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Evaluation of Traffic Crash Characteristics on Elevated Sections of Interstates in Louisiana

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13. Abstract
The research project aimed to analyze crash characteristics and identify common issues in selected major elevated interstate sections in Louisiana, including I-10 over the Atchafalaya Basin. Louisiana has several significant interstate sections elevated above land vegetation, roadways, and water bodies. The project utilized various approaches to analyze crash and speed data, identifying crash hotspots in eight elevated interstate sections with considerable camera coverage. The project specifically estimates truck lane restriction compliance rates on Atchafalaya Basin Bridge, the only site in Louisiana subjected to both truck lane restrictions and differential speed limits. A comprehensive analysis of 10,022 crashes from 2015-2020 on all eight sites revealed a collision distribution of 47% rear-end, 20% single-vehicle, and 16% sideswipe. Notable crash factors include crash hour (12 p.m. to 6 p.m.), drivers aged 25-64, and inattentiveness or distractions. Individual elevated section sites exhibited distinct crash characteristics, with rural sites having higher single-vehicle crash percentages and urban sites having higher rear-end crashes. Speed data analyses from the RITIS (Regional Integrated Transportation Information System) probe data platform revealed that speed limit violations were prevalent across nearly all analyzed elevated interstate sections, particularly on two longer sites with a 60 mph speed limit. ArcGIS-based crash hotspot analysis did not reveal a common pattern concerning roadway geometric characteristics. The Atchafalaya Basin Bridge had the highest percentage of hotspots with trucks as a crash factor (29%), and a notable 44% of hotspots were attributed to non-dry conditions. Speeding up to 10 mph above the PSL was observed at connected elevated segments due to a decrease in the speed limit from 70 mph at non-elevated segments. Speeding was lower in areas with sharp curvature or high AADT with merging/diverging vehicles. DeepMetrics (DPM) software and manual estimation were used to assess right-lane truck compliance on Atchafalaya Basin Bridge using video footage, revealing truck lane non-compliance at approximately 20%, with DPM estimates indicating compliance rates ranging from 77.1% to 82.3%.

Evaluation of Traffic Crash Characteristics on Elevated Sections of Interstates in Louisiana

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Implementation Statement

The hotspot analysis provides a list of segments with high-frequency crashes for the potential application of crash countermeasures using the prevalent crash characteristics. The results combining crash hotspots, degree of speeding, and truck percentage can also be utilized for strategic countermeasure development.

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Introduction

Interstates are playing an increasingly important role in traffic mobility in Louisiana, as the vehicle miles traveled (VMT) of the state's interstate system grew by 61% between 2000 and 2019—the second highest in the nation compared to other states [1]. Consequently, the state faces a considerable challenge to lower the frequency of crashes on the interstates. According to the National Highway Traffic Safety Administration (NHSTA) Fatality Analysis Reporting System (FARS) [2], an average of 32,044 fatal crashes occurred per year in the United States during 2009-2018, among which an average of 3,941 fatal crashes were on interstates. In 2019, 92 of the 727 fatalities on Louisiana roadways were on its 904 miles of interstates (1 fatality per 10 miles) [3]. Compared to 2019, the number of fatalities on Louisiana's roads grew by 14% in 2020, while the rise on the state's interstates was 23% [2].

Elevated sections of interstate highways carry high-speed traffic on non-expandable lanes and shoulder widths with inadequate clear zones for the safe recovery of vehicles that may leave the roadway. Adding to these constraints, unusual driving conditions such as foggy weather and icy pavement raise the crash risk of elevated interstate sections. Crashes in these sections not only affect individuals involved, but also result in heavy property damages that can be very costly to the state and federal governments. Due to limited accessibility on these long elevated sections (often limited to one or two entrance/exit locations along the bridge segment), even the more common no injury crashes could still be a key concern for incident response management.

Louisiana has several major interstate sections that are elevated above land vegetation, roadways, and water bodies (such as swamp basins and rivers). Among the several major elevated sections, the Atchafalaya Basin Bridge on I-10, connecting Baton Rouge and Lafayette, has been a special safety concern for decades in Louisiana. It is the only segment in Louisiana subjected to both truck lane restrictions (i.e., trucks use right lane only) and speed differential limits (55 mph for trucks and 60 mph for passenger cars) since September 2003 [4]. Since June 1997, the speed limit has been changed several times on this segment. First, it was increased from 55 mph to 70 mph in response to the National Maximum Speed Limit repeal. In August 1998, it was reduced from 70 mph to 60 mph. Finally, in September 2003, the speed limit for trucks was reduced to 55 mph along with the lane restriction.

With one of the aims to find how the regulations of reduced speed limits and lane restrictions affected safety, the latest LTRC sponsored study of 2012 (Final report 435) on the Atchafalaya Basin Bridge analyzed six years (before, 2000-2002 versus after, 2004-2006) of crash data [5]. Although those regulations were found to be unpopular among truck drivers, a decrease in the number of crashes, particularly truck crashes, was observed in the after period. Lane restriction compliance rates for trucks were in the range of 60% to 80%. However, according to recent data from over the past six years (2015-2020), the Atchafalaya Basin Bridge segment continued to experience a sporadically high number of crashes, with an average of 290 crashes occurring each year at a resulting crash rate of 81.7 per 100 million vehicle miles traveled (VMT).

To combat the high risk of crashes, the Atchafalaya Basin Bridge has been established as a highway safety corridor by Senate Bill 435/ ACT 426 [6]. The establishment of a highway safety corridor calls for the Louisiana Department of Transportation and Development (DOTD) to install additional signage on the Atchafalaya Basin Bridge, install camera safety devices to monitor vehicles traveling in excess of the posted speed limit, and issue warnings and citations. Implementation of such countermeasures can be strongly facilitated by understanding the crash characteristics, speeding pattern, and compliance with speed limits and truck lane restrictions.

Louisiana has several other major elevated sections on interstates with relatively common geometric characteristics. In order to fully comprehend the magnitude of the safety problems on elevated sections, it is important to explore the speeding and crash patterns along similar elevated segments.

Literature Review

This literature review was conducted to document the key relevant findings on the safety and speeding of elevated sections of interstates. Specifically, the review focused on the existing studies on elevated freeways in Louisiana and on elevated sections in jurisdictions beyond Louisiana. A review of studies on policies imposing truck lane restrictions and differential speed limits was also a key part of the review.

Prior Studies on Elevated Sections of Interstates in Louisiana

In 1994, a study on the traffic safety of the elevated section of Interstate-10 over the Atchafalaya Basin Bridge was performed by Harrell and Vankerkhove [7]. The study aimed to identify and analyze the contributing factors to the high crash rate on the bridge. Analyzed crash data from 1988 to 1994 revealed wet road surface conditions, unfamiliarity of the roadway, speeding, and following too closely were the main contributing factors that influenced the occurrence of high crash rate. Another relevant finding was that majority of the crashes that involved two vehicles or more were rear-end collisions. The speed limit on this section of the elevated freeway was reduced to 55 mph several years prior to the commencement of the study. The recommendations of the study included the use of warning signs and the increase in enforcement.

Later in 1997, after a sequence of fog-related crashes on the Interstate-10 Twin Span over Lake Pontchartrain, a committee was formed to propose cost-effective countermeasures for preventing similar future crashes [8]. The study scope covered fog-related crash analysis on the elevated sections of the I-10 Atchafalaya Basin Bridge, I-10 Bonnet Carre Spillway, I-10 New Orleans East Twin Spans, I-55 Manchac Swamp, and I-310 LaBranche Wetlands. The results indicated that 40 out of 2,485 reported crashes from 1991 to 1995 were identified to be fog-related involving run-off-roadway, pedestrian, and rear-end collisions. The three countermeasures recommended by the study are the use of detection systems, warning systems, and the implementation of positive guidance devices.

A further study, conducted in 1999, explored the crashes on the elevated sections of interstates in Louisiana including I-10 Atchafalaya Spillway, I-10 Bonnet Carre Spillway, I-10 New Orleans East Twin Span, I-55 Manchac Swamp, and I-310 LaBranche Wetlands [9]. In comparison to the statewide average, the crash rates for the elevated portions were found to be lower except for the I-10 over the Atchafalaya Spillway and the I-10 over the Bonnet Carre Spillway. However, the fatality rates on the I-55 over the Manchac Swamp and I-10 in New Orleans East were higher than the statewide average. Also, the majority of crashes were found to have occurred during wet weather conditions. Several recommendations by this study included the implementation of a temporal 60 mph speed limit, the use of dynamic speed limit signs, and an additional study on the use of the DSL and truck lane restriction policies on the elevated freeways.

To revisit the findings of the 1999 committee report, an updated crash data from 1997 to 2002 were analyzed in a 2003 supplementary study [10]. A traffic speed study was also conducted for the elevated section over the Atchafalaya Basin Bridge. The results from the crash analysis indicated that the overall crash rates for the elevated sections were equal to or lower than the statewide average except just prior to the implementation of the reduced speed limit in 1999. However, the fatality rate for the I-10 over the Atchafalaya Basin Bridge was higher as compared to the statewide average before the introduction of the reduced speed limit. Results from the traffic speed study showed that the 85th percentile speed ranged from 69 to 71 mph.

Korkut et al. examined the relationship between crash rate and traffic characteristics on the elevated sections of the Atchafalaya Basin Bridge on the I-10 in Louisiana following policies prohibiting trucks from using the left lane of the segment and imposing speed limits of 55 mph for trucks and 60 mph for cars [11]. The study developed regression models incorporating traffic characteristics such as degree of speeding between trucks and cars, speed variance, truck volume, and lane occupancy. Results from the analysis indicated that the crash rate increased when trucks breached the lane restriction policies. The study concluded that restricting trucks to the right lane with a truck speed limit of 55 mph and passenger car speed limit of 60 mph offered some safety benefits to the four-lane elevated rural interstate.

Ishak et al. investigated the traffic safety benefits of the differential speed limit and truck lane restriction policies on the I-10 over the Atchafalaya Basin Bridge in 2012 [5]. The operational policy restricted trucks to a speed limit of 55 mph and the use of the right lane only. The speeds of all other vehicles were limited to 60 mph with no lane restrictions imposed. The purpose of the study was to determine the traffic safety benefits of the operational policies as well as the compliance rate of trucks to the policies. Researchers collected three months of traffic data from the study section using the Remote Traffic Microwave Sensors. The traffic data was analyzed by using statistical techniques such as multiple linear regression, pairwise comparison, and a two-sample ttest. In addition, 12 years of data were used for a descriptive crash analysis and six years of crash data were used for a before-after study. Findings from the study indicated a truck lane restriction compliance rate of 60% to 80%. The presence of trucks substantially affected the traffic speed. Hence, a reduction in the traffic speed was observed as the volume of trucks increased. The safety analysis results identified a reduction in the total number of crashes and truck crashes after the implementation of the operational policies. The study did not attribute the reduction in crashes to the operational policies only but also to the improvements made to the study section such as shot abrasion and raised pavement markers. Table 1 summarizes the findings of the studies that have been conducted on the elevated sections of the interstates in Louisiana.

Table 1. Scope and key outcomes of existing studies on the elevated interstate sections in Louisiana

No.	Reference	Study	Outcomes	Operational policy studies	Safety analysis
[7]	Harrell and Vankerkhove, 1994	Traffic safety study	Recommendations to improve traffic safety on the I-10 Atchafalaya Basin Bridge.	Not available	Available
[8]	DOTD committee, 1997	Evaluation of fog-related crashes on Louisiana's elevated freeways	Three cost-effective recommendations were proposed by the committee to counteract fog-related crashes.	Not available	Available
[9]	DOTD committee, 1999	Analysis of crashes on elevated freeways	Recommendations on how to improve the safety of Louisiana's elevated freeways.	Not available	Available
[10]	DOTD committee, 2003	Supplemental study of the 1999 committee report	Review of the recommendations in the 1999 report	Not available	Available
[11]	Korkut et al., 2010	Examined the link between crash rate and traffic characteristics of the Atchafalaya Basin Bridge	The lane restrictions offered some safety benefits to the elevated rural interstate.	Available	Available
[5]	Ishak et al. 2012	Assessment of operational policy benefits on the I-10 Atchafalaya Basin Bridge	The study concluded that the operational policies somehow improved safety on the elevated sections.	Available	Available

Elevated Section Studies in Jurisdictions beyond Louisiana

This section of the review is focused on key relevant studies that have been conducted on elevated sections of freeways in other states and countries. Many studies based on freeways are available that may not be on elevated sections. For instance, Sun et al. conducted a study using the Jingjintang expressway to assess the traffic crash characteristics as a case study in China [12]. The goal of this study was to identify the causes of the high crash frequency and rates on the expressway and recommend safety enhancement measures. Three forms of data were collected for the study—geometric data, traffic flow data, and crash data. The study analyzed a total of 2,829 crashes for three years (2002-2004). Rear-end collisions were identified as the most common type of crash that occurred on the expressway. This was attributed to drivers following too closely and differential speed between trucks and cars on the expressway. Poor driver behavior, substandard vehicle conditions, overloaded trucks, and narrow shoulders were found to have contributed to the high crash frequency. Several unsafe roadway design elements were also identified—such as narrow shoulders, insufficient barriers along the roadway, lack of crash-worthy end treatments, etc. The research team proposed that driver education, strict enforcement of regulations against overloaded trucks, increasing shoulder width, and provision of forgiving roadside could improve safety on the expressway.

Although limited, studies on elevated freeways in other jurisdictions may aid in understanding the traffic crash characteristics in different contexts. Xu et al. investigated the effects of speed variance on the safety performance of urban elevated expressways in Shanghai-China [13]. The main objective of the research was to evaluate how differential speed influenced crash frequency. The study utilized probe vehicle data, loop detector data, road features, and crash data. The speed differential was derived by using the standard deviation of the cross-sectional speed mean and the cross-section speed standard deviation. The results indicated that the higher variations increased the likelihood of crashes on the elevated expressway. Furthermore, the length of the segment and the traffic volume influenced the occurrence of more property damage only crashes (PDO).

A study on the safety of narrow bridge sites was performed by Ivey et al in 1979 [14]. Twenty-five interstate highway bridges similar to the two-lane highway in Texas with a posted speed limit of 70 mph were considered. The study found that drivers recognized narrow bridges as a potential hazard, hence they tend to change their lateral position when the ratio of the bridge width to the approach roadway decreases. Corrective treatments recommended by the research to improve the safety of narrow bridges included the installation of a narrow bridge sign, stop signs, and advisory speed signs. In addition, installation of a smooth bridge rail, and approach guardrail were recommended to aid in the reduction of the impacts of crashes. Table 2 provides a review of the key selected studies conducted on elevated freeways in other states and countries.

Table 2. Scope and key outcomes on elevated freeways in other states and countries

No.	Reference	Study	Outcomes	Operational policy studies present	Safety Analysis
[12]	Sun et al.	Assessment of traffic crash characteristics on freeways in China	Rear-end collisions were the most common type of crash.	Not available	Available
[13]	Xu et al.	Investigation of the effects of speed variance on the safety of elevated expressways	Results indicated that higher speed variations increased the likelihood of crashes on the elevated expressway.	Not available	Available
[14]	Ivey et al.	Safety of narrow bridges study	Drivers recognized narrow bridges as potential hazards	Not available	Not available

Studies Investigating Truck Lane Restrictions

Over the last 20 years, lane restriction policies for trucks have been implemented widely across the United States to solve some traffic operation challenges caused by mixed lane use as well as to improve the safety [15]. Even though many studies examined the effects of lane restriction policies on level freeways, a limited number of studies are available on the safety of the policy on elevated freeways. This section will review selected key studies that have explored truck lane restrictions on interstates, expressways, motorways, etc.

In 2019, Das et al. performed research that investigated the safety impact of truck lane restrictions on freeways in Northern Texas [16]. The safety benefit of the prohibition of trucks from using the left-most lanes was evaluated in this study. A before-after study was conducted on 16 selected sites in the Dallas-Fort Worth area. Due to the limited crash data for the after years, the Enhanced Interchange Safety Analysis Tool was employed in predicting the after-year crash data. Results aided by the estimates from empirical Bayes method suggested that truck lane restrictions impacted positively on the safety performance of “large trucks” (often will be interchangeably used as only “trucks”) involved in fatal and injury crashes for freeways. The study concluded that truck lane restriction policies would contribute to the enhancement of safety on freeways.

Radhakrishnan and Wilmot conducted a literature review on the effects of left lane truck restriction policies on multilane highways [17]. The main objective of the study was to determine the impact of left lane truck restriction policies on traffic flow and safety, pavement structure, passenger car delays, and truck compliance on all multilane state and federal highways in Louisiana. A survey was administered to obtain the opinions of motorists on the impact of truck lane restrictions. Although 70% to 80% of the public welcomed the lane restriction policies, the study recommended that each location be evaluated independently before implementing the policy. Prohibiting trucks from the left lane on multilane highways were found to have reduced crash rates by 10% and improved traffic flow in certain conditions. On the contrary, restricting trucks to right lanes was found to hinder the flow entering and exiting traffic in urban setting as it impedes entering and exiting on the interstate.

Cate and Urbanik utilized VISSIM simulation in the investigation of the impact of left lane truck restriction policies on I-40 and I-75 in Knoxville, Tennessee [18]. Multiple simulation tests were performed in VISSIM models by incorporating traffic characteristics like volume, grade, percentage of trucks, and the presence of entrance and exit ramps. A comparison between models with lane restrictions and without lane restrictions suggested that there was little to no change in vehicle density implying truck lane restrictions had less impact on the level of service of freeways. A reduction in vehicle density was also observed. Left lane truck restriction reduced the travel time for passenger cars but marginally increased travel time for trucks. The speed differential between cars and trucks due the restriction is higher on uphill grade. A reduction in lane changes was also observed when lane restrictions were implemented.

Gan and Jo developed operational performance models for identifying the most efficient truck-lane restriction alternatives [19]. VISSIM simulation software was used to develop a model capacity from the free-flow speeds given in the Highway Capacity Manual. The model was then used to evaluate the effects of restricting trucks to using right lanes on three, four, or five-lane freeways. Findings from the simulation indicated that truck-lane restriction methods improved the average speed under low interchange density, low truck volumes, and low ramp volume conditions. Also, the restriction policy was found to have significantly reduced the frequency of lane changes by separating slow vehicles from faster vehicles. Truck lane restrictions were found to be appropriate for freeways with three, four, or five lanes.

Zavoina et al. explored the effects of truck lane restrictions on Interstate 20 near Fort Worth, Texas [20]. The truck lane restriction policy prohibited trucks from using the left lane on the six-lane (three in each direction) rural interstate highways. An analysis of the before-after implementation of the policy was conducted to examine the highway operational parameters such as vehicle classification, vehicle speed, and the time gap between vehicles on the I-20. The distribution of vehicles in both directions during both peak and off-peak hours showed that trucks on the wrong lane (i.e., left lane) decreased by 62% to 76%. However, no results with regard to directional distribution of cars, speed of either cars or trucks, or time gaps between vehicles could have been attributed to the truck restriction policy.

An evaluation of the truck operating characteristics on I-75 in Florida was performed by Mugarula and Mussa [21]. The study used field data and simulation analysis to address the impact middle lane restriction policies had on truck operating speeds and travel time. Results from the analysis of the field data indicated that the lane restriction policy had little to no negative effect on the truck speeds. The 85th percentile speed for the vehicles obtained was around 75 mph with a posted speed limit of 70 mph. Also, findings from the simulation showed that the lane restriction policy had no effect on the travel times for all the vehicles. On the contrary, the restriction was found to have reduced the number of lane changes, which could be a catalyst for potential crashes.

Hanscom compared the effects of left lane and right lane restriction policies had on traffic congestion [22]. The study segment with the left lane restriction was in an urban area close to Chicago with a three-lane section whilst that of the right lane restriction was a two-lane rural interstate in Wisconsin. It was concluded that the left lane truck restriction was beneficial to the traffic flow of the three-lane segment. However, for the right lane truck restriction on the two-lane segment, the policy caused an increase in the congestion of trucks on the left lane, which raised some safety issues.

Koehne et al. administered a survey among truckers and motorists to measure their opinions on truck lane restriction policies from their experiences as well as to gather some background characteristics such as their age, gender, and vehicle type [23]. The restriction policy prohibited trucks from traveling on the left-most lane on the ascending grades of three sections of an access-controlled highway. Study areas were located on the I-5 on the State Route 520 in the Washington State. The truck lane restriction policies were implemented mainly because of the large number of truck-volume-related complaints received from motorists. The results indicated that motorists and truckers viewed the truck lane restriction as a more viable option that could help reduce congestion.

Borchardt summarized the findings of the evaluation of lane restriction policies for the Houston demonstration project [24]. Based on a minimum 6-mile length criteria and a 4% truck volume, the researchers selected an 8-mile I-10 East Freeway for the project and collected and analyzed traffic volume data for 36 weeks. The estimated compliance rate of the truck lane restriction policy was substantially high ranging from 70% to 80% and was attributed to the high level of police enforcement. Additionally, results from the analysis of crash data showed a 68% reduction in the crash rate of the study segment following the lane restriction policies.

Agent and Pigman assessed the impact of large trucks on the safety of interstates in Kentucky [25]. The study examined crash data of the interstates by separating and examining crashes involving large trucks from 1998 to 2000. The crash characteristics of the truck crashes were then compared. Results from the analysis indicated that trucks formed the majority of the vehicles on the interstates. Although trucks were involved in a lesser number of crashes, crashes involving trucks were more fatal. Table 3 shows a summary of the literature review on truck lane restriction policies.

Table 3. Summary of previous studies on truck lane restriction policies

No.	Reference	Study	Outcomes	Involving Elevated Freeways
[14]	Das et al.	Safety benefits of prohibiting trucks from using left most lanes on freeways in Texas	A 56% reduction was obtained in large truck-related fatal and severe injury crashes.	No
[15]	Radhakrishnan and Wilmot	Identification of the effects of left lane restriction policies on multilane highways in Louisiana	Overall, the policy improved crash rate by 10%.	No
[16]	Cate and Urbanik	VISSIM simulation to investigate the impact of the left lane truck restriction policy	On level terrains, speed differential for cars and trucks was affected by less than 1 mph whilst that of 4% upgrades increased by 10 mph.	No
[17]	Gan and Jo	Development of operational performance models for identifying the most efficient truck lane restriction alternative	Truck lane restrictions were found to be appropriate for freeways with three, four, or five lanes.	No
[18]	Zavoina et al.	Study on left truck lane restrictions on I-20 near Fort Worth-Texas	Truck lane compliance rate for the study section was between 62% and 76%.	No
[20]	Mugarula and Mussa	Evaluation of the impact of middle lane restriction policies on truck operating speeds and travel time	The lane restriction had no effects on the travel time and the truck speed.	No
[21]	Hanscom	Comparison of the effects of left lane and right lane restriction policies on traffic congestion	Left lane truck restriction was beneficial to the traffic flow on the three-lane segment. The right lane restriction on the two-lane segment increased congestion.	No

[22].	Koehne et al.	Administration of a survey to obtain opinions about truck lane restriction policies	Motorists and truckers considered the truck lane restriction as a reasonable alternative that could relieve congestion.	No
[23]	Borchardt	Summary of the findings of an evaluation done on lane restriction policy for Houston demonstration project	A 68% reduction in the crash rate was observed.	No
[24]	Agent and Pigman	Assessment of the impact of large trucks on the safety of interstate highways in Kentucky	Trucks formed majority of the vehicles on the interstate and were involved in more fatal crashes.	No

Studies on the Impact of Differential Speed Limits

With the repeal of the National Maximum Speed Limit in 1995, the power to set speed limits was given back to the individual states. Since then, several states including Louisiana, California, Idaho, Indiana, and Michigan have either implemented or attempted to implement Differential Speed Limit (DSL) policies. This section includes a review of studies that targeted the safety benefits of the implementation of the DSL policies.

Davis et al. reviewed existing studies on implementing DSL with regard to the impact on the traffic safety and potential environmental benefits [26]. The safety-related outcomes indicated that it is best to implement DSL on multilane freeways in comparison to two-lane rural freeways. Also, most of the studies reviewed had conflicting conclusions about the safety benefits of the DSL policies.

Garber et al. compared the safety impact of uniform speed limit (USL) to DSL [27]. The study obtained 10-year (1991-2000) crash data for rural interstate highways in six different states. These six states were then grouped into four categories based on the type of speed limit policies employed. These categories are: (1) a switch from USL to DSL, (2) switch from DSL to USL, (3) retainment of DSL, and (4) retainment of USL. The results from the empirical Bayes approach, estimating expected post-implementation crashes with consideration to the regression-to-the-mean effects, showed crash frequency increased regardless of the type of speed limit policies employed. The study concluded that speed limit policies had no significant effect on the safety of roadways.

Sun et al. estimated the safety impacts of the differential speed limit and truck lane restrictions on the I-10 over the Atchafalaya Basin Bridge in Louisiana [4]. The differential speed limit policy required trucks to travel at a speed of 55 mph and cars at 60 mph. The naïve before-after method, the improved prediction before-after method, and the comparison method were used in this study. The outcome revealed that reduction a 13% and 77% reduction in the total crashes and truck crashes, respectively. It was concluded that the speed limit policy was beneficial to the Atchafalaya Basin Bridge segment.

