is pictured in Figure 5, Figure 6 and Figure 7, and. The northbound and southbound congestion analysis showed higher average daily congestion on Route 206. US-206 has a great deal of congestion occurring in the southbound direction in the month of April (Figure 5), where vehicles exit from I-295. This would require further detail to determine causation, but for the rest of the direction the congestion seems relatively stable.

Equation 1

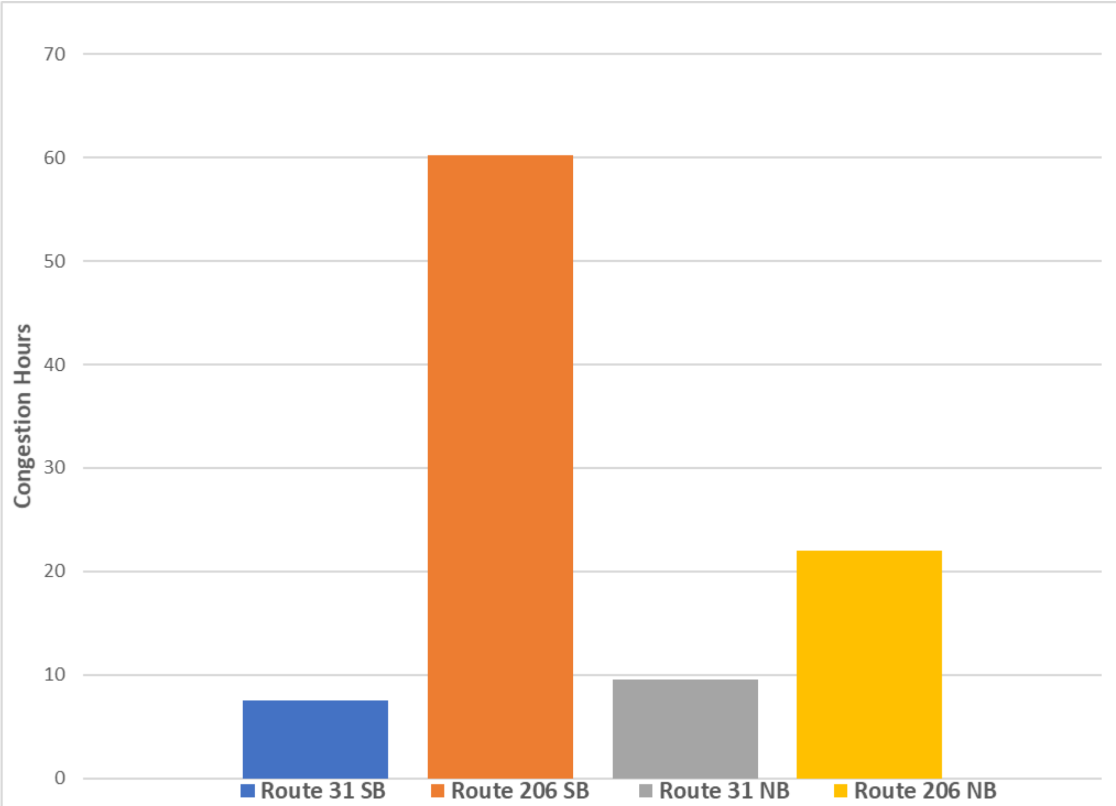

Figure 5. Aggregated Congestion Hours for each direction, April 2022

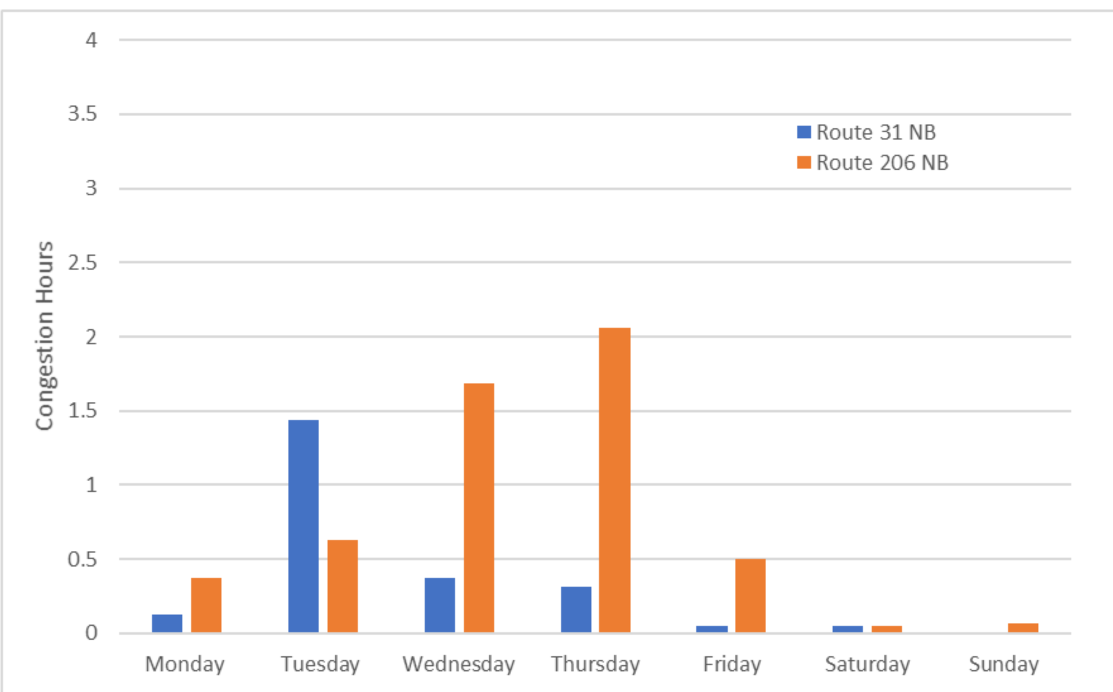

Figure 6. Aggregated Northbound Congestion Hours by day for each day in April 2022.

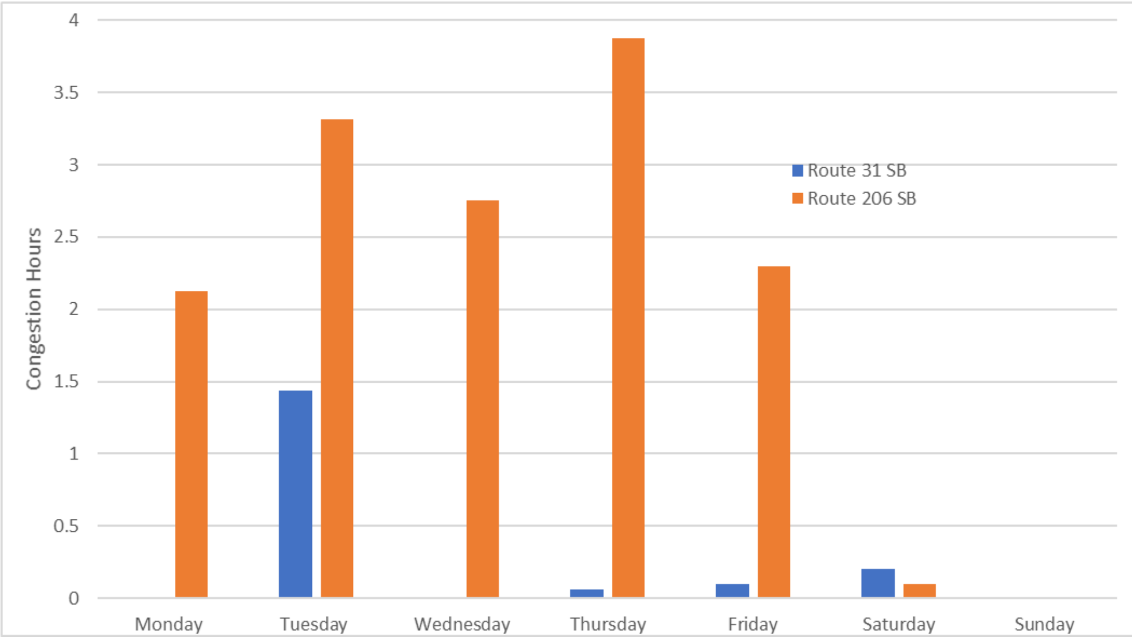

Figure 7. Aggregated Southbound Congestion Hours by day for each day in April, 2022.

7. CONCLUSIONS

Although the current posted speed limits of 35 and 40 mph on NJ Route 31 and US Route 202, respectively, are different, the two roads were found to converge at about the same speed for the 85th percentile, which was around 37.5 mph. This is below Route 31 posted speed and slightly above Route 206. When looking at the number of crashes as a function of the AADT, per Table 1, SR-31 experienced about 2.7 times more crashes per volume, and about 2.3 times the crashes per mile.

US-206 was found to incur more congestion (15% of the total month of April). This could be attributed to the 28-mph cutoff used in Equation 3, and further analysis will be conducted. But even with US-206 carrying more vehicles, SR-31 has more entrances, more intersections and more crossings per mile. A measure was proposed, RD that quantifies some of the geometrics, crashes, and AADT for a route. This metric is proposed for roadways under 20,000 AADT. For SR-37 the RD value was 1.88, while for US-206 that number was 0.23.

It appears that as a similar route to SR-31, US-206 functions well at the posted speed using 2-lanes and incurring fewer crash incidents. Although additional studies need to be conducted, SR-31 appears to be a good candidate for lane reduction to slow up traffic and potentially reduce the number of crashes. The question that needs to be answered is if this is a good trade off to reduce the posted speed, decrease the number of lanes, potentially reduce crash incidents, while providing greater access to the local population. Further research will need to review the frequency and availability of local transit in the area, as well as conduct survey of the local citizen, community leaders, and respective commercial, educational, and ecclesiastical entities.

8. 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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