Yuan and Garber examined the effects of differential speed limits on crash characteristics on rural interstate highways [28]. The study utilized speed data from five states (Iowa, Illinois, Indiana, Idaho, and Virginia) and crash data from six states (Arizona, Missouri, North Carolina, Arkansas, Idaho, and Virginia). The mean speed, speed variance, 85th percentile speed, median speed, and noncompliance rate were obtained from the speed data. The crash data was analyzed by the type of collision, the type of vehicle involved, and the crash severity. Results from the analysis revealed that neither USL nor DSL affected the trend in the crash rates.

Wilmot and Khanal conducted a review on the effects of speed limits on speed and safety [29]. Findings from the review indicated that drivers, in general, do not observe posted speed limits but rather use their speed depending on the environment they drive in such as controlled access facilities, the geometry of the road, and the weather conditions. Age, type of pavement, and vehicle safety devices were found to affect the relationship between speed and safety. One important finding was that motorists could not decide day or night during dawn and dusk when differential speed limits were implemented between day and night. Also, when differential speed limits are implemented in urban areas, there is the problem of renewing the start and end boundaries of the policy since urban areas are rapidly growing.

Monsere et al. assessed the impacts of a proposed change of interstate speed limit in Oregon [30]. Proposed maximum posted speed for passenger cars was 70 mph from 65 mph and for trucks was 65 mph from 55 mph. The difference between the passenger car speed and the truck speed (10 mph) was likely to increase the speed dispersion, which will have negative effects on safety. However, the increase to 70 mph for cars and 65 mph for trucks was likely to result in less speed dispersion which has a positive effect on safety.

Johnson and Murray investigated the speed distributions for trucks and passenger vehicles at some selected rural interstate highways in the United States [31]. The primary objective of this study was to assess the actual speed behavior of rural interstates with DSL policies. The study collected speed data from 19 selected rural interstate sites with differentials of 0, 5, 10, and 15 mph. The mean speeds, 85^{th} percentile speeds, compliance rates, and observed speed differentials were obtained using the speed data. The results indicated that the posted speed limit for the vehicles did not influence their 85^{th} percentile speeds. Table 4 contains the summary of the studies that investigated the impact of DSL policies.

Table 4. Summary of studies on differential speed limits

No.	Reference	Study	Outcomes	Involving Elevated Freeways?
[26]	Davis et al.	Determine the traffic safety and environmental benefits of DSL	Implementation of DSL is expected to provide better safety outcomes on multilane freeways in comparison to rural two-lane freeways.	No
[27]	Garber et al.	Comparison between uniform speed limit (USL) and differential speed limit (DSL)	Crash frequency increased regardless of the type of speed limit policy.	No
[4]	Sun et al.	Safety impact of DSL on the Atchafalaya Basin Bridge in Louisiana	The DSL policy was beneficial to the freeway segment.	Yes
[28]	Yuan and Garber	Effects of differential speed limit on crash characteristics on rural interstate highways	DSL did not affect the trend in the crash rates.	No
[29]	Wilmot and Khanal	Effects of speed limits on speed and safety	Drivers could not differentiate between dawn and dusk for day and night DSL policies.	No
[30]	Monsere et al.	Impacts of a proposed speed limit change in Oregon	Outcome was inconclusive.	No
[31]	Johnson and Murray	Speed distribution for trucks and cars on some interstates	The posted speed limit did not affect the 85th percentile speeds.	No

Objective

The main objective of the research project was to conduct a crash analysis on selected elevated highway segments to identify common crash characteristics, issues, and similarities or differences between car and truck crashes. Specifically, the research aimed to determine if the crash characteristics observed on the elevated section of I-10 over the Atchafalaya Basin were similar to those on other elevated highway segments in Louisiana. Another objective was to utilize a video analytical software that could classify and count vehicles for estimating the compliance of truck lane restrictions on the Atchafalaya Basin Bridge.

Scope

The defining aspects that outline the scope of this research project are as follows:

- The research project was confined to a total of eight elevated sections in Louisiana, each more than 1 mile in length and equipped with cameras during the study period.
- In the context of speed analysis for this study, speeding occurs on a site when the estimated 85th percentile speed is above the posted speed limit. The degree of speeding is identified as the amount by which the 85th percentile speed exceeds the posted speed limit (PSL) for a particular segment under investigation.
- The investigation of differential speed limit and truck lane restriction policies in practice was limited to only one site out of eight, the Atchafalaya Basin Bridge, which was the only elevated section with these policies in place.
- The use of video analytical software to explore truck lane restriction compliance was limited to footage from five specific camera locations on the Atchafalaya Basin Bridge.

Methodology

This chapter is divided into multiple sections that describe the methods undertaken in this research. The section "Site Selection and Description" labels the sites selected in addition to the selection criteria that were established by thorough review of the elevated sections by the project review committee. The next section describes the procedure to collect speed data on the selected sites from the probe data platform of RITIS (Regional Integrated Transportation Information System). Hotspot analysis was performed using ArcGIS to identify the sections with high crash density. The following section includes a description of how the video analytical tool "DeepMetrics" was utilized to determine the compliance rate of truck lane restrictions.

Site Selection and Description

The study used the I-10 over the Atchafalaya Basin Bridge as a baseline and sought to identify other elevated sections with comparable features. Although about 12,000 bridges can be located in the Louisiana bridge database, 608 bridges with a length greater than one mile were selected in the initial screening process. Out of 419 camera locations on the bridge of the Louisiana Department of Transportation and Development, several bridge sites with camera coverage were selected from a list of 608 bridges.

Similarities to the I-10 across the Atchafalaya Basin Bridge in terms of a comparable number of access points and a comparable roadway classification were also considered. After several reviews by project review committee members, the following criteria were used when identifying the start and end of the sites at each camera coverage in the final selection process to pinpoint the study sites:

- Not less than a mile,
- Similar AADT throughout the section with no significant exit or entry,
- Presence of state-controlled camera coverage anywhere within the segment, and
- Covering defined integer number of XD segments identifiable in the RITIS system.

Figure 1 illustrates the locations of the finally selected eight sites. All of the sites are on interstate highways or interstate bypasses. Except for Site 7, all the sites are located in the southern DOTD districts of Louisiana. The features of the eight elevated sites are shown in Table 5.

Figure 1. Location of selected sites in Louisiana

Table 5. Features of selected elevated sections

Site Number	Site Name	Number of Lanes	Length (miles)	Posted speed limit (mph)	Surrounding land use
1	I-10 over Bonnet Carre Spillway	4	12.08	60	Water, vegetation
2	I-10 over Atchafalaya Basin	4	24.17	55 (trucks) 60 (all other vehicles)	Water, vegetation, roadway
3	I-110 (over 67 Plank Rd & Evangeline Street)	6	5.76	60	Roadway
4	I-310 La Branche Wetlands	4	5.16	70	Vegetation
5	I-10 Twin Span Bridge	6	6.62	70	Water
6	I-55 Manchac Swamp Bridge	4	14.2	70	Water
7	I-220 over Cross Lake Shreveport	4	1.94	70	Water
8	I-10 Over Perkins Road	6	2.26	60	Roadway

Identification of Study Segments on RITIS

To determine if the vehicles adhered to the posted speed limits on the selected elevated interstate sections, archived speed data was collected from the RITIS system. Identifying the pre-designated segments within the selected sites was the first step before finding the archived vehicle speed data processed from multiple institutional and crowdsourced data sources into the RITIS system. The Probe Data Analytics (PDA) suite archives all data, which may be queried, analyzed, downloaded, or exported and used to create performance metrics [32]. Speed data was extracted using the Massive Data Downloader tool from the PDA suite of the RITIS system.

The traffic and location-based information in the RITIS system is provided through the INRIX architecture. The INRIX architecture utilizes Traffic Message Channel (TMC) segments and/or eXtreme Definition (XD) segments as the basis for defining road sections on which speed and incident data are reported. The XD is a more consistent, unambiguous, and granular definition of road segments in comparison to the conventional TMC segments, which vary greatly in length depending on the distance between neighboring TMC location codes. Because of their shorter lengths, XD segments offer more granularity of data than TMC segments.

XD segments were considered for archived speed data extraction except for site 2 (Atchafalaya Basin Bridge), which has separate speed limits imposed for passenger vehicles (60 mph) and trucks (55 mph). Separate speed data for passenger vehicles and trucks can only be extracted from the TMC segments in the current RITIS system. Table 6 shows the total XD or TMC segments for each site and the range of length for each segment. The average length of predesignated XD segments was around half a mile. The TMC segments in Site 2 had an average length of 3.44 miles.

Table 6. Details of segments for each site

Site Number	Total number of segments (Data type)	Average segment length (mile)	Range of segment length (mile)
Site 1	39 (XD)	0.62	0.32 - 0.98
Site 2	14 (TMC)	3.44	0.27 - 7.59
Site 3	26 (XD)	0.45	0.07 - 0.98
Site 4	18 (XD)	0.58	0.52 - 0.69
Site 5	25 (XD)	0.55	0.17- 0.70
Site 6	44 (XD)	0.65	0.33 - 0.96
Site 7	8 (XD)	0.49	0.48 - 0.49
Site 8	8 (XD)	0.55	0.16 - 0.88

Description of Selected Sites

The location details of the sites are described below. Appendix A presents the locations of the sites in Figures A1 to A8. The segments are ordered based on the TMC/XD identifier and not always in order of the travel direction. The letter following the segment number (N, S, E, and W) indicates the travel direction. The length of each segment is provided in miles on each map of the eight sites. Additionally, an arrow in each figure shows the travel direction. Different colors of each segment within a site are only for separating the segments.

Site 1: The I-10 Bonnet Carre Spillway Bridge is a twin concrete bridge with two lanes in each direction. It goes over the Bonnet Carre Spillway, Lake Pontchartrain, LaBranche Wetlands in St. Charles Parish, and a part of St. John the Baptist and Jefferson Parishes.

Site 2: The I-10 Atchafalaya Basin Bridge, also known as the Louisiana Airborne Memorial Bridge, connects Baton Rouge and Lafayette by a pair of parallel bridges with two lanes in each direction. This portion of I-10 has 14 TMC segments in total (seven in westbound and seven in eastbound).

Site 3: The elevated section of Interstate I-110 is an urban interstate situated in Baton Rouge Parish. Each direction has three travel lanes. This site 13 XD segments northbound and 14 XD segments southbound.

Site 4: The I-310 is a short offshoot road of I-10 situated in St. Charles Parish west of New Orleans. A portion in the southward's direction is elevated, traverses the LaBranche

Wetlands, and connects to U.S. Route 61 at St. Rose. This site covers 18 XD segments altogether, nine in each direction.

Site 5: The I-10 Twin Span Bridge, sometimes referred to as the Frank Davis Memorial Bridge, consists of two parallel, three-lane trestle bridges. It crosses the eastern edge of Lake Pontchartrain from New Orleans to Slidell in southern Louisiana. Site 5 has 12 XD segments eastbound and 13 in westbound.

Site 6: The I-55 Manchac Swamp Bridge is a twin-trestle concrete bridge that spans a portion of Lake Maurepas and has two lanes in either direction. Site 6 has 22 XD segments in each direction.

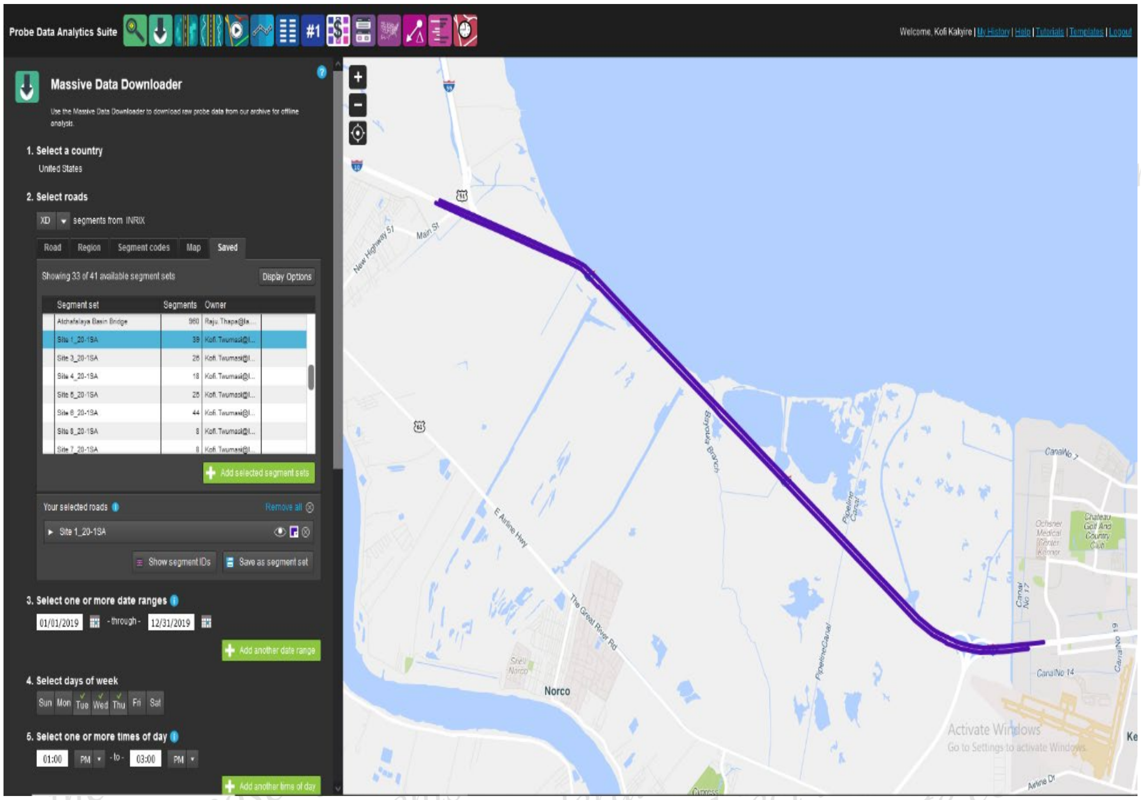
Site 7: The I-220 is an east-west bypass route around Shreveport in the northwest region of Louisiana. A portion of this interstate is elevated and spans the Cross Lake. It has a total of eight XD segments (four segments westbound and four segments eastbound).

Site 8: The part of I-10 that passes over the Perkins Road in Baton Rouge has three lanes in each direction. There are a total of eight XD segments (three eastbound and five westbound) along this stretch of roadway.

Speed Data Collection from RITIS

Under the PDA suite, the Massive Data Downloader interface provides speed data on XD or TMC segments. Speed data for 2019, 2020, 2021, and 2022 (up to September) were collected by specifying the time intervals during Tuesdays through Thursdays from 1 p.m. to 3 p.m. The selected time intervals during specific weekdays were chosen to ensure that traffic flow was unobstructed. Additionally, incidents that may have impacted traffic flow during these periods were excluded. The temporal granularity, implying averaging time for collective traffic speed data extraction, was selected as five minutes (between 5, 10, 15, and 60 minutes) ensuring a sufficient sample from INRIX. Figure 2 shows an example of the inputs at Site 1 to acquire speed data.

Figure 2. RITIS typical selection of the extent of site 1 (I-10 over Bonnet Carre Spillway)



The speed data were downloaded in Comma-Separated Values (CSV) file format for each of the eight sites to estimate the 85th percentile speed and compare it with its respective posted speed limit. Idealistically, the 85th percentile speed and the posted speed limit should essentially overlap [33]. If the estimated 85^{th} percentile speed is above the posted speed limit, then it indicates speeding occurs on that site.

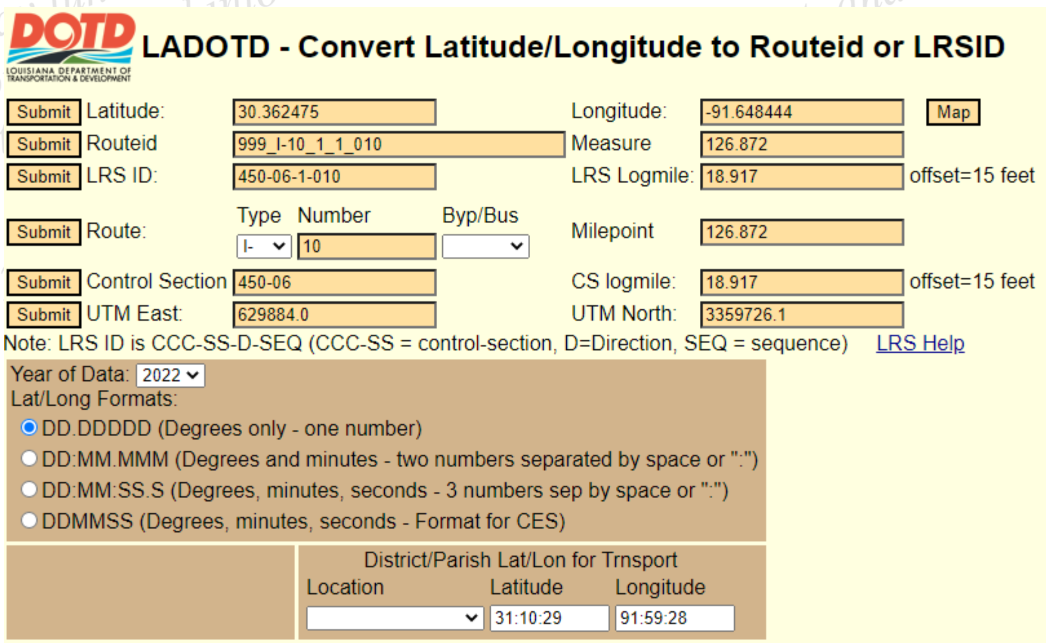
Collection and Analysis of Crash Data

Crash data on the selected elevated sections enabled researchers to explore multiple aspects associated with crashes. First, crash data indicated which crash characteristics were prevalent on the study sites. Second, hotspot analyses on the study sites delivered the location of hotspots, i.e., individual segments that had more frequent crashes beyond a specific threshold. Third, the identification of hotspots helped researchers identify and compare them with associated geometric characteristics and speeding patterns.

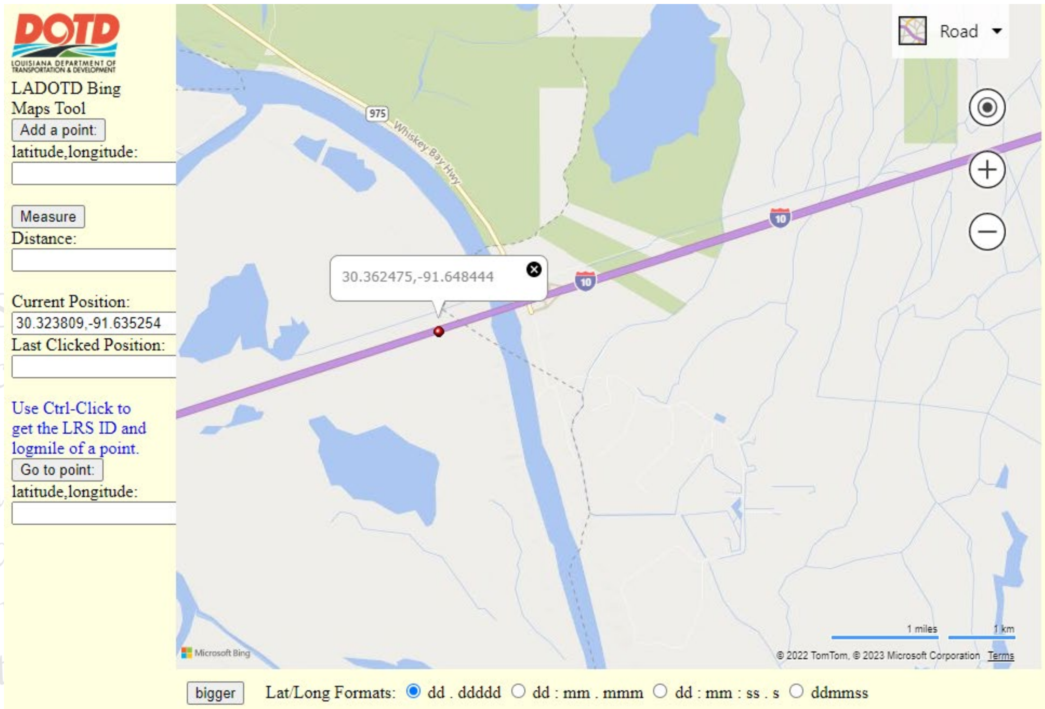
Crash Data Collection

To identify crashes on the selected elevated sections, all eight sites were located using Louisiana's combined standard location identifiers—control section, part of the Linear Referencing System ID (LRS-ID), and associated logmiles [34]. Using coordinates (latitude and longitude) of the start points and end points as input in the DOTD's Lat/Long to control section conversion tool, control section, and logmiles of the eight sites were identified. An example conversion of starting location coordinates of Site 2 to control section and logmile has been presented in Figure 3.

Figure 3. A conversion of starting point coordinates to (a) control section and logmile with (b) map



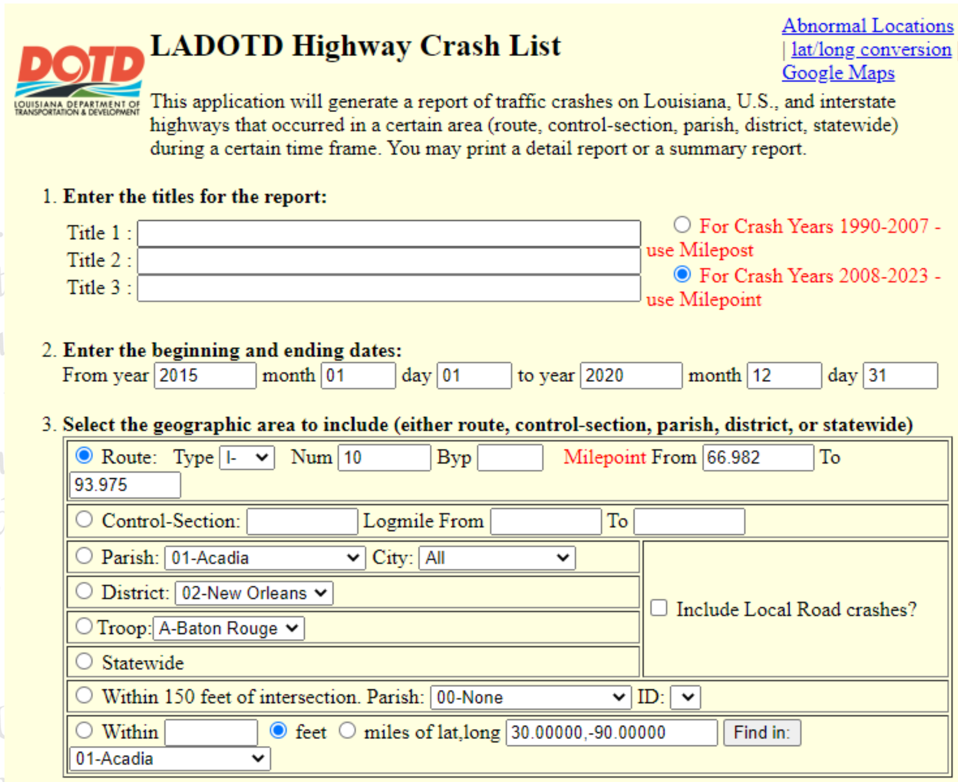
(a)



(b)

Using a control section and ranges of logmiles as input, crash data on the selected eight elevated sections were collected from the online Louisiana highway crash data repository “Crash1” [3]. A partial screenshot of the Crash1 web user interface is presented in Figure 4. Data of police-reported crashes spanning six years from 2015 to 2020 were extracted from Crash1 in CSV format files and contained crash characteristics for driver and vehicle, roadway, and crash environment across all eight sites.

Figure 4. Crash 1 web interface



Hotspot Analysis

Hotspot analysis identifies areas of a roadway where a high frequency of crashes occurs and, in this process, finds potential links between crash patterns and specific roadway attributes such as geometry, traffic volume, driver behavior, and other factors. Performing a hotspot analysis required knowledge of locations of individual crashes on the study sites, which was provided in the crash data exported from Crash1. Several steps were carried out using ArcGIS Pro software: sliding window approach to identify the threshold of minimum number of crashes for a crash cluster and using Density-based Spatial Clustering of Applications with Noise (DBSCAN) tool to generate density-based crash cluster. In both cases, crash clusters were compared with ArcGIS auto-generated heatmaps for validation of clusters.

A sliding window method (Figure 5) was employed to identify hotspots of traffic crashes on various sites. A window of length 1,000 ft. was placed on the roadway, and the number of crashes within the window was estimated. The window was then moved along the roadway with an overlap of 250 ft. and the number of crashes was estimated again. The percentage of crash frequency was calculated for each segment, and after several trials, a minimum of 90th percentile values was estimated to consider a segment as a hotspot. The hotspots identified using this method were compared to crash heatmaps generated using ArcGIS Pro and found to be similar. A sample result chart from the sliding window analysis and its comparison to ArcGIS pro heatmap is shown in Figure 6. The threshold crash frequency values for all the sites were recorded for use in a later density-based clustering method.

Figure 5. Sample showing the procedure for sliding window method

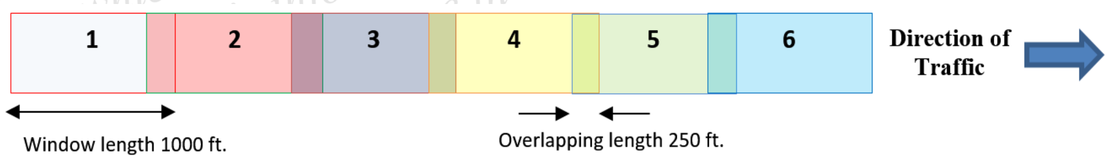
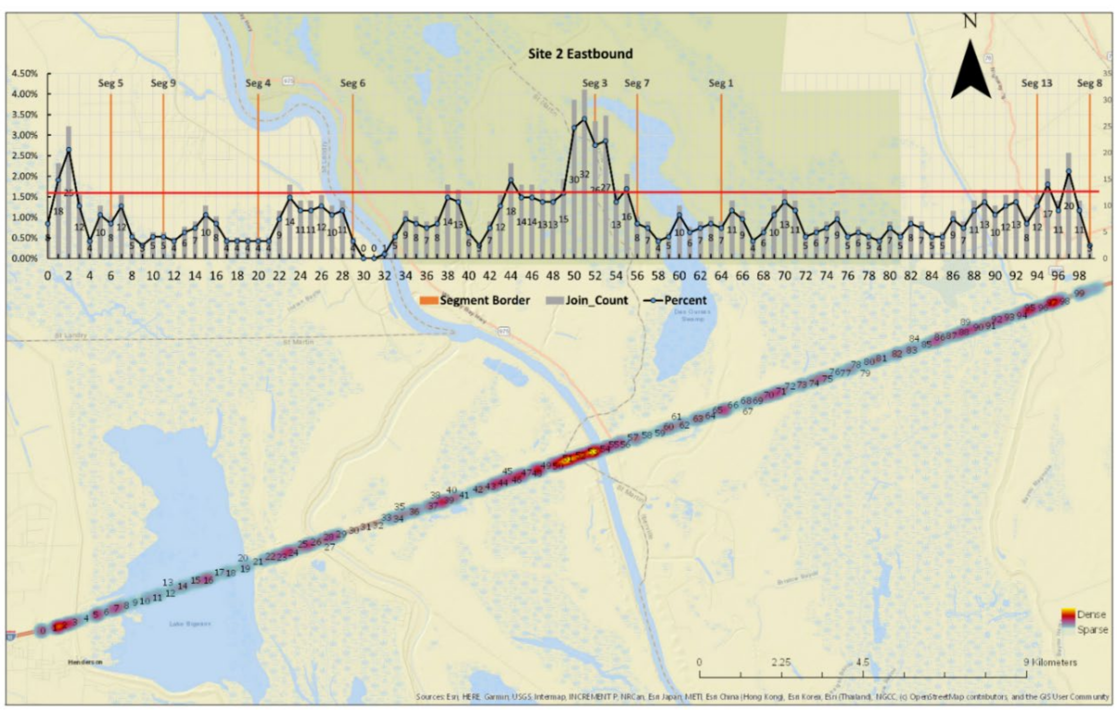


Figure 6. Site 2 eastbound crash hotspots-comparison between the sliding window method and the ArcGIS heatmap

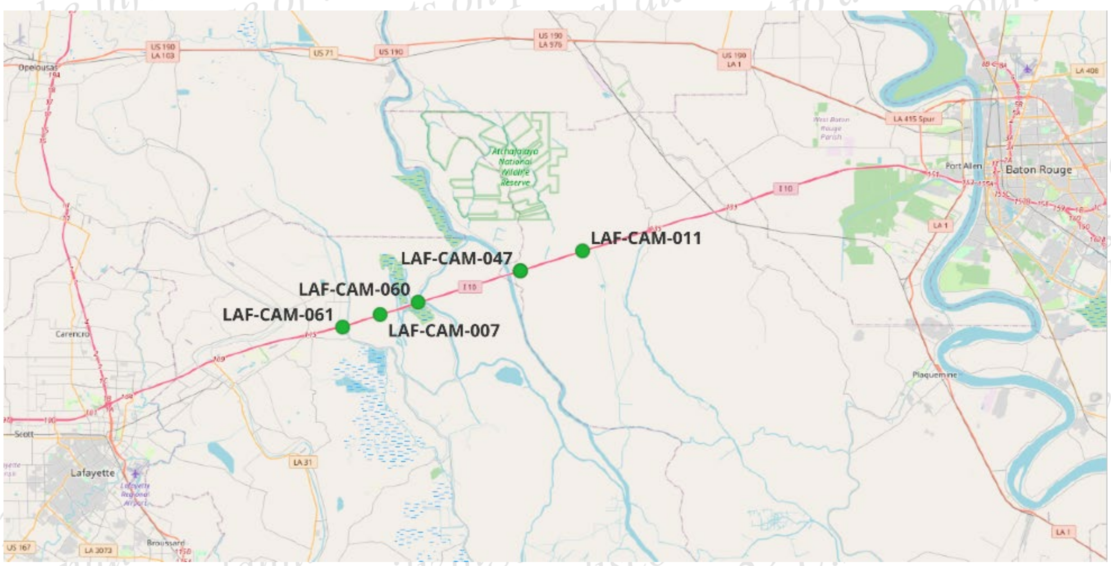


The DBSCAN algorithm was used to develop the clusters on the crash data. This method involves grouping close proximity points (crash coordinates) into clusters using a specified search distance. The selection of two key parameters, search distance and minimum features per cluster, is crucial. Several trials were conducted to determine the search distance with a value of 650 ft. chosen after trials.

Data for Truck Lane Restriction Compliance

Truck lane compliance rate could only be estimated for Site 2—Atchafalaya Basin Bridge—the only site with truck lane restrictions imposed in place. The following subsections explain how this study utilized a video analytics system called DeepMetrics to investigate truck compliance rates at Site 2. Although the DeepMetrics system can also perform advanced functions including estimating speed, gap, and headways, it was primarily employed to detect, count, and classify vehicles from the recorded video feeds. The CCTV cameras on Site 2, which are owned by the state, were accessed with the permission from DOTD. After cross-checking the locations and positions of the cameras, a total of five camera feeds were selected for the observation of traffic flow. The map in Figure 7 presents the locations of the cameras that were utilized for video data collection.

Figure 7. Locations of cameras on Site 2 used for truck compliance observation

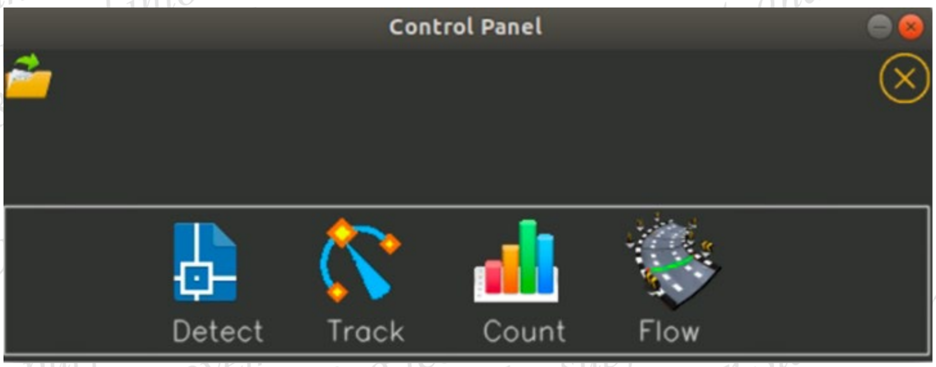


Prior to running through the DeepMetrics system, video data was collected using the links to the live streams provided by DOTD. Appendix B provides diagrams indicating steps to record videos from DOTD camera feeds using a virtual media player from a workstation. Video data was collected from May 15 to June 30 of 2022 during 1 p.m. to 3 p.m. from Tuesdays to Thursdays. For some days, data collection was suspended due to unavailable or poor quality of streaming.

Counting Trucks on DeepMetrics Software

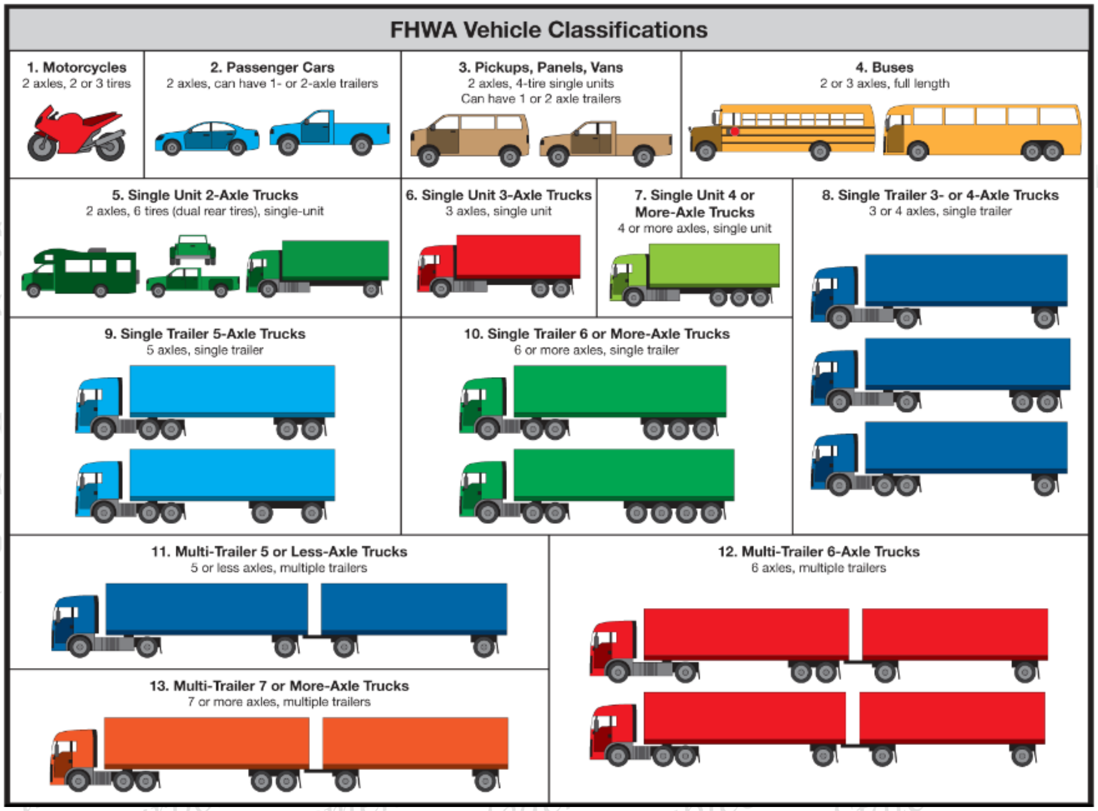
The DeepMetrics (DPM) software, developed by the Missouri Center of Transportation Innovation (MCTI), has four main virtual components or panels: detection, tracking, counting, and flow panel. Videos recorded during the analysis period were processed using the "Detect" command from the control panel of DPM (Figure 8).

Figure 8. Control panel



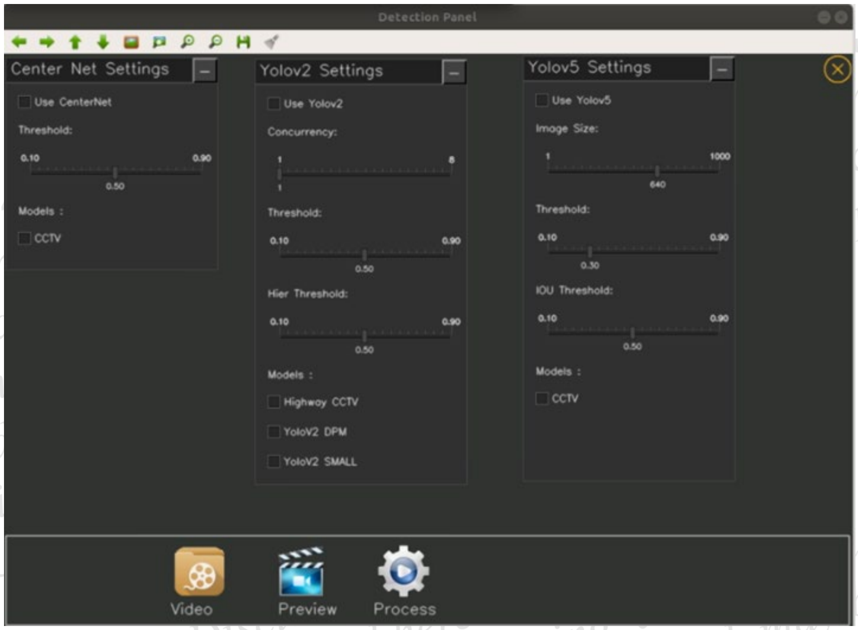
The videos were then run through the "Detection Panel." The detection panel uses AI that has been trained to detect and classify different types of objects in a traffic scene. Vehicles are classified into eight distinct types: pedestrians, bicycles, motorcycles, passenger cars, buses, single-unit trucks, single-trailer, and multi-trailer trucks. As a result, the system is expected to detect vehicles irrespective of the traffic or weather conditions. Hence, the accuracy of the system may decline under conditions where vehicles are not easily recognized by the human vision system. The software detects FHWA traffic classes 7 through 12 (as presented in Figure 9) as "Trucks."

Figure 9. FHWA vehicle classification



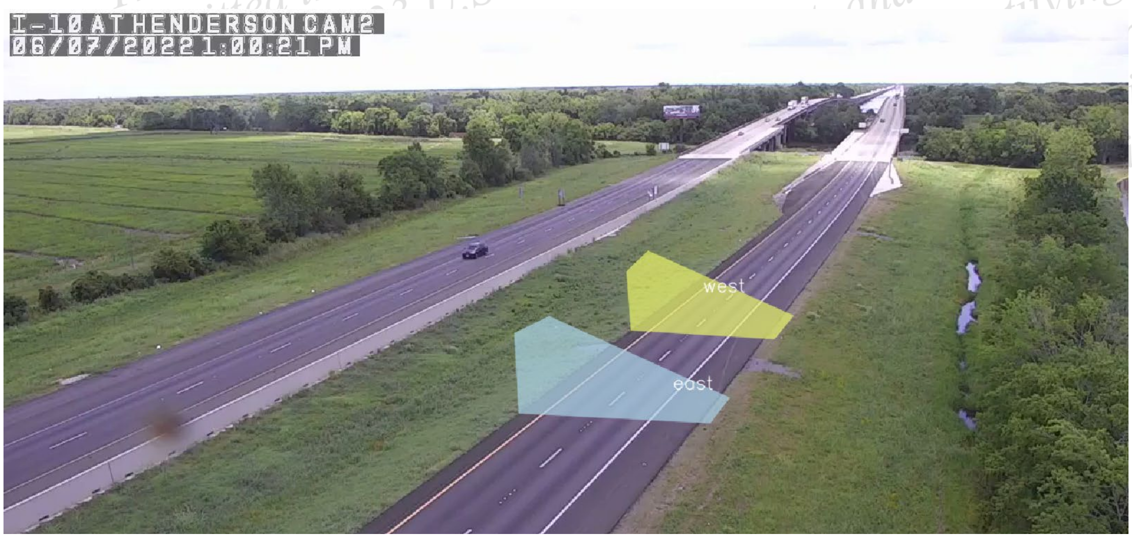
The DPM has three different AI models for object detection (Figure 10). Users can select their preferred detector based on factors such as processing speed, camera resolution, road type, and number of classes. After several trials among three models, Yolov2 was identified as appropriate model for more accurate truck detection.

Figure 10. Detection panel



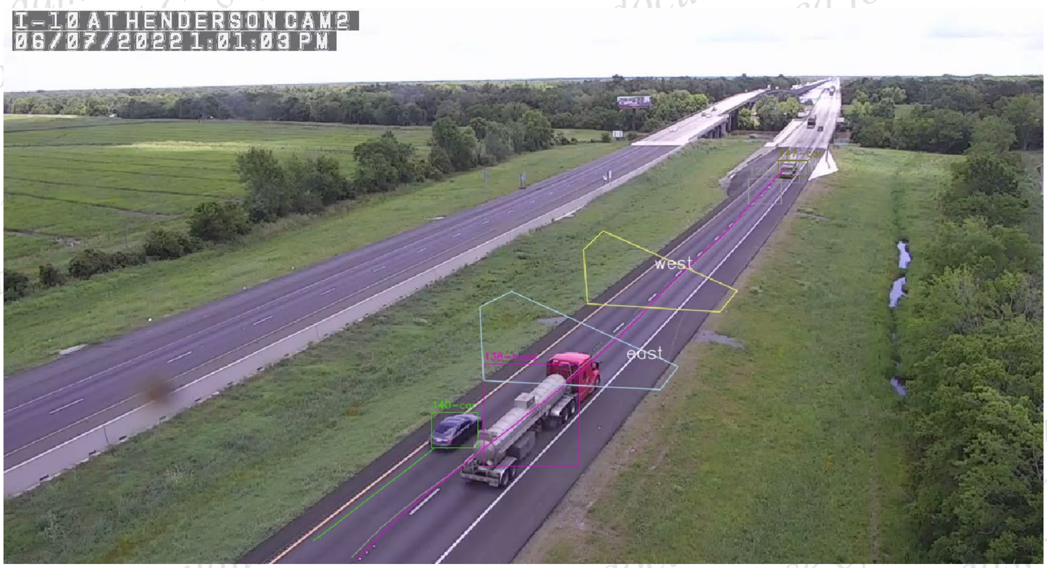
Non-compliance of right lane for trucks was estimated in two steps. Trucks were counted by drawing two polygons on the left lane that only detect vehicle trajectory on the left lane. Another run of the counting was performed by tracking the trajectory on all lanes in one direction (Figure 11). The subtracted data provides the number of vehicles in the right lane.

Figure 11. Polygons to detect and classify vehicles in DeepMetrics



Vehicle tracking is another key component of the DPM system. It enables the system to generate trajectories for each vehicle as they enter and exit the traffic scene. The tracker first takes inputs from the detection panel, then it uses spatial and temporal information to assign a unique identification number to each vehicle. The polygons are used to detect the entrance and exit points for each vehicle. The software automatically assigns directions to each trajectory and then aggregate counts at intervals (1, 5, 15, 30, or 60 minutes) specified by the user. The figure also shows vehicles with trajectories and assigned directions as they traverse the polygons (Figure 12). Locations of the cameras were further checked for a possible relationship with geometric characteristics. Additionally, these locations were further matched with hotspot locations.

Figure 12. Trajectories of vehicles in DeepMetrics



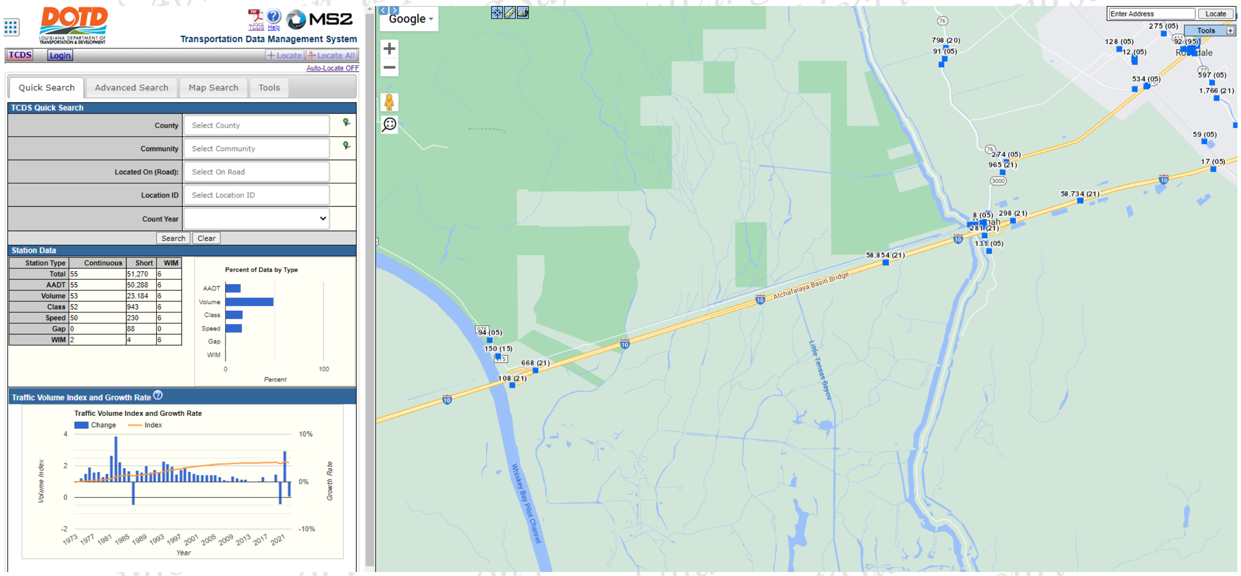
It should be noted that, from the restricted camera perspective, it was not possible to discern instances of trucks overtaking vehicles using the left lane. Furthermore, the DeepMetrics software employed in this study did not offer the option for customization to detect passing trucks specifically. Consequently, the research categorized all trucks observed in the left lane as non-compliant.

Truck Volume data Collection from MS2

Truck volume data were collected for the remaining sites from MS2 panel of DOTD Transportation Data Management System that periodically collects traffic volume data. In

Figure 13, blue markers indicate the locations of traffic count stations on and around the Atchafalaya Basin Bridge, with each station also displaying the latest AADT estimates and their corresponding year of estimation in parentheses.

Figure 13. Volume data from MS2



Discussion of Results

Crash Data Analysis

A total of 10,022 traffic crashes occurred on the eight elevated sections from 2015 to 2020, the patterns of which are expected to be diverse. The area type was determined from the functional classification, designated as either urban interstate or rural interstate, as indicated in the highway section table of the MS Access crash databases. In addition to presenting area type, number of lanes, and AADT in vehicles per day, Table 7 estimates crashes per mile per lane as well as crash rates in terms of per 100 million vehicle miles traveled (VMT), taking into account the AADT.

Table 7. Comparison of crash rates and traffic characteristics

Site	Area Type	# of Lanes	AADT (vpd)	Crashes per mile per lane	Crash Rate in 100 million VMT	Fatal & Severe Injury Crash Rate in 100 million VMT
1	Urban	4	67,000 to 76,000	44.5	113.6	1.06
2	Rural	4	37,000 to 43,000	17.9	81.7	1.23
3	Urban	6	45,000 to 54,000	58.4	323.3	4.00
4	Urban	4	50,000 to 57,000	19.6	67.0	0.50
5	Rural	6	64,200 to 86,000	11.1	40.5	0.83
6	Rural	4	20,000 to 30,000	7.5	54.8	1.16
7	Urban	4	62,300 to 69,700	27.6	76.5	1.79
8	Urban	6	152,000 to 198,000	194.6	304.7	1.15

It is worth noting that Site 1 (over Bonnet Carre Spillway) with surrounding land use of water and vegetation (Table 5) has been classified as an urban site due to its connection to urban areas, despite not being a bypass (such as Site 3: I-110, Site 4: I-310, and Site 7: I-220) and not being elevated above an urban roadway (like Site 8: I-10 Over Perkins Road). Both urban and rural sites, presented in Table 7, have a mix of four- and six-lane configurations. Urban sites generally have higher AADT values compared to rural sites. Site 8, an urban site, has the highest AADT ranging from 152,000 to 198,000 vehicles per day. The lowest AADT is observed at rural Site 6, with a range of 20,000 to 30,000 vehicles per day. Site 8, an urban site with six lanes, has the highest total crashes per mile per lane at 194.6, while rural Site 6 has the lowest at 7.5 during 2015-2020.

The statewide average crash rate for urban interstate is 14.8 crashes per mile per year and 6.1 crashes per mile per year for rural interstate during 2015-2020. Except for Site 4 and Site 6, crash rates at the selected sites are higher than the state average. The crash rates adjusted for AADT also show a contrast between urban and rural sites, as presented in Table 7. Urban six-lane Site 3 has the highest crash rate at 323.3 per 100 million VMT, while six-lane rural Site 5 has the lowest at 40.5 per 100 million VMT. Among four-lane sites, urban Site 1 has the highest crash rate at 113.6, while urban Site 4 has the lowest at 67.0. In general, urban six-lane sites have higher crash rates. Site 2 has a fatal and severe injury crash rate of 1.23 per 100 million VMT, which is higher than the rates for Sites 1, 4, 5, 6, and 8, but lower than the rate for Site 7. Site 3 has the highest rate of 4 per 100 million VMT.

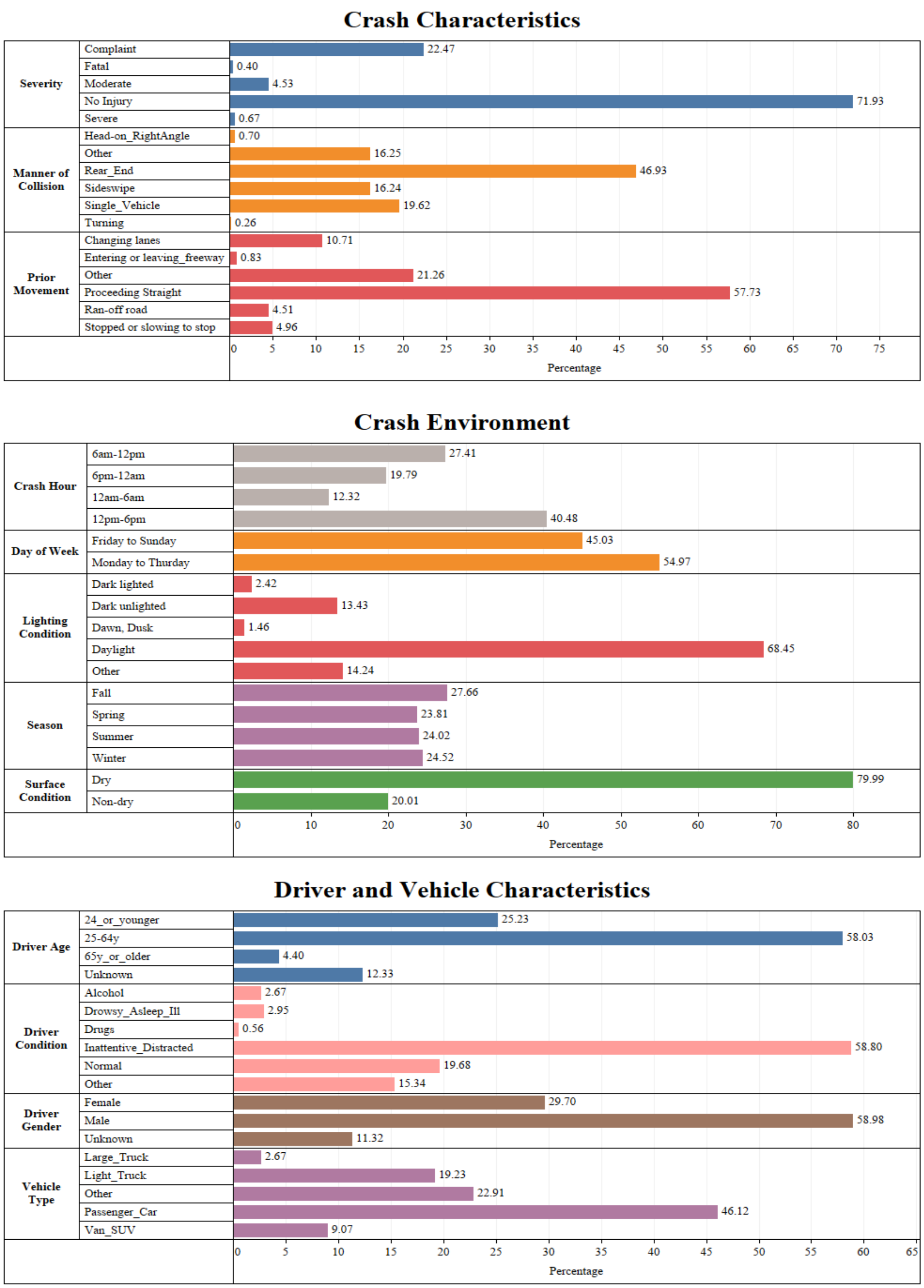
Distributions of Crash Characteristics

Distribution of characteristics of the important categories in the crash data implies perspectives from the possible prevalent scenarios. The results of inter-distributions of the categories in the prepared collective dataset of all elevated sections are presented in Figure 14 and are described below.

- *Severity:* A total 40 (0.4%) of 10,022 crashes during the crash analysis period resulted in fatal injuries as majority of the crashes involved no injury (71.93%). Fatal and severe crashes may be sporadic in nature; however, they often result in multiple casualties from collisions between multiple vehicles driving within a restricted environment.
- *Manner of Collisions:* Rear-ends were the most frequent type of crashes in the study, accounting for nearly 47% of all crashes. This was followed by single vehicle crashes, which accounted for nearly 20% of all crashes, and sideswipe crashes, which accounted for approximately 16% of all crashes.
- *Prior movement:* The actions of the vehicle driven by the driver just prior to the crash play a crucial role in determining the crash scenario. In most cases, the vehicle was proceeding straight (57.73%), which often results in rear-end crashes. Lane changing for the purpose of passing/overtaking or entering/exiting the elevated sections accounted for 10.71% of all elevated section crashes. Running off the road, which typically leads to single vehicle crashes, accounted for 4.51% of the elevated section crashes. There were 4.9% of crashes involving the vehicle stopping or slowing to stop may have been caused by a mechanical failure of the vehicle.

- *Crash hour:* The quarterly distribution of daily crashes suggest the majority of crashes occurred during the afternoon period, specifically between 12 p.m. to 6 p.m. However, a closer examination of the data reveals that the highest concentration of crashes took place during the afternoon rush hour (4 p.m. to 6 p.m.).
- *Day of the week:* Percentage of crashes was lower Friday to Sunday (around the weekend, 45.03%) in comparison to Monday to Thursday (remaining days of the week, 54.97%) due to unequal number of days in those two groups. However, crashes per day was higher around the weekend (52.21%) than remaining days of the week (47.79%).
- *Lighting condition:* The lighting conditions at the time of the crash are crucial in terms of visibility on elevated sections. Most crashes occurred during daylight hours (68.45%), followed by dark unlit conditions (13.43%). Only a small percentage took place in the dark but with lighting (2.42%) and during dawn and dusk (1.46%).
- *Season:* The elevated section crashes were quite evenly distributed among four seasons.
- *Surface condition:* For the majority of the elevated section crashes studied, the road surface was dry, with about 80% of the crashes taking place under such conditions.
- *Driver age:* The majority of drivers in the crashes on elevated sections, approximately 58%, were between the ages of 25 and 64 years. This indicates that middle-aged drivers are more likely to be involved in crashes on elevated sections compared to other age groups. On the other hand, young drivers, between the ages of 15 and 24 years, represented a quarter of all crashes that occurred on the selected elevated sections.
- *Driver gender:* The majority of elevated section crashes was caused by male drivers (58.98%), while female drivers were responsible for 29.7% of the crashes.
- *Driver condition:* Although it is expected for drivers to stay more alert while driving on elevated sections, the results showed that a significant portion (58.80%) of the drivers were either not paying attention or were distracted. On the other hand, instances of drivers under the influence of alcohol (2.67%) or drugs (0.56%) were relatively rare.
- *Vehicle type:* The predominant types of vehicles involved in elevated section crashes were passenger cars (46.12%), followed by light trucks (19.23%), and vans or SUVs (9.07%). Large trucks were involved in a comparatively small proportion of crashes, accounting for only 2.67%.

Figure 14. Crash characteristics for all selected elevated sections



Site by Site Crash Characteristics

A site-specific distribution of crash characteristics provides unique overrepresentation of features that may be exclusive to each individual site. Several patterns of crashes at each individual site may seem to mirror the patterns seen across all sites. For every location, the majority of crashes resulted in no injuries and involved drivers primarily between the ages of 25 to 64 who had been inattentive or distracted.

The most prevalent types of collisions were rear-end crashes, followed by single vehicle and sideswipe crashes. Except for Site 2, all rural sites have higher percentages of single-vehicle crashes. However, only Site 6 exceeds the 43.2% statewide average for rural interstates from 2015-2020 data. In contrast, urban sites (Site 1, Site 3, Site 4, Site 7, and Site 8) feature proportionately higher rear-end crashes, with Site 1 surpassing the 50.5% statewide average for urban interstates from the same data period.

Specific elevated section sites may have unique crash characteristics that set them apart from others. Such findings are summarized below from Figure 15:

- Site 1 (I-10 over Bonnet Carre Spillway) may be noted for a higher incidence of rear-end collisions, lane changing incidents, crashes over the weekend, crashes in dark-unlighted conditions, crashes involving passenger cars and van/SUV, and a higher prevalence of distracted driving compared to other sites.
- The Site 2 (Atchafalaya Basin Bridge) is characterized by a higher proportion of male drivers involved in crashes.
- Site 3 (I-110 over 67 Plank Rd & Evangeline Street) can be characterized by a higher concentration of crashes involving young drivers (under 24 years of age), female drivers, and passenger cars.
- Crashes at Site 4 (I-310 LaBranche Wetlands) were predominantly concentrated in the spring season, unlike the other sites.
- Among all sites, the lowest number of crashes occur in the daily quarter between midnight and 6 a.m., but Site 5 (I-10 Twin Span Bridge) has the largest percentage of crashes during this time period at 19.27%.
- In comparison to other sites, Site 6 (I-55 Manchac Swamp Bridge) experiences a high number of single vehicle crashes, particularly on surfaces that are not dry, which could be related to weather conditions with precipitation. Site 6 has a low AADT, but experiences a higher percentages of crashes with light trucks in comparison to other sites.

- Among all sites, Site 7 (I-220 over Cross Lake Shreveport) has the largest proportion of proceeding straight before crash.
- Site 8 (I-10 over Perkins Road) has the largest proportion of no injury crashes and crashes that occurred between 12 p.m. to 6 p.m.

Figure 15. Crash characteristics—Site by Site Analysis

Crash Characteristics

		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Severity	Fatal	0.28	0.98	0.35	0.00	0.91	1.17	0.00	0.04
	Severe	0.65	0.52	0.89	0.74	1.13	0.94	2.34	0.34
	Moderate	4.24	4.62	5.70	3.70	8.84	5.16	5.14	3.07
	Complaint	29.24	23.18	21.94	21.98	26.08	30.99	31.78	14.25
	No Injury	65.60	70.69	71.12	73.58	63.04	61.74	60.75	82.30
Manner of Collision	Head-on_RightAngle	0.79	0.52	0.69	1.48	0.91	0.23	1.40	0.61
	Other	1.12	14.45	15.26	13.83	11.79	8.22	14.95	33.04
	Rear_End	58.61	44.97	45.62	40.99	36.05	27.46	46.73	45.59
	Sideswipe	20.11	15.55	15.55	14.32	13.61	9.62	20.09	15.57
	Single_Vehicle	19.04	24.16	22.59	29.38	37.64	54.46	16.82	4.93
	Turning	0.33	0.35	0.30	0.00	0.00	0.00	0.00	0.27
Prior Movement	Changing lanes	20.90	8.79	8.42	11.36	10.43	7.98	5.61	6.21
	Entering or leaving_freeway	1.54	0.64	0.64	1.23	0.45	0.70	0.93	0.53
	Other	4.38	25.38	25.11	29.38	33.11	27.93	19.63	25.20
	Proceeding Straight	54.28	55.95	58.94	49.14	47.39	55.16	68.22	63.40
	Ran-off road	9.17	3.93	3.47	4.20	4.54	3.29	3.74	2.20
	Stopped or slowing to stop	9.73	5.32	3.42	4.69	4.08	4.93	1.87	2.46

Crash Environment

		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Crash Hour	6am-12pm	25.70	25.43	31.01	27.16	25.62	26.53	30.37	27.59
	6pm-12am	21.74	18.38	20.11	21.73	27.89	18.54	17.29	17.62
	12am-6am	16.71	14.51	11.44	14.32	19.27	18.08	5.61	6.14
	12pm-6pm	35.85	41.68	37.44	36.79	27.21	36.85	46.73	48.65
Day of Week	Friday to Sunday	53.54	51.33	38.29	40.00	44.44	38.26	39.72	41.53
	Monday to Thurday	46.46	48.67	61.71	60.00	55.56	61.74	60.28	58.47
Lighting Condition	Dark lighted	5.87	1.68	1.93	1.73	1.36	2.58	0.93	0.87
	Dark unlighted	29.61	10.06	10.55	11.60	15.19	15.73	4.67	5.00
	Dawn, Dusk	3.72	1.10	1.04	1.23	0.45	0.70	0.47	0.57
	Daylight	60.71	67.40	68.40	68.15	53.97	59.39	80.37	78.44
	Other	0.09	19.77	18.08	17.28	29.02	21.60	13.55	15.12
Season	Fall	27.75	27.34	28.33	17.53	28.34	25.35	25.70	29.25
	Spring	24.63	22.08	24.42	33.33	20.63	23.47	22.43	23.04
	Summer	21.46	28.79	21.59	27.65	28.12	27.70	21.96	23.15
	Winter	26.16	21.79	25.66	21.48	22.90	23.47	29.91	24.55
Surface Condition	Dry	85.10	78.38	76.87	86.17	73.24	57.28	83.18	82.87
	Non-dry	14.90	21.62	23.13	13.83	26.76	42.72	16.82	17.13

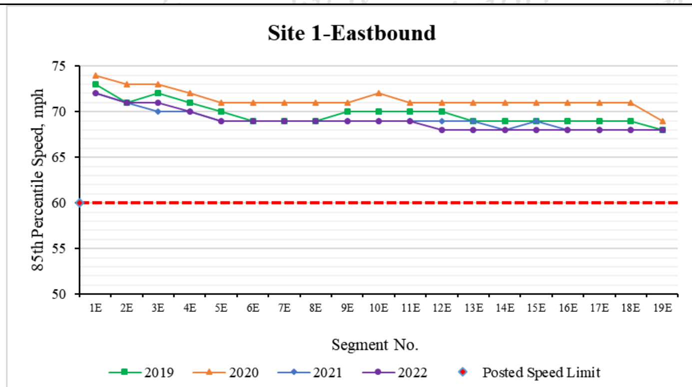
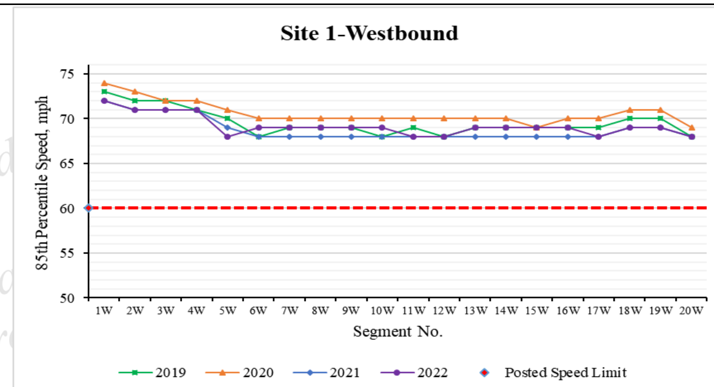
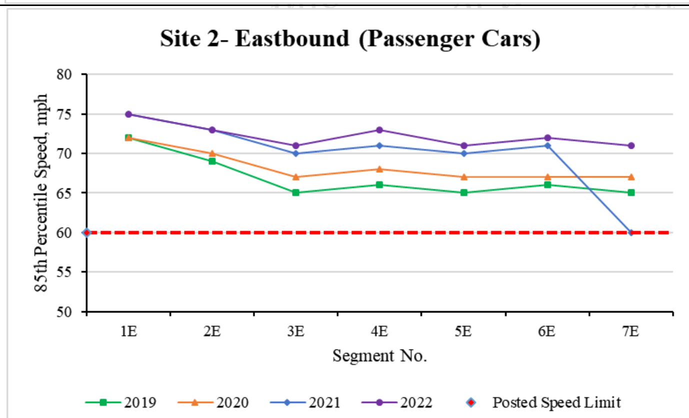
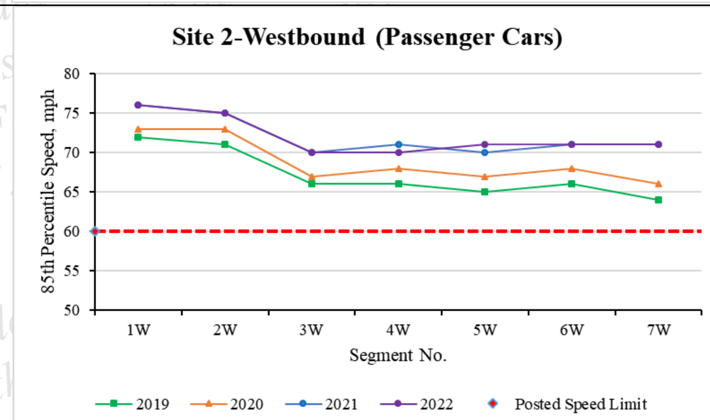
Driver and Vehicle Characteristics

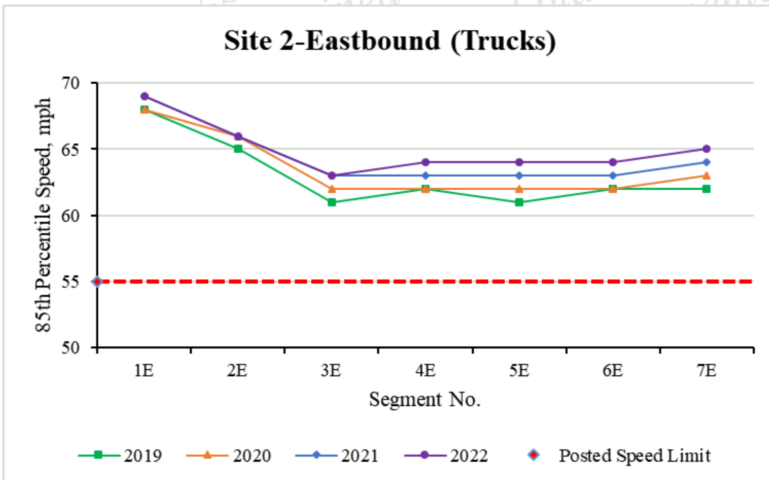
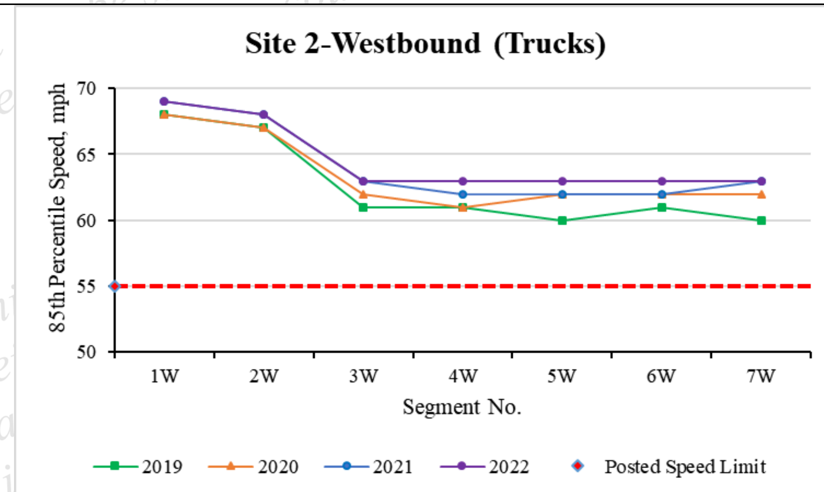
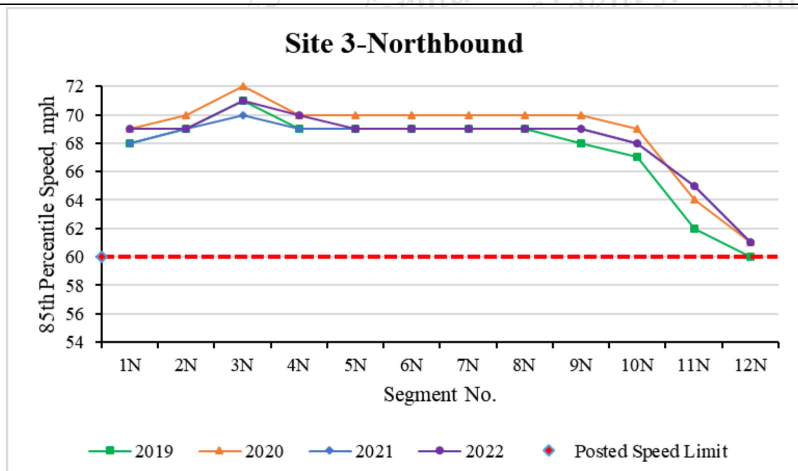
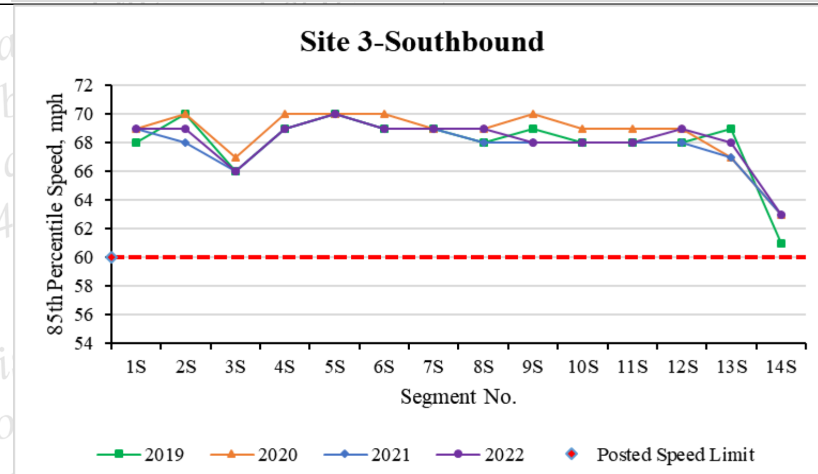
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Driver Age	24_or_younger	25.93	22.02	27.93	22.96	15.65	25.59	21.03	26.94
	25-64y	61.17	64.68	51.26	61.48	65.31	61.27	58.88	53.96
	65y_or_older	3.45	5.55	4.80	3.21	3.63	3.29	6.07	4.47
	Unknown	9.45	7.75	16.00	12.35	15.42	9.86	14.02	14.63
Driver Condition	Alcohol	4.80	3.01	1.88	3.70	4.76	3.05	1.40	0.87
	Drowsy_Asleep_Ill	4.10	5.32	1.39	4.94	3.17	6.10	3.27	0.80
	Drugs	0.79	0.81	0.05	0.74	2.04	1.17	0.47	0.23
	Inattentive_Distracted	72.49	54.57	44.73	68.15	47.17	64.79	34.58	62.71
	Normal	6.05	23.18	32.49	8.40	23.81	13.62	40.65	18.98
	Other	11.78	13.12	19.47	14.07	19.05	11.27	19.63	16.41
Driver Gender	Female	27.93	21.68	35.91	25.19	23.81	26.06	31.31	33.80
	Male	64.34	71.45	48.84	64.20	62.59	65.02	56.54	52.03
	Unknown	7.73	6.88	15.26	10.62	13.61	8.92	12.15	14.17
Vehicle Type	Large_Truck	5.40	2.89	1.73	0.99	1.81	1.41	0.93	1.78
	Light_Truck	21.46	21.45	14.96	22.47	19.73	27.00	24.30	16.98
	Other	2.75	31.50	23.87	26.17	24.72	23.71	23.83	31.94
	Passenger_Car	51.68	36.71	53.10	42.96	47.39	42.72	44.86	43.35
	Van_SUV	18.72	7.46	6.34	7.41	6.35	5.16	6.07	5.95

Speed Analysis Results by Site

Table 8 presents temporal and spatial trends of 85th percentile speeds for each of the eight sites according to the direction of travel depicted on Figures A1 to A8 in Appendix A. The PSL for each site is also referenced on each chart for ease of comparison. Speeding is said to occur when the estimated 85th percentile speed is above the PSL. The degree of speeding reflects the amount by which the 85th percentile speed exceeds the PSL for the segment. It appears that for all eight sites, speeding occurred frequently. The observable trends from the plots in Table 8 are presented next.

Table 8. Segment by segment yearly 85th percentile speed on all eight elevated sections in both directions

Site	Direction 1	Direction 2
1		
2 Passenger Vehicles		

Site	Direction 1	Direction 2
2 Trucks		
3		

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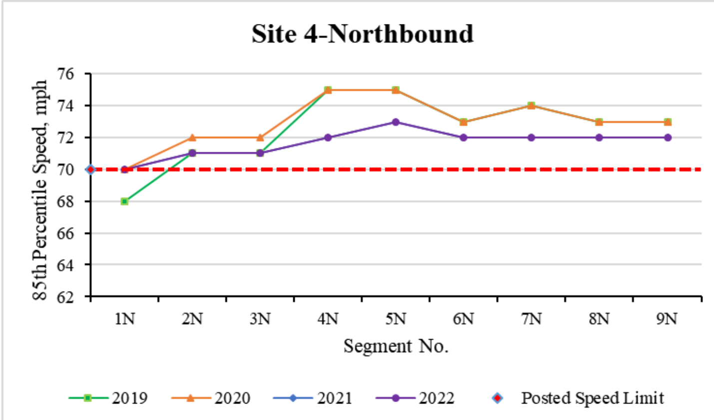
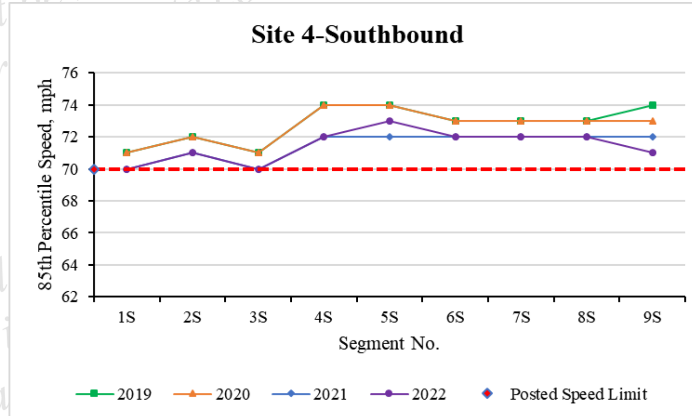
<tr><th>Site</th><th>Direction 1</th><th>Direction 2</th></tr>
<tr><td>4</td><td>
</td><td>
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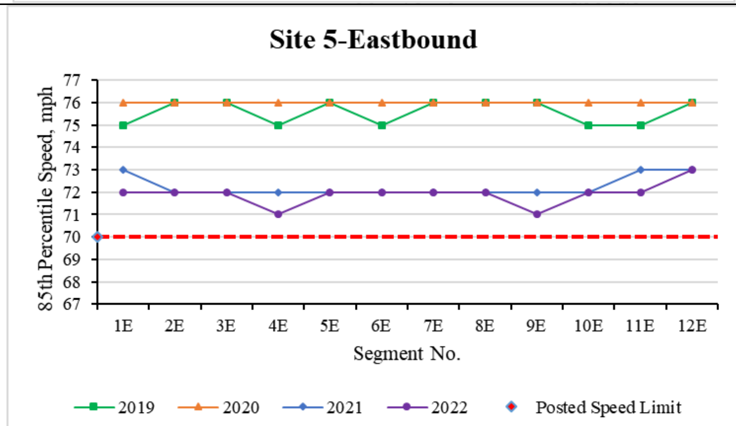
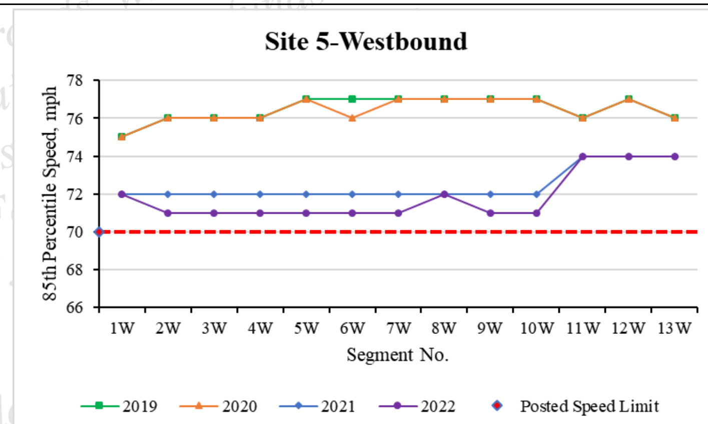
<tr><td>5</td><td>
</td><td>
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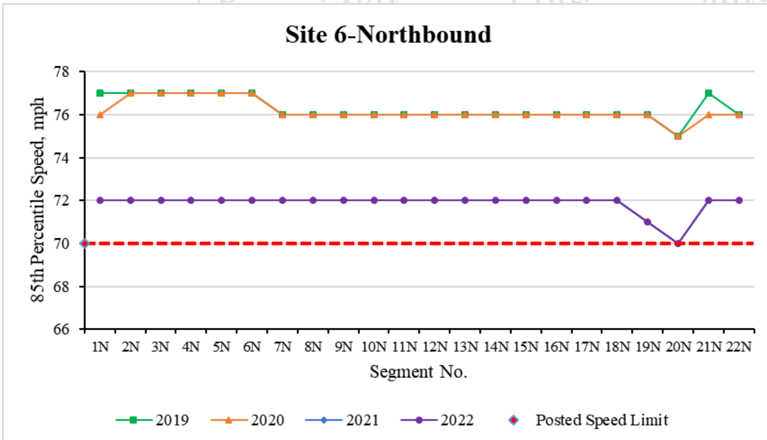
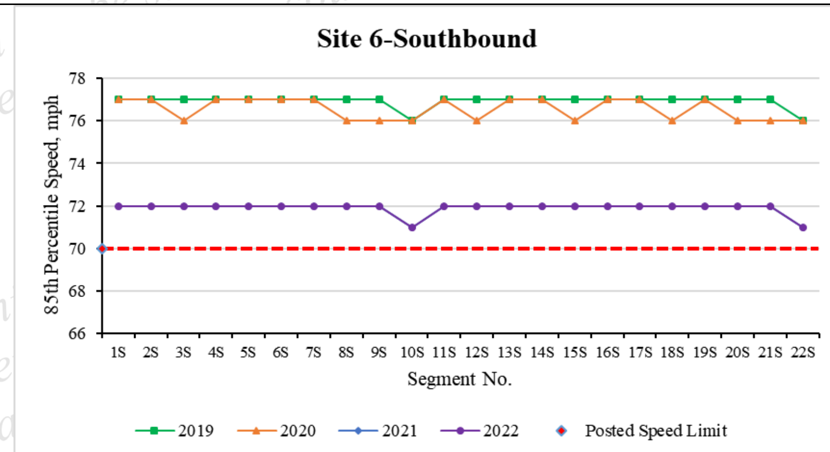
<table>
<tr><th>Site</th><th>Direction 1</th><th>Direction 2</th></tr>
<tr><td>6</td><td>
</td><td>
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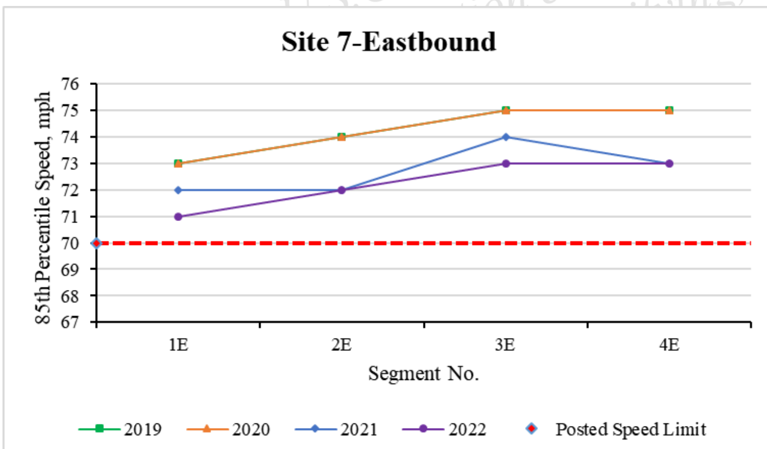
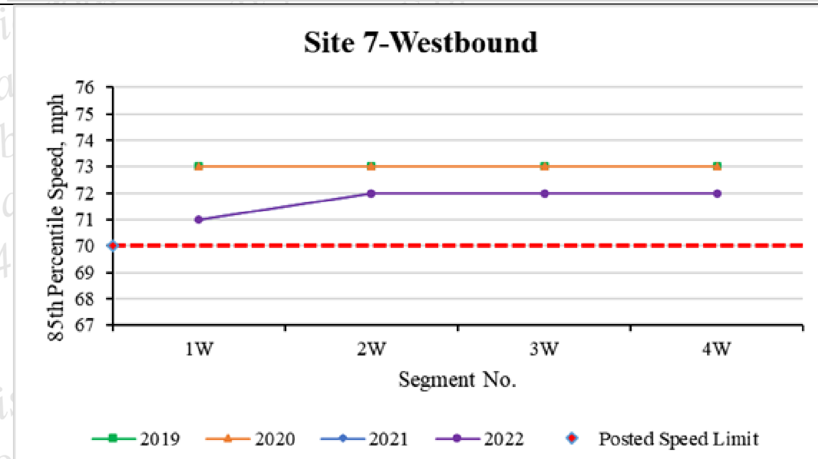
<tr><td>7</td><td>
</td><td>
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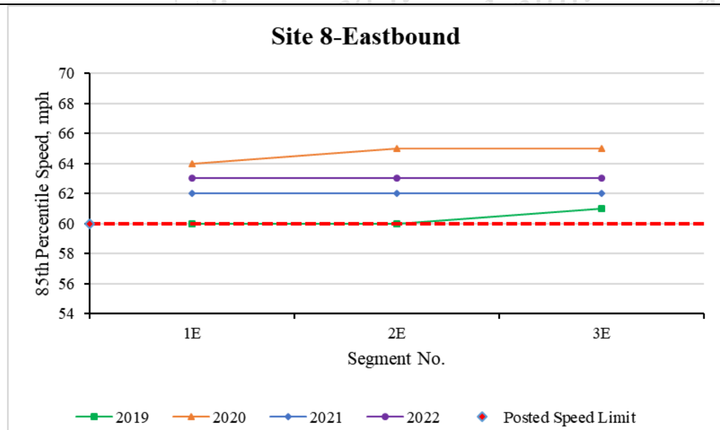
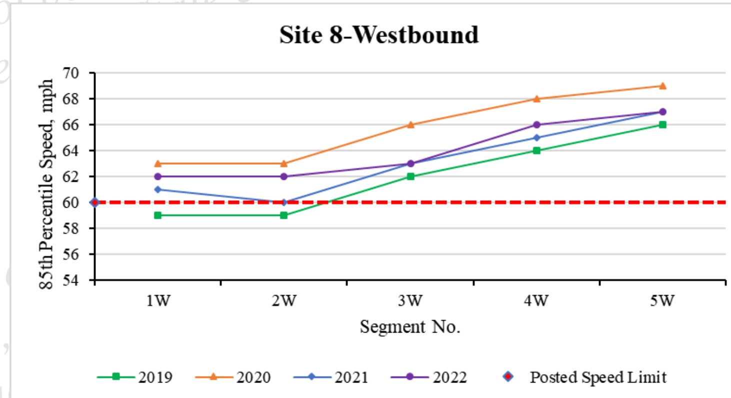
</table>

Site	Direction 1	Direction 2
8		

Site 2, Atchafalaya Basin Bridge on I-10, has an AADT of 37,000 to 43,000 vehicles per day (vpd). The site has almost all segments with an 85th percentile speed that exceeded the PSL by more than 5 mph. Despite the fact that passenger cars are expected to travel at a speed at or below 60 mph, the investigation revealed that the majority of passenger vehicle drivers exceed 70 mph in 2021 and 2022, as the figures on Table 8 indicates. Similarly, trucks are supposed to drive at or below 55 mph, the data indicated that most trucks are driven at speeds more than 60 mph.

Site 1, Bonnet Carre Spillway Bridge, a 12 mile long site which has two lanes in both direction but has a relatively higher AADT compared to Atchafalaya Basin Bridge, ranging from 67,000 to 76,000 vpd. Although the speed limit is 60 mph, the 85th percentile speed is at least 68 mph or above in both direction. Several segments appear to have even higher 85th percentile speed both northbound (1E, 2E, 3E) and southbound (1W, 2W, 3W).

Site 3, the 6-lane elevated section of Interstate 110 in Baton Rouge, has higher AADT that Atchafalaya Basin Bridge, ranging from 45,000 to 54,000 vpd. Despite having 60 mph speed limit, this elevated interstate bypass section have at least 66 mph 85th percentile speed for majority of the sections except segments 11N and 12N northbound and 14S.

Site 4, I-310, a 6-mile-long offshoot road of I-10, has an AADT of 50,000 to 57,000 vpd. Unlike Atchafalaya Basin Bridge, this site has a speed limit of 70 mph. This elevated segment has relatively lower number of speed limit violations, as the 85th percentile speed data suggest. The maximum 85th percentile speed northbound is 75 mph and southbound is 74 mph.

Site 5, the 7-mile-long 6-lane I-10 Twin Span Bridge, has an AADT of 64,200 to 86,000 vpd with 70 mph speed limit. The 85th percentile speed was 75 or 77 mph in 2019 and 2020, and it varied between 71 and 74 mph in 2021 and 2022. This indicates a decline in speed in 2021 and 2022.

Site 6, I-55 Manchac Swamp Bridge, is a 14-mile-long site with an AADT ranged from 20,000 to 30,000, the only site with AADT lower than Atchafalaya Basin Bridge. This rural site has a speed limit of 70 mph. In 2019 and 2020, the 85th percentile speed was in between 75 to 77 mph, 5 to 7 mph above speed limit. However, in 2020 and 2021 the 85th percentile speed decreased 70 to 72 mph.

Site 7, I-220 over Cross Lake Shreveport, is the 2-mile-long Shreveport bypass with AADT in between 62,300 to 69,700. The 85th percentile speed varied from 71 to 75 mph eastbound and was in between 71 to 73 mph.

Site 8 is a less than 2.5-mile stretch located on I-10 in Baton Rouge with 6 lanes and has an AADT ranging from 152,000 to 198,000 vpd, which is more than four times greater than the AADT of the Atchafalaya Basin Bridge. The speed limit was 60 mph, with 85th percentile speed variations observed in the northbound direction ranging from 60 to 65 mph, and in the southbound direction ranging from 59 to 69 mph. The 60 mph site has much lower speeding compared to two other longer sites with PSL of 60 mph, Site 1 and Site 2. This higher operating speed in Site 1 and Site may be attributed to dull and monotonous driving environment [35], [36] on longer elevated sites with relatively low PSL of 60 mph.

Sites 4, 5, 6, and 7 have a speed limit of 70 mph and exhibited similar 85th percentile speeds across most segments in 2019 and 2020, which were generally higher than the comparable speeds in 2021 and 2022. Notably, there was a decreasing trend in speeds for these sites with a 70 mph speed limit towards 2021 and 2022. Site 5, among the sites with a 70 mph speed limit, experienced a larger decrease in the 85th speed percentile. In 2019 and 2020, the 85th percentile speed was equal to or above the posted speed limit (PSL) plus 5 mph, but in 2021 and 2022, it dropped below the PSL+5 mph threshold.

The 85th percentile speed plot reveals variations in speed across segments. This speeding behavior can be influenced by a number of factors, for example, lane and shoulder width, presence of entry and exit and adjacent land use, change in speed limit, presence of speed enforcement, etc. The next section explores roadway and geometric characteristics of the segments associated with speeding.

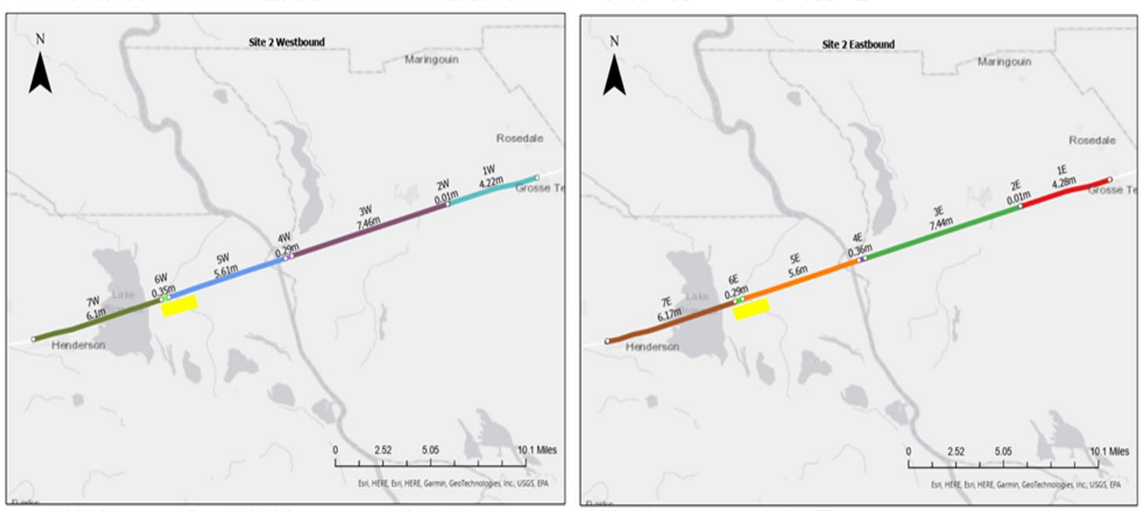
Elevated Section Characteristics and Speeding

Characteristics of cross-sectional elements, especially adequate lane width, shoulder width, and degree of curvature provide drivers with a greater sense of safety as well as easier navigation. On elevated sections, these elements may be geometrically restricted, but could still vary by site. From the speed analysis in the previous section, speeding issues were found to be dominant on almost all individual segments within each site regardless of geometric configuration especially in terms of lane width and shoulder width. The discussions on speed analysis results by site are based on the speed data of 2021 and 2022 focusing on more recent speeding trend.

Geometric Characteristics and Speeding on Atchafalaya Basin Bridge

Given the greater breadth of Atchafalaya Basin Bridge (Site 2) in this study, it is important to investigate the issue further on this site. This site is a four-lane (2-lane per direction) highway with considerably straight section with a lane width of 12 ft. A comparison of speed could not be made with varying lane width on Site 2. The only geometric configurations that were largely different were at the exit and entrance points. Additional merging or diverging lanes at entrance or exit, respectively, do create additional conflict points implying greater risk of speeding. The best candidate location for further exploration of any speeding pattern has been highlighted in Figure 16. In addition to entrance and exit, this small rural 4-lane section has almost no shoulder, whereas outside shoulder width of 10 ft. is maintained on major portions of the bridge. This candidate section is a 1.5 mile stretch section on both directions that crosses the Atchafalaya River, between 5E, 6E, 7E eastbound and 5W, 6W, 7W westbound.

Figure 16. Candidate location of further exploration of speeding issue on Site 2

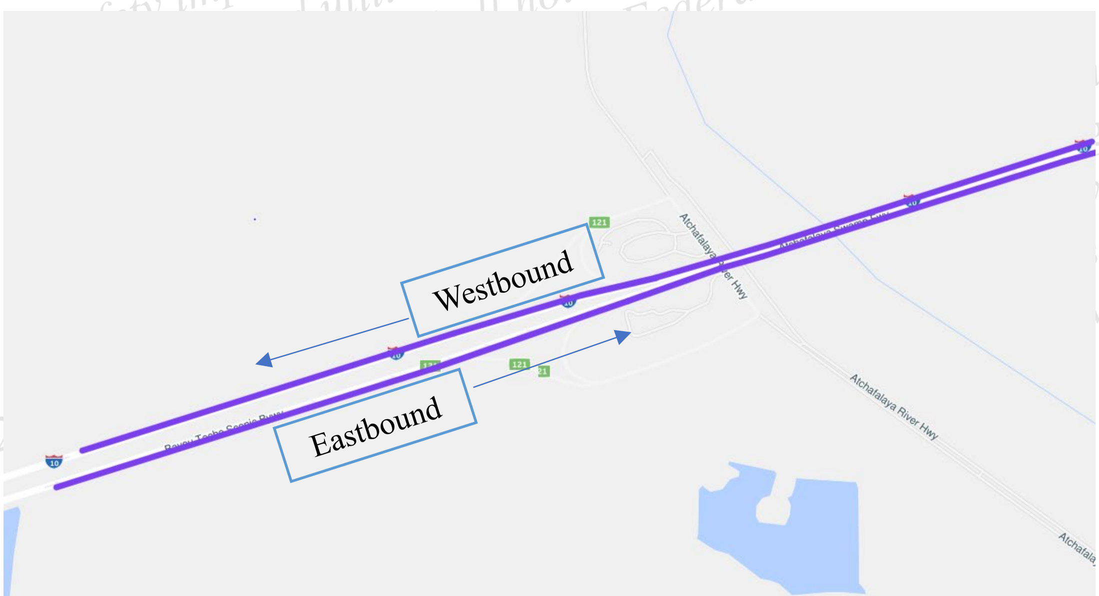


A “Google Street View” before this section eastbound can be seen in Figure 17, where a sign indicates “Narrow width shoulder next 1.5 miles.” This section covers 6W westbound and 6E eastbound partially covering other long TMC sections (Figure 16) — 5W and 7W westbound and 5E and 7E eastbound. Considering speed results on Table 8 on these large 4 TMC sections may not represent speeding data specifically for this 1.5

mile candidate section, an additional XD analysis covering only this candidate section (Figure 18) was performed. It should be noted that the XD segmentation on INRIX is not capable of segregating truck and passenger vehicle speed data as yet.

Figure 17. Eastbound Google Street view prior to the candidate location on Site 2 (source: maps.google.com)

Figure 18. XD section covering the candidate section on Site 2



The result of eastbound speed distribution on this candidate section can be found in Figure 19. The estimated 85th percentile speed on the combined XD segments covering the eastbound for collectively all vehicles was 67.8 mph. From the cumulative distribution as presented in Figure 20, the estimated 85th percentile speed on the combined XD segments covering the westbound for collectively all vehicles was 68.4 mph. Both are above the PSL of 60 mph (passenger vehicles) and 55 mph (trucks). Similar to the speed patterns on the remaining TMC segments of Site 2 as presented in Table 8, speed can still be in the range of PSL+5 mph or above despite the presence of narrow shoulders and increased conflict points due to entrance or exit.

Figure 19. Cumulative speed distribution of candidate section—eastbound

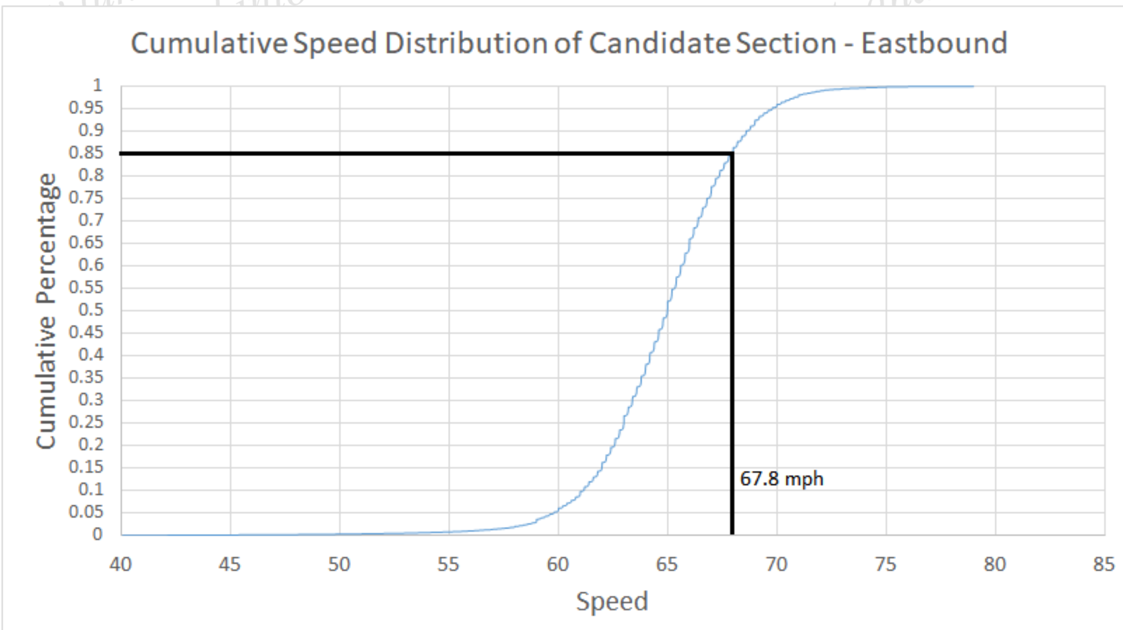
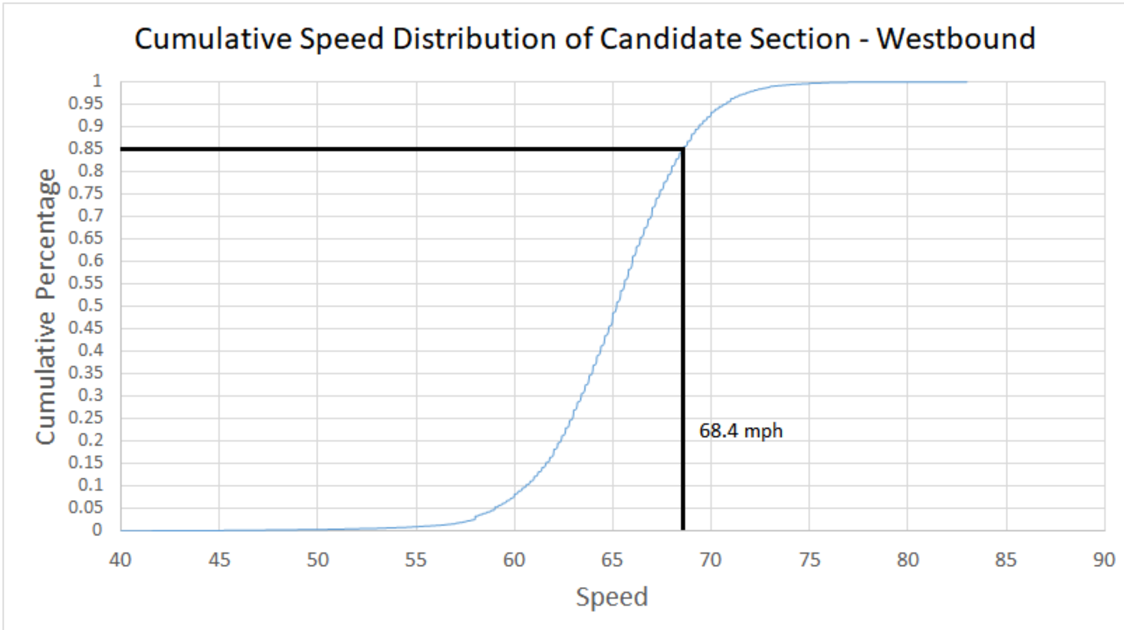


Figure 20. Cumulative speed distribution of candidate section—westbound



Roadway Characteristics and Speeding on Remaining Sites

Site 1: Site 1, the I-10 Bonnet Carre Spillway Bridge on Perkins Rd connects I-55 northbound and I-310 southbound, has an AADT higher than Atchafalaya Basin Bridge ranging from 67,000 to 76,000 vehicles per day (vpd) from 2020 and 2021 estimates. Similar to Site 2, this site has 4 lanes with 2 in each direction. Lane with and shoulder width on this site is consistently 12 ft. and 10 ft., respectively.

The excessive speeds were estimated by subtracting PSL from 85th percentile speed in 2021 and 2022, as presented in Table 9. Despite the large cross-sectional consistency over the site, on I-10, further east of the bridge the speed limit is increased to 70 mph, which probably explains the relatively higher speeding in the range of speed limit+10 mph on the site's 1E, 2E, 3E, 4E, and 1W, 2W, 3W, 4W segments. All of these high-speeding segments are in the eastern end portions of the bridge (see Figure A1). On the eastbound entrance of the site 1, drivers' may have taken an unexpectedly longer adjustment time to a lower PSL, transitioning from 70 mph to 60 mph. Similarly, westbound drivers may tend to speed up after the exit knowing a higher PSL ahead. Speed adjustment issues may have resulted in such high operating speeds in these segments.

Table 9. Geometric characteristics of Site 1 with speeding estimates

EB Segment	EB Degree of Speeding in 2021	EB Degree of Speeding in 2022	WB Segment	WB Degree of Speeding in 2021	WB Degree of Speeding in 2022
1E	12	12	1W	12	12
2E	11	11	2W	11	11
3E	10	11	3W	11	11
4E	10	10	4W	11	11
5E	9	9	5W	9	8
6E	9	9	6W	8	9
7E	9	9	7W	8	9
8E	9	9	8W	8	9
9E	9	9	9W	8	9
10E	9	9	10W	8	9
11E	9	9	11W	8	8
12E	9	8	12W	8	8
13E	9	8	13W	8	9
14E	8	8	14W	8	9
15E	9	8	15W	8	9
16E	8	8	16W	8	9
17E	8	8	17W	8	8
18E	8	8	18W	9	9
19E	8	8	19W	9	9
			20W	8	8

Note: PSL = Posted Speed Limit, 60 mph for Site 1; Degree of Speeding indicates the PSL subtracted from the 85th Percentile speed

Site 3: Site 3, I-110 over 67 Plank Road and Evangeline Street, is the Baton Rouge Bypass which has an AADT similar to Site 2 (Atchafalaya Basin Bridge), ranging from 45,000 to 54,000 vpd. Unlike Site 2, there are 6 lanes (3 in each direction). As presented in Table 10, shoulder width varied in the range of 0 to 20 ft., whereas the lane width was consistently 12 ft. Only three of the 26 segments had an 85th percentile speed less than 5 mph over the PSL of 60 mph. This site had 23 segments with high speeds. Even though all six lanes had a wide lane width and a narrow shoulder width, the 85th percentile speed was high.

Table 10. Geometric characteristics of Site 3 with speeding estimates

	Segment	Estimated Approx. Shoulder Width (ft.)	Degree of Speeding in 2021	Degree of Speeding in 2022
Northbound	1N	20	9	9
	2N	20	9	9
	3N	20	11	11
	4N	16 to 20	10	10
	5N	0 to 16	9	9
	6N	0	9	9
	7N	0	9	9
	8N	0	9	9
	9N	0	9	9

	10N	0	8	8
	11N	0 to 20	5	5
	12N	20	1	1
Southbound	1S	20	9	9
	2S	20	9	9
	3S	20	6	6
	4S	20	9	9
	5S	16 to 20	10	10
	6S	0 to 16	9	9
	7S	0	9	9
	8S	0	9	9
	9S	0	8	8
	10S	0	8	8
	11S	0	8	8
	12S	0	9	9
	13S	0	8	8
	14S	0 to 20	3	3

Note: PSL = Posted Speed Limit, 60 mph for Site 3; Degree of Speeding indicates the PSL subtracted from the 85th Percentile speed

A drop in speeding on segments 11N, 12N, and 14S was noticeable from Table 10 and the graphs in Table 8. This speed drop may be attributed to the sharp curve that can be spotted from the maps covering segments 11N, 12N, and 14S. Due to presumably large change in curvature in addition to multiple entrances and exits (presented in Figure 21), drivers are compelled to lower speed in these segments.

Figure 21. Site 3 section with curvature

Sites 4, 5, 6, 7: For sites 4, 5, 6, and 7, the 85th percentile speed for all segments was less than 5 mph above the posted speed limit in 2021 and 2022. All of these segments had a posted speed limit of 70 mph. The majority of these stretches have 12 to 13 ft. lane and 10 ft. shoulder. The results are summarized in Table 11.

Table 11. Characteristics of Sites 4, 5, 6 & 7 with speeding estimates

Site	Direction	Average AADT (vpd)	Estimated Approx. Lane Width (ft.)	Estimated Approx. Shoulder Width (ft.)	Maximum Degree of Speeding in 2021	Maximum Degree of Speeding in 2022
4 (4-lane) PSL: 70 mph	Northbound	50,000 to 57,000	12	10	2	3
	Southbound		12	10	3	3
5 (6-lane) PSL: 70 mph	Eastbound	86,200	12 to 13	10 to 20	3	3
	Westbound		12 to 13	10 to 20	2	4
6 (4-lane) PSL: 70 mph	Northbound	20,000 to 30,000	12	0 to 10	2	2
	Southbound		12	0 to 10	2	2
7 (6-lane) PSL: 70 mph	Eastbound	62,300 to 69,700	12	10	4	3
	Westbound		12	10	2	2

Note: PSL = Posted Speed Limit, 60 mph for all sites; Degree of Speeding indicates the PSL subtracted from the 85th Percentile speed

Site 8: In comparison to Site 2 (Atchafalaya Basin Bridge), this site 8 over Perkins Road in Baton Rouge is 8 times smaller in length (approximately 2.2 miles), however has 3 lanes in both directions and a shoulder width of up to 10 ft. Despite the speed limit of 60 mph, estimated 85th percentile speed on all XD eastbound segments of Site 8 was within the range of PSL+5 mph and westbound 85th percentile speed was also within PSL+5 mph for 2 out of 5 westbound XD segments in 2021 and 2022. No discernible characteristics can be found directly linking lane width and shoulder width with the degree of speeding between the PSL and 85th percentile speed in 2021 and 2022, as presented in Table 12. Therefore, exposure characteristics besides geometric characteristics require consideration.

Table 12. Geometric characteristics of Site 8 with speeding estimates

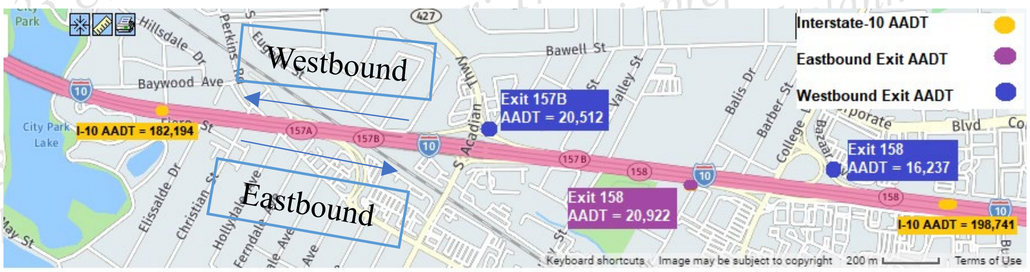
Seg-ment		Estimated Approx. Lane Width (ft.)	Estimated Approx. Shoulder Width (ft.)	Degree of Speeding in 2021	Degree of Speeding in 2022
Eastbound	1E	12	0 to 10	2	3
	2E	12	0 to 10	2	3
	3E	12	10	2	3
Westbound	1W	12	10	1	2
	2W	12	0 to 10	0	2
	3W	12	0 to 10	3	3
	4W	12	10	5	6
	5W	12	10	7	7

Note: PSL = Posted Speed Limit, 60 mph for Site 8; Degree of Speeding indicates the PSL subtracted from the 85th Percentile speed

Regardless of geometric characteristics, this I-10 site (Site 8) has several entry and exit points from and to Baton Rouge with a high volume of traffic. East direction of this site carries a large volume of traffic by merging I-10 and I-12. The average AADT of this site about 180,000 during 2019-2021, about 4.5 times of Site 2.

Figure 22 presents the Site 8 volume count stations and associated AADTs estimated in 2022. In addition to the AADTs estimated at the exits, the large difference between the AADT estimated outside the eastern end (198,741 vpd) and AADT estimated inside the site (182,194 vpd) suggest large movements in and out of this 2.2 mile site. Despite the high traffic volume on this site, significant number of merging/diverging vehicles are most likely preventing a high-speed platooning.

Figure 22. AADT at different points of the Site 8 and at exits



Results of Crash Hotspot Analysis

A total of 57 hotspot locations on eight selected sites were identified through the DBSCAN algorithm on ArcGIS. Individual frequency thresholds selected at 90th percentile for each site was applied. Identified hotspots were found to vary by crash rates, estimated as crashes per mile, and therefore, were ranked from highest to lowest crash rates. The list of all the hotspots, along with individual crash estimates and ranks, can be found in Appendix C. Table 13 summarizes the hotspot characteristics of all 8 sites by direction in terms of number of hotspots, length of hotspots, hotspot coverage, and ranking of hotspots. The hotspot coverage was calculated as the percentage of the total length of hotspots in relation to the total length of the site.

In addition to containing the top 5 hotspots, site 8 has the highest hotspot coverage as well as highest estimated crash rates, as presented in Table 13. In comparison to other sites, Site 6 exhibits the lowest crash rates overall as well as for number of hotspots. Site

2 - Atchafalaya Basin Bridge, despite being the longest, has comparatively low crash rates. Even though Site 7 is the shortest, it has high crash rates, with 332 crashes per mile northbound and 321.7 crashes per mile southbound.

Table 13. Hotspot summary by sites

Site	Direction	Site length (mile)	Crashes per mile	Total Hotspots	Total Length of Hotspots (mile)	Hotspot Coverage	Hotspot Crashes per mile	Hotspot Ranking: Lowest, Average, Highest
Site 1: I-10 over Bonnet Carre Spillway	east	12.03	101.0	4	2.02	17%	192.3	10, 13.5, 16
	west	12.23	76.4	3	2.34	19%	122.0	17, 18, 19
Site 2: I-10 over Atchafalaya Basin	east	24.15	37.0	4	2.63	11%	61.9	23, 30.8, 43
	west	24.04	35.1	5	4.68	19%	69.1	20, 30.2, 40
Site 3: I-110 (over 67 Plank Rd & Evangeline Street)	north	5.83	171.4	3	1.37	23%	302.1	8, 10.3, 12
	south	5.75	176.9	2	0.72	13%	474.1	6, 6.5, 7
Site 4: I-310 LaBranche Wetlands	north	5.29	35.9	2	0.93	18%	62.6	32, 32.5, 33
	south	5.17	41.8	3	1.25	24%	66.2	22, 27.7, 37
Site 5: I-10 Twin Span Bridge	east	6.65	38.3	5	2.18	33%	64.1	21, 30, 38
	west	7.02	26.6	3	1.84	26%	55.3	31, 33.7, 36
Site 6: I-55 Manchac Swamp Bridge	north	14.29	16.4	7	3.04	21%	32.2	42, 49.1, 57
	south	14.28	13.6	9	2.68	19%	31.4	41, 49.6, 56
Site 7: I-220 over Cross Lake Shreveport	north	1.96	67.9	1	0.25	13%	332.0	9, 9, 9
	south	1.92	43.2	1	0.26	14%	321.7	14, 14, 14
Site 8: I-10 Over Perkins Road	east	2.18	543.6	3	1.12	51%	654.1	1, 3.3, 5
	west	2.26	642.0	2	0.90	40%	861.6	2, 2.5, 3

Although the hotspot summary in Table 13 provides a comparable overview of the extent of crash concentration for all eight sites, discussions by sites combining pertinent roadway, crash and speeding pattern provide more context of identified hotspots. In the following subsections, the hotspots are further discussed in terms of key potential association with geometric configuration, prevalent crash characteristics, and degrees of speeding.

Since the hotspots do not necessarily have a precise spatial match with the predefined XD/TMC segments identified in the INRIX system, the following discussions are based on the XD/TMC segments that fully or largely encompass the hotspots. Site by site geometric characteristics often vary and were identified based on most prevailing ones that existed on the site in prior discussions. In the following subsections, they were further investigated aiming to identify most critical cross-sectional elements, as hotspots are often substantially shorter in length. Using the coordinates of crashes, prevalent crash characteristics of a hotspot were estimated from proportional odds of their percentages within the hotspot boundaries to their percentages within the entire site boundaries. To filter and identify key prevalent characteristics, two criteria were set up based on several trial runs — a minimum of 20% share of attribute/characteristic in the distribution of a specific variable within the hotspot, and the minimum estimated odds of 1.3 times compared to the whole site. The term "higher proportional odds" refer to odds higher than 1.3 times their percentages within the hotspot boundaries to their percentages within the entire site boundaries. These identified prevalent crash characteristics may not necessarily be causally inter-related.

Hotspot Segments on Site 2 – Atchafalaya Basin Bridge

Characteristics of Site 2 hotspots are presented in Table 14. The locations of hotspots on eastbound and westbound directions are presented in Figure 23 and Figure 24 respectively. Remaining hotspots are presented in Appendix D. Although these figures enumerate the segmentations required for DBSCAN algorithm to identify crash clusters i.e. hotspots, the order of the hotspots in Table 14 follow the numerical orders in those figures. The discussions on important crash characteristics of hotspots on Site 2 are below, in which hotspot number indicates overall rank of hotspot among all eight sites.

- *Hotspot with highest crash rate:* As presented in Table 14, highest crash rate on westbound direction on the Atchafalaya Basin Bridge was 89.32 crashes per mile (rank #20). It should be noted that this section was partly the candidate section identified on Figure 16 that had narrow shoulder. It partially implicates that the absence of shoulder along with increased conflict points due to entry/exit may potentially contribute to higher crash rates within a site.
- *Prevalent human factor:* Generally known to be underreported, along with most elevated sections, Site 2 has considerably large proportion of distraction/inattentiveness involved crashes at 54.57%. Two Site 2 hotspots, #20 and #40 overall, were found to have distracted/inattentive driving involved crashes with higher proportional odds.
- *Geometric factors of hotspots with higher odds of truck crashes:* The highest crash rate on eastbound direction were found in hotspot ranked #23, in which trucks can be specifically found to be among prevalent factors in crashes distributed within all vehicle categories. This hotspot also partially includes the eastbound entrance of the bridge. Trucks also tend to be driven at 10 mph above truck PSL (55 mph). From observation it was seen that, prior to the entrance, this hotspot segment partially includes relatively wider (>20 ft.) left shoulder besides 10 ft. right shoulder providing all drivers including truck drivers additional

comfort to speed up. Crashes with large truck account for 2.89% of total crashes in Site 2; however, large truck was involved in higher proportion of crashes on 2 other Site 2 hotspots ranked #25 and #28 in addition to hotspot ranked #23. All 3 hotspots do not visibly vary in terms of lane width (12 ft.) and right shoulder width (10 ft.). The difference between 85th percentile speed and PSL for truck (55 mph) is consistently above PSL+5 range, with degree of speeding being 8 mph on hotspots ranked #25, 10 mph on #23, and 11 mph on hotspot #28.

- *Manner of collisions by entry/exit:* Besides sideswipe crashes on hotspot #39, common types of prevalent collisions are – single vehicle and rear-end. Single vehicle crashes occurred largely on segments without entry/exit configuration on Site 2. In line with the common trend of large presence of rear-end crashes on interstates, they can be found on both types of sections – continuous segments and segments with entry/exit.
- *Changing lanes:* Prior movement of changing lanes can be found in hotspot ranked #40. Large trucks were not largely associated with this hotspot, this hotspot was rather associated with light trucks.
- *Others:* Non-dry surface condition remains a concern as it appears in most hotspots, #25, #28, #29, #39, and #43. Crashes with prior movement of stopped or slowing to stop mostly involve a disabled vehicle and can be particularly a challenging issue on segments with relatively narrow shoulder, hotspot #29 with 4 ft. shoulder.

Table 14. Hotspots on Site 2 and associated characteristics

	Length	Crashes/mile	#Hot-spot Rank	Entry/ Exit	LW/ SW	Prevalent Crash Characteristics	Pass. Veh. Max Degree of Speeding in 2022	Truck Max Degree of Speeding in 2022
Site 2 East	0.65	38.28	43	No	12/12	Crash Hour=6pm-12am Surface Condition=Non-dry, Manner of Collision=Single Vehicle	11	8
	0.83	**76.18**	**23**	**No**	**12/10**	**Driver Gender=Female, Vehicle Type=Large Truck, Manner of Collision=Single Vehicle**	**11**	**10**
	0.69	64.94	29	Yes	12/4	Season=Winter, Surface Condition=Non-dry, Manner of Collision=Rear-end, Prior Movement=Stopped or slowing to stop	11	9
	0.46	65.36	28	Yes	12/10	Surface Condition=Non-dry, Vehicle Type=Van/SUV, Vehicle Type=Large Truck	11	11
Site 2 West	0.62	48.54	39	No	12/10	Crash Hour=6am-12pm, Surface Condition=Non-dry, Driver Gender=Female, Manner of Collision=Single Vehicle, Manner of Collision=Sideswipe	11	8

	0.83	69.01	25	No	12/10	Crash Hour=6am-12pm, DOW=Mon to Thu, Season=Fall, Surface Condition=Non-dry, Vehicle Type=Large Truck, Manner of Collision=Single Vehicle	11	8
	0.44	45.98	40	No	12/10	Crash Hour=12am-6am, Season=Summer, Season=Fall, Lighting Condition=Dark (unlighted), Driver Condition=Inattentive/Distracted, Vehicle Type=Light Truck, Manner of Collision=Rear-end, Prior Movement=Changing lanes	11	8
	1.38	**89.32**	**20**	**Yes**	**12/1**	**Driver Condition=Inattentive/Distracted**	**11**	**8**
	1.42	65.45	27	Yes	12/5	Season=Winter	11	8

Note: PSL = Posted Speed Limit, 60 mph for Passenger Vehicles and 55 mph for Trucks on Site 2; LW= Lane Width; SW = Shoulder Width; Degree of Speeding indicates the PSL subtracted from the 85th Percentile speed

Figure 23. Hotspot locations for Site 2 Atchafalaya Basin Bridge—eastbound

Figure 24. Hotspot locations for Site 2 Atchafalaya Basin Bridge—westbound

Discussions on Hotspots of the Other Seven Sites

The characteristics of the hotspots are presented in Table 15. The rows with bold text represent the highest ranked hotspots with the largest crash rates for that site. The figures presenting the hotspots on other sites are included in Appendix D.

The primary crash type observed at the top eastbound hotspot in Site 1 was rear-end crashes, identified in hotspot #10. On the other hand, the primary crash type observed at the top westbound hotspot in Site 1 was sideswipe crashes, identified in hotspot #17. Additionally, hotspot #16 also showed a linkage to prior movement of changing lanes. Hotspot #19 mainly includes crashes that occurred during nighttime. Finally, hotspot #15 in Site 1 was found to include crashes involving young drivers aged 24 years or younger.

The combination of inattentive or distracted driving was found to be a common factor contributing to crashes in two hotspots in Site 3, specifically in hotspots #6 and #12. Hotspot #6, located in the southbound direction, was identified as the top hotspot in Site 3.

The top hotspots in Site 4, identified as #22 in the southbound direction and #32 in the northbound direction, were associated with non-dry conditions as well as large truck crashes. Hotspot #22 also included rear-end crashes and sideswipe crashes with prior movement of changing lanes, while hotspot #37 included rear-end crashes with stopped or slowing-to-stop movements. Hotspot #24 was also found to occur under nighttime and dark-unlighted conditions. In addition, several hotspots in Site 4 involved young drivers, specifically in hotspots #24, #32, and #33.

In Site 5, multiple hotspots (#21 and #35) were identified as being associated with sideswipe crashes in tandem with prior movement of changing lanes. Unlike the previously discussed hotspots, several hotspots in Site 5 were associated with single vehicle crashes and prior movement of running off road (#34 and #38). Other notable attributes identified in Site 5 hotspots were inattentive or distracted driving (#21, #26, #34, and #38), non-dry surface conditions (#26, #34, #36), and crashes occurring on Fridays to Sundays (#30, #35, and #38).

The hotspots in Site 6 were characterized by several notable attributes, such as driver age groups of 24 or younger (#41, #48, and #52) and 25 to 64 years old (#44, #49, and #56). Inattentive and distracted driving also appeared in several hotspots (#41, #49, #54, and

#56), and one hotspot included drowsy driving (#53). Furthermore, several hotspots included single vehicle, sideswipe, and rear-end crashes, as well as prior movement of changing lanes and running off the road. Consistent with relatively higher proportion of crashes on non-dry surface (Figure 15), hotspots #44 and #55 also show non-dry surface as a prevalent characteristics in this site.

Site 7 had two hotspots, each in one direction. The northbound hotspot (#9) has 12pm-6pm, Fall, 24 or younger aged drivers. The southbound hotspot has 12pm-6pm, inattentive or distracted driving. Site 8, despite possessing a large frequency of crashes, had no specific prevalent characteristics with higher odds compared non-hotspot sites.

Table 15. Hotspots on remaining sites and associated characteristics

Site	Length	Crashes per mile	Overall Hotspot Rank	Entry/ Exit	LW/SW (ft.)	Prevalent Crash Characteristics	PSL	Max Degree of Speeding in 2022
Site 1 West	1.23	124.08	18	Yes	12/10	Driver Gender=Female	60	11
	0.48	97.51	19	No	12/12	Crash Hour=6pm-12am, Crash Hour=12am-6am	60	9
	0.63	**136.51**	**17**	**Yes**	**12/10**	**Crash Hour=12pm-6pm, Season=Winter, Surface Condition=Non-dry, Manner of Collision=Sideswipe, Prior Movement=Changing lanes**	**60**	**9**
Site 1 East	**0.53**	**259.05**	**10**	**Yes**	**12/10**	**Crash Hour=12pm-6pm, Lighting Condition=Daylight, Vehicle Type=Light Truck, Vehicle Type=Van/SUV, Manner of Collision=Rear-end**	**60**	**12**
	0.49	165.98	15	Yes	12/10	Crash Hour=12pm-6pm, Driver Gender=Female, Driver Age=24 or younger	60	12
	0.52	199.23	13	No	12/10	Crash Hour=12pm-6pm, Lighting Condition=Daylight, Vehicle Type=Light Truck, Vehicle Type=Van/SUV	60	9
	0.49	139.34	16	Yes	12/11	Season=Winter, Vehicle Type=Van/SUV, Manner of Collision=Sideswipe, Prior Movement=Changing lanes	60	8
Site 3 North	0.45	222.47	12	Yes	12/≤1	Driver Condition=Inattentive/Distracted, Manner of Collision=Rear-end	60	8
	0.45	**439.29**	**8**	**Yes**	**12/≤1**	**Crash Hour=6am-12pm, Season=Winter**	**60**	**5**
	0.46	245.65	11	Yes	12/≤1	Crash Hour=6am-12pm, Vehicle Type=Light Truck	60	9
Site 3 South	0.26	466.67	7	Yes	12/≤1	None	60	8
	0.46	**478.26**	**6**	**Yes**	**12/1**	**Crash Hour=6am-12pm, Driver Condition=Inattentive/Distracted, Vehicle Type=Van/SUV, Manner of Collision=Rear-end**	**60**	**3**
Site 4 North	0.46	61.54	33	Yes	12/10	Crash Hour=6am-12pm, Season=Summer, Driver Age=24 or younger, Manner of Collision=Sideswipe	70	0
	0.47	**63.69**	**32**	**Yes**	**12/10**	**Season=Spring, Surface Condition=Non-dry, Driver Age=24 or younger, Vehicle Type=Large Truck, Manner of Collision=Sideswipe, Prior Movement=Changing lanes**	**70**	**2**
Site 4 South	0.45	75.72	24	Yes	12/10	Crash Hour=6pm-12am, Crash Hour=12am-6am, Lighting Condition=Dark (unlighted), Driver Age=24 or younger	70	0
	0.50	50.40	37	No	12/10	Crash Hour=6am-12pm, Season=Spring, Manner of Collision=Rear-end, Prior Movement=Stopped or slowing to stop	70	2
	0.31	**77.92**	**22**	**No**	**12/10**	**Season=Spring, Surface Condition=Non-dry, Vehicle Type=Light Truck, Manner of Collision=Rear-end**	**70**	**2**
Site 5 East	0.41	68.97	26	No	12/12	Crash Hour=12am-6am, Season=Spring, Surface Condition=Non-dry, Driver Condition=Inattentive/Distracted, Vehicle Type=Van/SUV,	70	2

Site	Length	Crashes per mile	Overall Hotspot Rank	Entry/ Exit	LW/SW (ft.)	Prevalent Crash Characteristics	PSL	Max Degree of Speeding in 2022
						Manner of Collision=Single vehicle, Prior Movement=Ran-off road		
	0.57	**80.28**	**21**	**No**	**12/12**	**Crash Hour=12pm-6pm, Season=Spring, Driver Gender=Female, Driver Condition=Inattentive/Distracted, Vehicle Type=Van/SUV, Manner of Collision=Single vehicle, Manner of Collision=Sideswipe, Prior Movement=Changing lanes**	**70**	**2**
	0.41	49.02	38	No	12/12	Crash Hour=12am-6am, DOW=Fri to Sun, Lighting Condition=Dark (unlighted), Driver Gender=Female, Driver Age=24 or younger, Driver Condition=Inattentive/Distracted, Vehicle Type=Van/SUV, Manner of Collision=Single vehicle, Prior Movement=Ran-off road	70	2
	0.41	51.34	35	No	12/12	Crash Hour=12am-6am, DOW=Fri to Sun, Season=Winter, Vehicle Type=Van/SUV, Manner of Collision=Rear-end, Manner of Collision=Sideswipe, Prior Movement=Changing lanes	70	2
	0.39	64.43	30	Yes	12/11	Crash Hour=12pm-6pm, DOW=Fri to Sun, Season=Spring, Vehicle Type=Van/SUV	70	2
Site 5 West	1.22	54.78	34	No	12/12	Crash Hour=6am-12pm, Season=Spring, Surface Condition=Non-dry, Lighting Condition=Daylight, Driver Gender=Female, Driver Condition=Inattentive/Distracted, Manner of Collision=Single vehicle, Prior Movement=Ran-off road	70	1
	0.25	**64.26**	**31**	**Yes**	**12/12**	**Crash Hour=12am-6am, Season=Fall, Driver Gender=Female, Manner of Collision=Rear-end**	**70**	**4**
	0.37	51.08	36	Yes	12/11	Crash Hour=6am-12pm, Season=Winter, Surface Condition=Non-dry	70	4
Site 6 North	1.02	31.47	50	No	12/10	DOW=Mon to Thu, Season=Fall, Manner of Collision=Sideswipe, Prior Movement=Changing lanes	70	2
	0.25	32.52	48	No	12/10	Season=Spring, Driver Age=24 or younger, Vehicle Type=Light Truck, Manner of Collision=Rear-end	70	2
	0.25	36.00	46	No	12/10	Crash Hour=6am-12pm, Crash Hour=12am-6am, Season=Summer, Manner of Collision=Rear-end, Manner of Collision=Sideswipe	70	2
	0.61	**39.41**	**42**	**Yes**	**12/10**	**Crash Hour=12pm-6pm, Season=Spring, Vehicle Type=Light Truck**	**70**	**2**
	0.41	21.90	57	No	12/10	Crash Hour=12pm-6pm, DOW=Mon to Thu, Season=Summer, Season=Fall, Lighting Condition=Daylight, Vehicle Type=Light Truck, Manner of Collision=Sideswipe	70	2
	0.26	34.09	47	No	12/10	Crash Hour=12pm-6pm, Crash Hour=12am-6am, DOW=Mon to Thu, Season=Winter, Manner of Collision=Rear-end, Manner of Collision=Sideswipe	70	2
	0.25	28.46	54	No	12/10	Crash Hour=12pm-6pm, Crash Hour=12am-6am, Season=Spring, Season=Summer, Driver Gender=Female, Driver Condition=Inattentive/Distracted, Vehicle Type=Van/SUV, Vehicle Type=Large Truck, Manner of Collision=Single vehicle, Prior Movement=Ran-off road	70	2
Site 6 South	0.25	28.00	55	No	12/10	Crash Hour=12am-6am, DOW=Mon to Thu, Season=Spring, Season=Fall, Surface Condition=Non-dry, Lighting Condition=Dawn/Dusk, Driver Gender=Male, Vehicle Type=Light Truck, Manner of Collision=Rear-end, Prior Movement=Ran-off road	70	2
	0.24	37.34	45	No	12/10	Crash Hour=12am-6am, DOW=Mon to Thu, Season=Spring, Vehicle Type=Passenger Car, Manner of Collision=Rear-end	70	2
	0.55	28.88	52	No	12/10	Season=Spring, Driver Age=24 or younger, Vehicle Type=Passenger Car	70	2

Site	Length	Crashes per mile	Overall Hotspot Rank	Entry/ Exit	LW/SW (ft.)	Prevalent Crash Characteristics	PSL	Max Degree of Speeding in 2022
	0.29	27.21	56	No	12/10	Crash Hour=6am-12pm, Lighting Condition=Daylight, Driver Age=25-64y, Driver Condition=Inattentive/Distracted, Manner of Collision=Single vehicle, Prior Movement=Ran-off road	70	2
	0.23	29.79	51	No	12/10	Crash Hour=6pm-12am, Crash Hour=12am-6am, DOW=Mon to Thu, Season=Winter, Season=Fall, Lighting Condition=Dark (unlighted), Vehicle Type=Van/SUV, Manner of Collision=Sideswipe, Prior Movement=Changing lanes, Prior Movement=Ran-off road	70	2
	0.22	32.11	49	No	12/10	Crash Hour=12am-6am, DOW=Mon to Thu, Lighting Condition=Dark (unlighted), Driver Age=25-64y, Driver Condition=Inattentive/Distracted, Vehicle Type=Light Truck, Vehicle Type=Van/SUV, Prior Movement=Changing lanes	70	2
	0.25	**39.53**	**41**	**No**	**12/10**	**Crash Hour=12am-6am, DOW=Mon to Thu, Season=Spring, Driver Gender=Female, Driver Age=24 or younger, Driver Condition=Inattentive/Distracted, Vehicle Type=Large Truck, Manner of Collision=Sideswipe**	**70**	**2**
	0.21	37.74	44	No	12/10	Crash Hour=12pm-6pm, Season=Winter, Surface Condition=Non-dry, Driver Gender=Female, Driver Age=25-64y, Vehicle Type=Passenger Car, Vehicle Type=Van/SUV, Manner of Collision=Single vehicle	70	2
	0.42	28.64	53	No	12/10	Crash Hour=6am-12pm, DOW=Mon to Thu, Season=Winter, Driver Condition=Drowsy/Asleep/Ill, Vehicle Type=Van/SUV, Manner of Collision=Rear-end	70	2
Site 7 North	**0.25**	**332.02**	**9**	**Yes**	**12/10**	**Crash Hour=12pm-6pm, Season=Fall, Driver Age=24 or younger**	**70**	**1**
Site 7 South	**0.26**	**178.29**	**14**	**Yes**	**12/10**	**Crash Hour=12pm-6pm, Driver Condition=Inattentive/Distracted**	**70**	**1**
Site 8 East	0.34	660.71	4	Yes	12/≤1	None	60	3
	0.50	522.00	5	Yes	12/≤1	None	60	3
	0.28	**882.14**	**1**	**Yes**	**12/≤1**	**None**	**60**	**3**
Site 8 West	0.44	857.80	3	Yes	12/≤1	None	60	2
	0.46	**865.22**	**2**	**Yes**	**12/≤1**	**None**	**60**	**3**

Comparison of Characteristics Remaining Sites with Site 2

Prevalence of rear-end crashes, inattentive or distracted driving are common findings of these seven sites which were also identified in Site 2 – Atchafalaya Basin Bridge. Hotspots with prevalent prior movement of 'changing lanes' had a strong association with light truck and/or van/SUV. No prevalent presence of large truck can be found in those hotspots. In several cases, this movement may potentially be linked to largely sideswipe crashes.

Site 2 has the second highest percentage of total hotspot length with non-dry conditions as a factor. Estimated length of hotspots with non-dry condition as a factor in Table 14 and 15 and total length of hotspots in Table 12 showed, out of all the hotspots in Site 2, 44% had non-dry conditions as a factor. Site 5 also had a high percentage of total hotspot length with non-dry conditions as a factor at 50%, while Site 1, Site 4, and Site 6 had lower percentages at 14%, 36%, and 8% respectively..

Site 2 – Atchafalaya Basin Bridge featured several hotspots with large truck, hotspots ranked #32 (Site 4 north), #41 (Site 6 south), and #54 (Site 6 North). All of these hotspots have a PSL of 70 mph and interestingly the overall estimated speeding of 2 mph based on 85th percentile speed can be observed. These hotspots are also geometrically similar, with a 12 ft. lane and a 10 ft. shoulder. Only two sites featured hotspots with large trucks as a factor. Site 2 had the highest percentage of total hotspot length affected at 29%, with 2.12 miles of its total 7.32 miles of hotspots involving large trucks. Site 4 had the second highest percentage of total hotspot length affected by large trucks at 21%, while sites 1, 3, 5, 6, and 7 had no hotspots with large trucks as a factor.

Although no presence of any association of age group can be found in site 2 – Atchafalaya Basin Bridge, several hotspots in remaining seven sites had young driver age group (24 or younger) prevalently present. A temporal pattern of crashes cannot be detected with hotspots associating any geometric or speeding characteristics.

Results of Truck Lane Restriction Compliance

Three types of vehicle counts – total vehicles, trucks, and trucks on the left lane – were obtained before estimating the compliance of truck lane restriction on site 2, Atchafalaya

Basin Bridge. These counts were produced by running the recorded live feed of DOTD cameras (locations presented in Figure 7 on Site 2 map) through the DPM system.

Estimated Compliance of Truck Lane Restrictions

The compliance rate for truck lane restrictions, which require driving in the right lane, was estimated by analyzing instances of non-compliance, which are less frequent. Non-compliance rates were calculated for each camera location by dividing the average truck volume in the left lane by the total average truck volume, using hourly video data from the DPM. These calculations were also manually verified by counting the instances of non-compliance. Both DPM and manual counts are presented in Table 16. Two camera systems (LAF-CAM-047 and LAF-CAM-061) could capture videos in both directions. More details of the selected video counts are presented in Appendix E.

Table 16. Site 2 camera locations and associated counts

Camera ID	Dir.	DPM				Manual			
		Avg Veh	Avg Truck (% Avg Veh)	Avg Truck on left lane	% Lane Non-Compliance	Avg Veh	Avg Truck (% Avg Veh)	Avg Truck on left lane	% Lane Non-Compliance
LAF-CAM-047	East	2,892.2	836.7 (28.9%)	165.0	19.7%	3,112.0	911.5 (29.3%)	165.2	18.1%
LAF-CAM-061	East	2,747.0	993 (36.1%)	218.0	22.0%	2,778.5	1,000.3 (36%)	222.8	22.3%
LAF-CAM-007	West	3,132.1	919.1 (29.3%)	172.2	18.7%	3,203.9	923.1 (28.8%)	164.8	17.9%
LAF-CAM-011	West	3,242.0	1,014 (31.3%)	179.0	17.7%	3,058.2	969.6 (31.7%)	171.8	17.7%
LAF-CAM-047	West	3,009.0	951 (31.6%)	192.5	20.2%	3,048.3	964.7 (31.6%)	169.0	17.5%
LAF-CAM-060	West	3,353.0	1,258 (37.5%)	253.0	20.1%	3,231.0	1,096 (33.9%)	221.0	20.2%
LAF-CAM-061	West	2,652.6	972.2 (36.7%)	223.0	22.9%	2,624.0	911.6 (34.7%)	226.2	24.8%

Both the DPM counts and manual counts suggest truck lane non-compliance appears to be around 20%. From the DPM estimates, the average percentages of trucks in the total vehicle composition vary from 28.9% to 37.5%, whereas the non-compliance of truck lane restriction varies from 17.7% to 22.9% meaning the compliance of truck lane restriction varies from 77.1% to 82.3%. According to the manual counts, the percentages of trucks in the total vehicle composition vary from 28.8% to 36%, whereas the non-compliance of truck lane restriction varies from 17.5% to 24.8%. A direct correlation may exist between truck percentage and non-compliance of lane restriction, as the Pearson correlation coefficient between those two from the DPM count is 0.685 (moderate correlation) and from the manual count is 0.797 (strong correlation)[1] [37].

Estimated Discrepancies in Vehicle Counts

The detection, classification, and count of vehicles in the DPM system are expected to be highly accurate, within +/-5% error rate for intersections and even higher accuracy for continuous segments. However, a difference on a larger scale has been found to exist for a number of camera locations, as the absolute differences between the DPM and manual count have been presented in Table 17. The largest difference in the count of total vehicles on average (7.1%) was found in the LAF-CAM-047 camera capturing eastbound traffic flow. The largest differences in total truck counts and truck counts on the left lane (i.e. non-compliant to lane restrictions), 14.8% and 14.5% respectively, were in the counts of the video feed of the camera LAF-CAM-060.

Observing several runs of the vehicle detection from the vehicle trajectories (Figure 12) through the polygons (Figure 11), multiple issues have been detected that possibly have contributed to the count discrepancies besides affected visibility due to weather conditions. As described earlier, the software detects FHWA traffic classes 7 through 12 as "Trucks" (presented in Figure 18). However, the software may overestimate some counts of trucks, as class 6 and class 7 can only be visually differentiated by axle number, which is often not clear from the video due to the position of the camera. Second, the trajectories of two vehicles traveling alongside occupying both lanes through the polygons (Figure 11) misjudge them as one truck. Third, the presence of camera location may have affected accurate detection, classification, and count of vehicle types. For example, the largest discrepancies can be found in the total truck count and left lane truck count are for the camera ID LAF-CAM-060 (Table 17). This could very well be due to the location of the camera. This camera location may be deemed as non-ideal as per the instructions of the DPM.

[1] Strength of correlation: 0-0.10 = Negligent, 0.1-0.39 = Weak, 0.4-0.69 = Moderate, 0.7-0.89 = Strong, 0.9-1 = Very Strong

Figure 25. LAF-CAM-060 camera location possibly affecting westbound truck count

Table 17. Estimated differences between the DPM and manual counts

Camera ID	Direction	Absolute difference: DPM vs. Manual Count		
		Total Vehicles	Total Truck	Trucks on Left Lane
LAF-CAM-047	East	7.1%	8.2%	0.1%
LAF-CAM-061	East	1.1%	0.7%	2.1%
LAF-CAM-007	West	2.2%	0.4%	4.5%
LAF-CAM-011	West	6.0%	4.6%	4.2%
LAF-CAM-047	West	1.3%	1.4%	13.9%
LAF-CAM-060	West	3.8%	14.8%	14.5%
LAF-CAM-061	West	1.1%	6.6%	1.4%

Compliance of Truck Lane Restrictions and Segment Characteristics

The geometric, speeding characteristics and truck volumes associated with the camera locations are presented in Table 18. LAF-CAM-047 and LAF-CAM-060 are located around entry/exit sections with narrow shoulders (1 ft. or less). The non-compliance rate of truck lane restriction is 18.1% (LAF-CAM-047, East), 17.5% (LAF-CAM-047, West), and 20.2% (LAF-CAM-060, West). The camera locations with the two highest non-compliance rates are ID LAF-CAM-061 west (24.8%) and ID LAF-CAM-061 east (22.3%), which are hotspots in both directions, ranked #25, and #23. Both non-accessible sections had a 12 ft. lane and a 10 ft. shoulder. This may imply trucks are slightly less likely to comply with lane restrictions at sections without access. Nevertheless, non-compliance of lane restriction exists regardless of geometric configuration. Truck speed may not also be correlated with the non-compliance rate. The findings of truck percentage and crash characteristics on the other sites are as follows:

- Sections with higher truck percentages will more likely to be a crash hotspots (Table 18). 2 out of 3 locations with large truck percentage can be directly linked to truck-involved crashes, as the large truck has been identified as a factor in those crashes.
- LAF-CAM-061 east camera with 36% trucks is located in hotspot #23 (Table 14). In addition the factor, 'Vehicle Type=Large Truck,' other associated characteristics are - Driver Gender=Female, and Manner of Collision=Single Vehicle.
- LAF-CAM-061 west camera with 34.7% trucks is located in hotspot #25. In addition the factor, 'Vehicle Type=Large Truck,' other attributes are - Crash Hour=6am-12pm, DOW=Mon to Thu, Season=Fall, Surface Condition=Non-dry, Manner of Collision=Single Vehicle.
- LAF-CAM-060 west camera 33.9% trucks is located in hotspot #20. Although highest in crash rate, the hotspot containing this location doesn't include 'Vehicle Type=Large Truck' as a factor, the only included factor is 'Driver Condition=Inattentive/Distracted.'

Table 18. DOTD CCTV camera location and associated site characteristics

Camera ID	Dir.	PV Speed		Truck Speed		LW/SW (ft.)	Hotspot #	Avg Truck (% Avg Veh)	Truck Lane Non-Compliance	Entry/Exit
		2021	2022	2021	2022					
LAF-CAM-047	East	70	71	63	63	12/≤1	N/A[1]	911.5 (29.3%)	18.1%	Yes
LAF-CAM-061	East	60	71	64	65	12/10	23	1,000.3 (36%)	22.3%	No
LAF-CAM-007	West	71	71	63	63	12/10	N/A	923.1 (28.8%)	17.9%	No
LAF-CAM-011	West	70	70	63	63	12/12	N/A	969.6 (31.7%)	17.7%	No
LAF-CAM-047	West	71	70	62	63	12/≤1	27	964.7 (31.6%)	17.5%	Yes
LAF-CAM-060	West	71	71	62	63	12/≤1	20	1,096 (33.9%)	20.2%	Yes
LAF-CAM-061	West	71	71	63	63	12/10	25	911.6 (34.7%)	24.8%	No

Note: [1] N/A = Not hotspot; LW = Lane Width, SW = Shoulder Width

The projected truck AADTs were estimated from the traffic volume counted from 3 count stations located within the site 2. In the state MS2 traffic count system, count of volume of the latest year has been included. Table 19 presents the count station locations and associated estimated total AADT and truck AADT by year. The low-AADT of trucks in 2020 may be a result of then declining manufacturing and transport industries impacted by the COVID-19 pandemic. It should also be noted that the truck volumes are projected volumes, which may not have been derived from direct counts.

The findings of truck percentage and crash characteristics on sites excluding site 2 are as follows:

- Site 1 MS2 station with 30% truck percentage belongs to hotspot 13. From Table 15, the associated crash attributes are - Crash Hour=12pm-6pm, Lighting Condition=Daylight, Vehicle Type=Light Truck, Vehicle Type=Van/SUV.
- Site 5 MS2 station with 8% truck percentage belongs to hotspot ranked 31. Associated crash attributes are - Crash Hour=12am-6am, Season=Fall, Driver Gender=Female, Manner of Collision=Rear-end.
- Site 6 MS2 station 1 with 30% truck percentage belongs to hotspot ranked 50. Associated crash attributes are - DOW=Mon to Thu, Season=Fall, Manner of Collision=Sideswipe, Prior Movement=Changing lanes.
- Site 6 MS2 station 2 with 30% truck percentage belongs to hotspot ranked 42. Associated crash attributes are - Crash Hour=12pm-6pm, Season=Spring, Vehicle Type=Light Truck.
- Site 8 MS2 stations belong the hotspot 3 with no prevalent characteristics.

Table 19. Count station locations and associated AADT on Sites 1, 3-8

Site Number	Location	Latitude	Longitude	Year	AADT	Truck	% Truck	Speed limit	Lane width	Shoulder width	85th Percentile	Hotspot
Site 1	2	30.079673	-90.410318	2021	76177	22702	30	60	12	8	68	13
Site 3	1	30.528841	-91.166575	2020	43619	7678	18	60	12	3	69	N/A
Site 3	2	30.520041	-91.160569	2021	56914	16960	30	60	12	≤1	69	N/A
Site 4	2	29.993104	-90.298627	2021	56783	16921	30	70	12	4	71	N/A
Site 5	1	30.154543	-89.854256	2021	1600	130	8	70	12	8	74	31
Site 6	1	30.277045	-90.400067	2021	29159	8688	30	70	12	18	72	50
Site 6	2	30.191687	-90.437314	2021	29499	8787	30	70	12	5	72	42
Site 7	No data			No data	No data	No data	No data	70				
Site 8	1	30.433651	-91.176463	2021	197070	58726	30	60	12	7	62	3
Site 8	2	30.429354	-91.172238	2021	187499	55871	30	60	12	7	62	3
Site 8	3	30.42522	-91.161259	2021	184781	55065	30	60	12	10	63	3

Conclusions

The objective of the research project was to analyze crash characteristics and identify common issues in selected major elevated interstate sections in Louisiana, including I-10 over the Atchafalaya Basin. The project employed various approaches to analyze crash and speed data, identify crash hotspots in all elevated sections, and estimate compliance rates for truck lane restrictions on the Atchafalaya Basin Bridge.

A comprehensive crash data analysis was conducted with crashes that occurred in 2015-2020 on eight elevated section sites: 1) I-10 over Bonnet Carre Spillway, 2) I-10 over Atchafalaya Basin, 3) I-110 (over 67 Plank Rd & Evangeline Street), 4) I-310 La Branche Wetlands, 5) I-10 Twin Span Bridge, 6) I-55 Manchac Swamp Bridge, 7) I-220 over Cross Lake Shreveport, 8) I-10 Over Perkins Road.

Out of 10,022 analyzed crashes, rear-ends were the most common crash type at 47%, followed by single vehicle crashes at 20% and sideswipe crashes at 16%. The statewide average crash rate for urban interstate is 14.8 crashes per mile per year and 6.1 crashes per mile per year for rural interstate. Crash rates at the selected sites are higher than the state average, except for Site 4 and Site 6. Site 2 has a fatal and severe injury crash rate of 1.23 per 100 million VMT, behind Site 3 and Site 3 has the highest rate of 4 per 100 million VMT.

The majority of crashes occurred when vehicles were proceeding straight (57.73%), with 10.71% involving lane-changing on elevated sections, 4.51% running off the road leading to single vehicle crashes, and 4.9% where vehicles stopped or slowed down. Most drivers involved were aged 25-64-years, and 58.8% were found to be inattentive or distracted, with instances of drivers under the influence of alcohol (2.67%) or drugs (0.56%) being relatively rare. In terms of severity, 0.4% resulted in fatal injuries, with most crashes involving no injury.

Particular elevated section sites may exhibit unique crash characteristics, distinguished by their relatively higher percentages compared to others. Notably, Site 1, I-10 over Bonnet Carre Spillway, sees more rear-end collisions (58.61%), lane-changing incidents (20.90%), and distracted driving (72.49%) than other sites. Site 2, Atchafalaya Basin Bridge, has a relatively higher proportion of male drivers involved in crashes (71.45%). Site 3, I-110 over 67 Plank Road & Evangeline Street, features a higher concentration of crashes involving young drivers under 24 years of age (27.93%). Site 6, I-55 Manchac

Swamp Bridge, experiences a high number of single vehicle crashes (54.46%). Excluding Site 2, rural sites have higher single-vehicle crash percentages, but only Site 6 surpasses the 43.2% statewide rural average. Conversely, urban sites exhibit more rear-end crashes, with Site 1 exceeding the 50.5% urban interstate average from 2015-2020 data.

Speed data analyses for the sites were conducted using the data collected from the RITIS platform. Despite the restrictive environment of driving, speed limit violations (driving above PSL) have been detected to be a substantially common issue on almost all segregated analyzed segments of elevated interstate sections. In terms of the speed limit, it was considerably clear that the degree of speed limit violation (estimated by subtracting the PSL from the 85th percentile speed) was higher on elevated sections with a 60 mph PSL in comparison with a 70 mph PSL. Speed analysis of eight sites divided into smaller TMC/XD segments revealed that drivers exceeded the speed limit by at least 5 mph or more on the two longest sites among the 8 elevated sites with a 60 mph speed limit: Site 1 (I-10 over Bonnet Carre Spillway) and Site 2 (Atchafalaya Basin Bridge). At Site 2, 85th percentile speeds for both passenger vehicles and trucks were estimated to be at PSL+5 mph or above for most segments, with a slight increase observed in 2021 and 2022 compared to 2019 and 2020. For 70 mph speed limit sites (4, 5, 6, and 7), 85th percentile speeds declined in 2021 and 2022. With few exceptions, the 85th percentile speeds of the segments were higher than the statewide average operating speed of 65 mph. It should be noted that findings related to speed analysis for 2022 should be interpreted with caution, as only speed data from January to September was available at the time of analysis.

The crash hotspot analysis conducted using ArcGIS revealed that the segments with a higher frequency of crashes did not appear to have a common pattern in terms of roadway geometric characteristics, number of lanes, or area type, although they often included segments with entry/exit points and narrow shoulders. Both Site 2 and Site 5 have a significant percentage of hotspots affected by non-dry conditions, at 44% and 50%, respectively. Only two sites had hotspots with large trucks as a factor: Site 2 had the highest percentage at 29% (2.12 miles of 7.32 miles), while Site 4 had 21%; other sites had no hotspots involving large trucks.

However, site-by-site exploratory analysis revealed some interesting findings. The 1.5 mile stretch of rural 4-lane section on Site 2 - Atchafalaya Basin bridge, featuring an entrance/exit and no shoulder, has been found to exhibit speeding with an 85th percentile speed of up to 68 mph on the 60 mph limit. Speeding can reach up to 10 mph above the PSL in Site 1, where eastbound drivers enter the site with a speed limit reduction from 70 mph to 60 mph, and westbound drivers increase speed anticipating a higher PSL ahead while exiting the site. This pattern is also observed at the eastern end of the Atchafalaya Basin Bridge. On Site 3 of I-110 over 67 Plank Road and Evangeline Street, which is an urban 6-lane section with a maximum degree of speeding of 11 mph, drivers are forced to slow down due to the sharp curvature, resulting in a significant reduction in speeding to as little as 1 mph. At Site 8 on I-10 Over Perkins Road, an urban six-lane roadway with a 60 mph posted speed limit and an average annual daily traffic (AADT) of up to 198,000, a significant number of vehicles merging and diverging are likely hindering the ability to achieve high-speed platooning.

As speeding was largely prevalent on all elevated sections, discernible patterns connecting crash characteristics and speeding were rare. However, crashes involving trucks could be found across a range of degrees of speeding, from 2 to 12 mph. Despite sufficient evidence of the benefit of the DSL in prior studies, in this study, truck crashes may be involved in some rear-end crashes but could not be linked with the vehicle's prior movement in changing lanes. The integration of truck volume data from the DOTD's MS2 system with crash hotspot locations on Atchafalaya Basin Bridge indicates that areas with an estimated truck percentage of 33% or more are associated with single-vehicle crashes, non-dry surface conditions, and distracted/inattentive driving as the primary contributing factors. In the remaining sites, multiple locations with 30% truck percentages were linked to light-truck crashes.

The DeepMetrics (DPM) software was utilized to detect, count, and classify vehicles from the video footage limited to five camera locations on the Atchafalaya Basin Bridge to estimate the right-lane compliance of trucks. Both DPM and manual counts revealed truck lane non-compliance to be approximately 20%, with DPM estimates suggesting truck percentages in total vehicle composition ranging from 28.9% to 37.5%, and compliance of truck lane restrictions ranging from 77.1% to 82.3%.

Recommendations

Based on the findings of this research, the following recommendations can be provided:

- The list of hotspots and associated crashes could be used when developing safety countermeasures for hotspots on elevated sections. Prior to applying countermeasures on elevated sections, the results combining crash hotspots, degree of speeding, and truck percentage can be utilized as a supplementary guide for strategic countermeasure development.
- Since the results relating to speeding and truck percentages are inconclusive, further research can be conducted to investigate lane-by-lane volume (for both passenger vehicles and trucks) and lane-by-lane speed. This research should provide concrete evidence on the impact and identification of associative crash and geometric characteristics in connection with differential speed limits (DSL) and compliance of truck lane restrictions.

Acronyms, Abbreviations, and Symbols

Term	Description
AASHTO	American Association of State Highway and Transportation Officials
CCTV	Closed-Circuit Television
CSV	Comma Separated Values
DPM	DeepMetrics
DSL	Differential Speed Limit
FHWA	Federal Highway Administration
ft.	foot (feet)
LADOTD	Louisiana Department of Transportation and Development
LTRC	Louisiana Transportation Research Center
MCTI	Missouri Center of Transportation Innovation
MS	Microsoft
MVM	Million Vehicle Miles
PDO	Property Damage Only
PSL	Posted Speed Limit
RITIS	Regional Integrated Transportation Information System
TMC	Traffic Message Channel
USL	Uniform Speed Limit
vpd	vehicles per day
XD	eXtreme Definition
m	meter(s)

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Appendices

Appendix A: Site Locations and Analysis Segments

Figure A1. Segments of Site 1 (I-10 over Bonnet Carre Spillway)

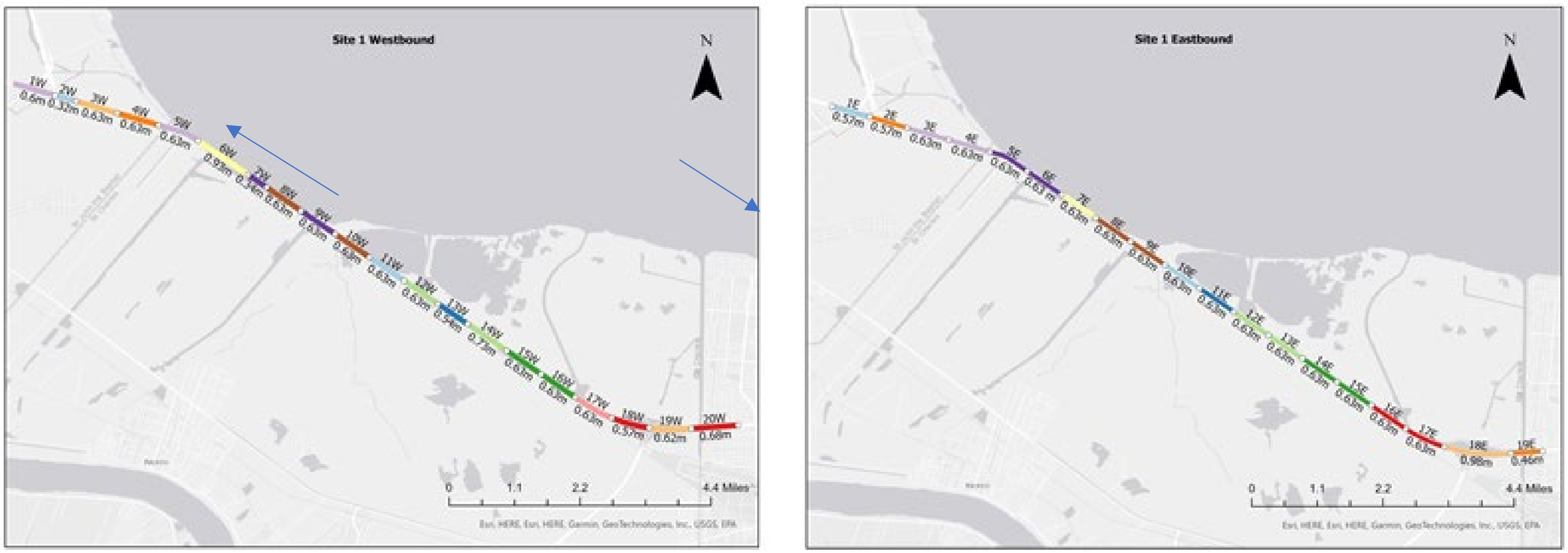


Figure A2. Segments of Site 2 (I-10 Atchafalaya Basin Bridge)

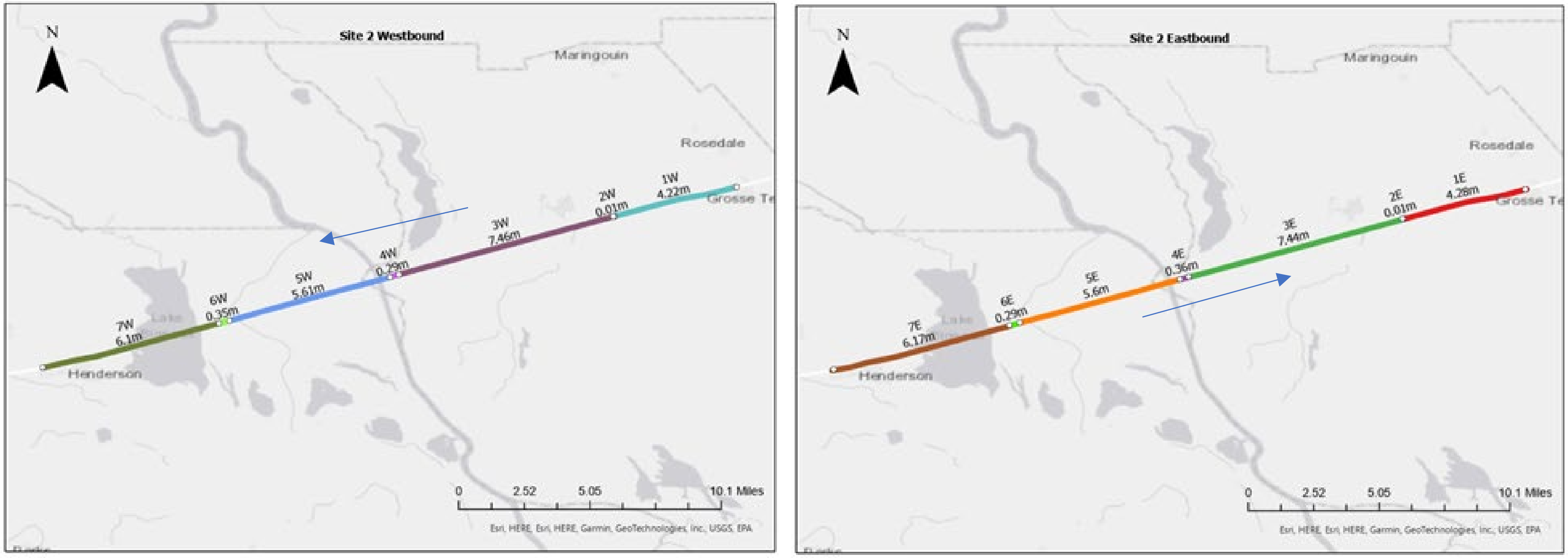


Figure A3. Segments of Site 3 (I-110 over 67 Plank Road and Evangeline Street)

Figure A4. Segments of Site 4 (I-310 St. Rose)

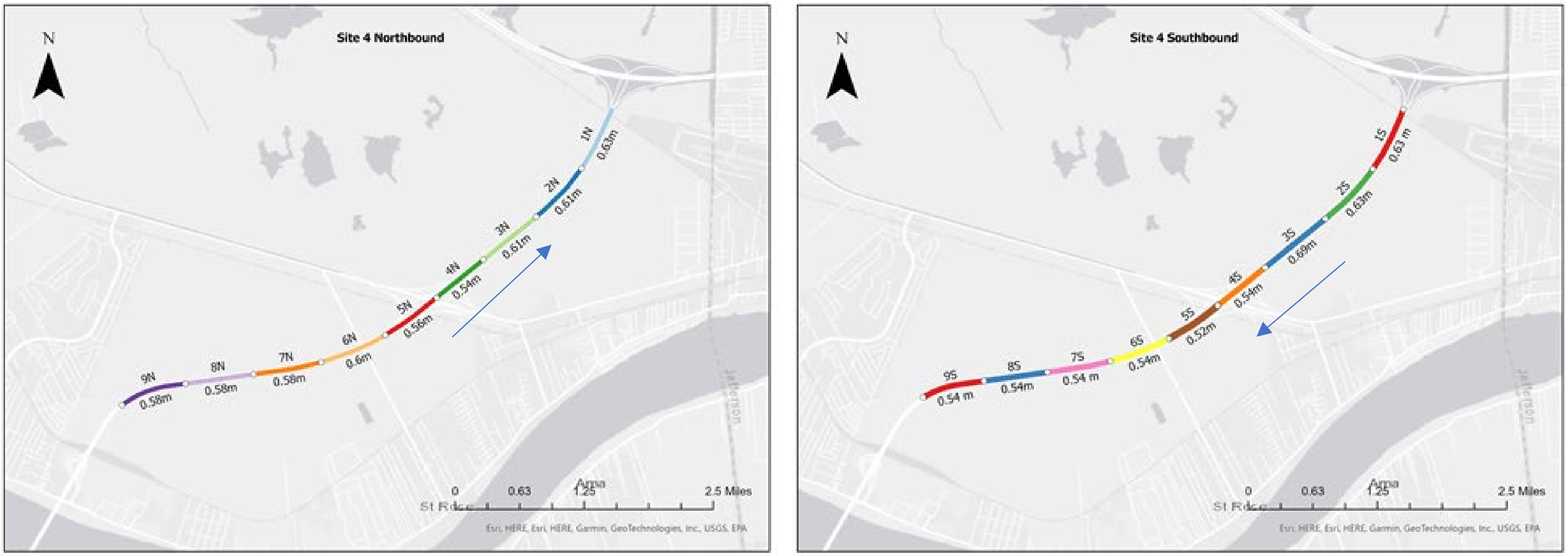
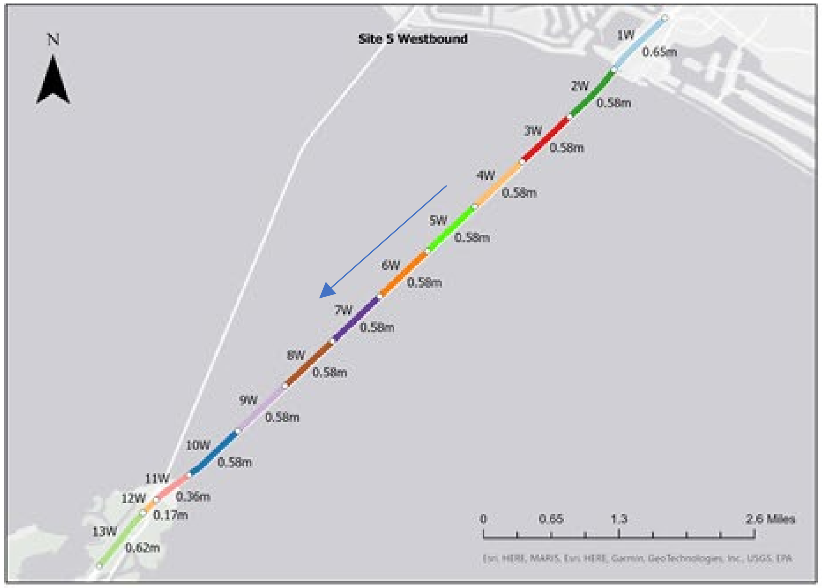


Figure A5. Segments of Site 5 (I-10 Twin Span Bridge)



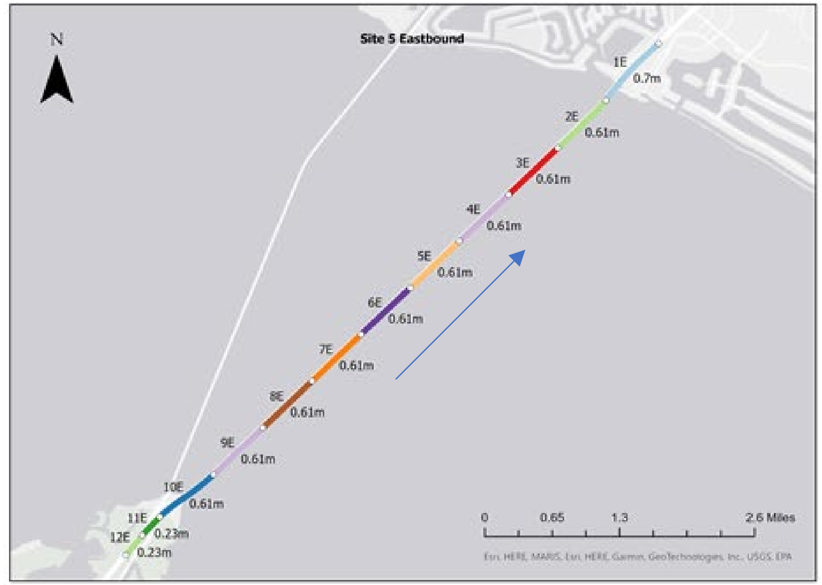


Figure A6. Segments of Site 6 (I-55 Manchac Swamp Bridge)

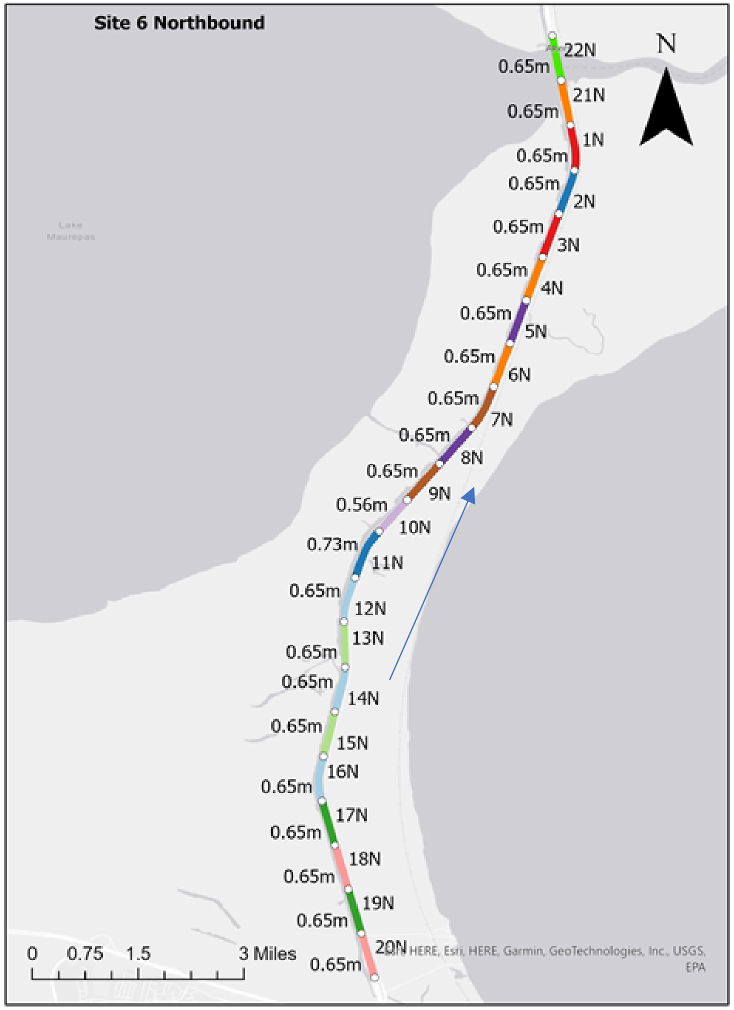


Figure A7. Segments of site 7 (I-220 over Cross Lake, Shreveport)

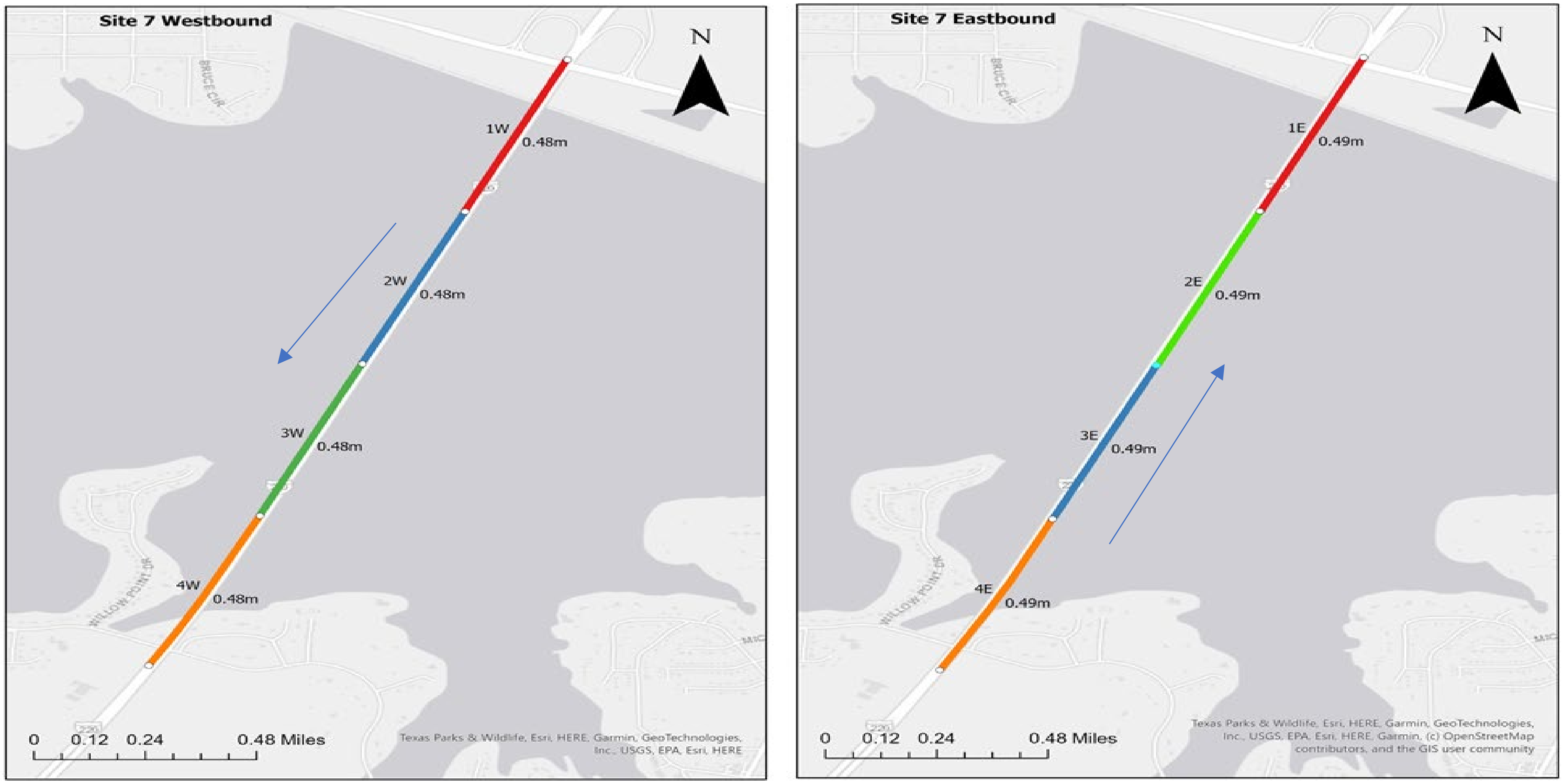
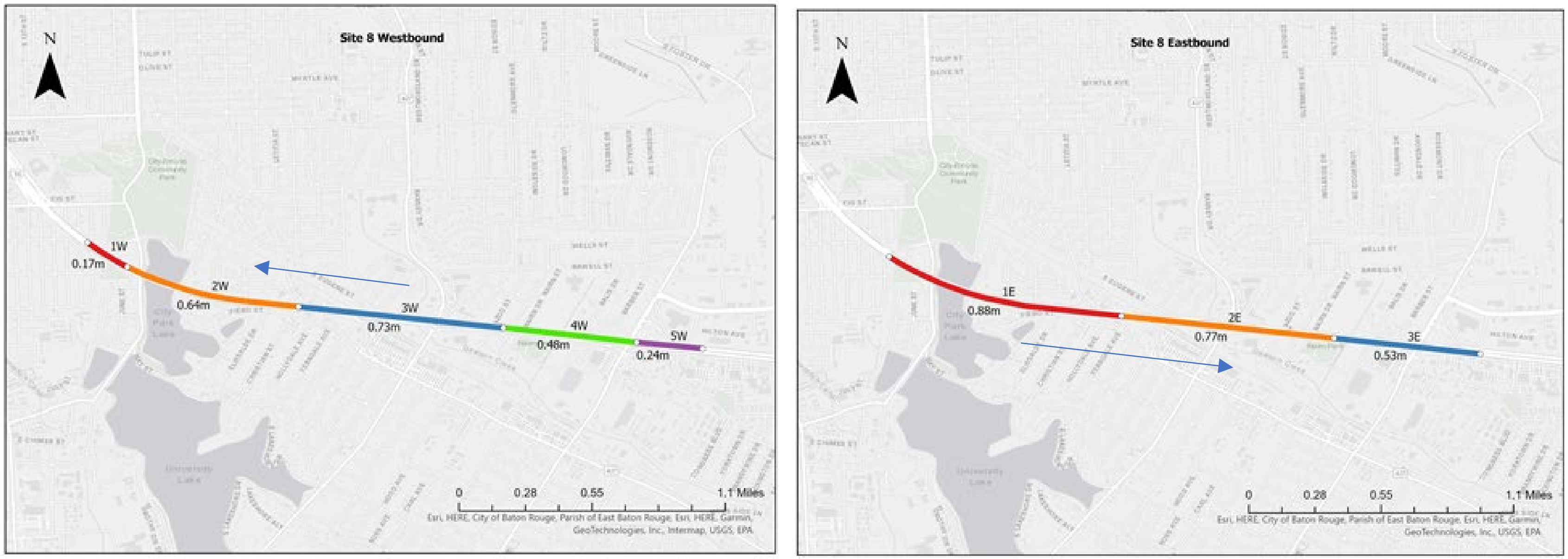


Figure A8. Segments of Site 8 (I-10 over Perkins Road)



Appendix B: DeepMetrics

Figure B1. Step 1 to recording DOTD camera video from provide link (redacted) using video player

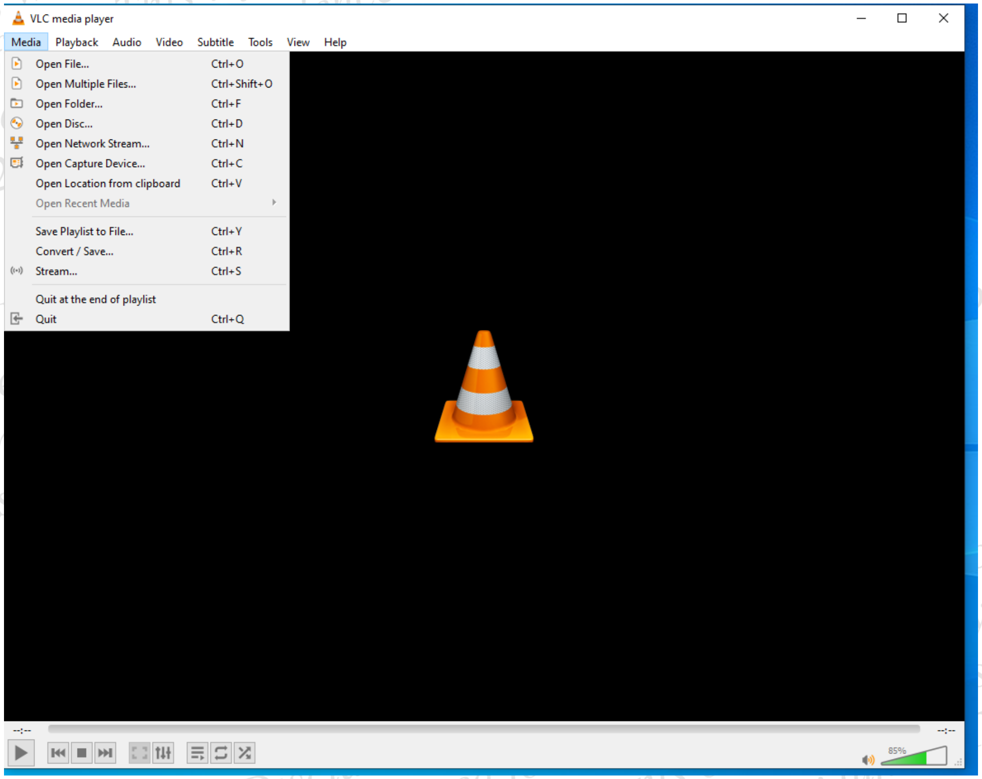


Figure B2. Step 2 to recording DOTD camera video from provide link (redacted) using video player

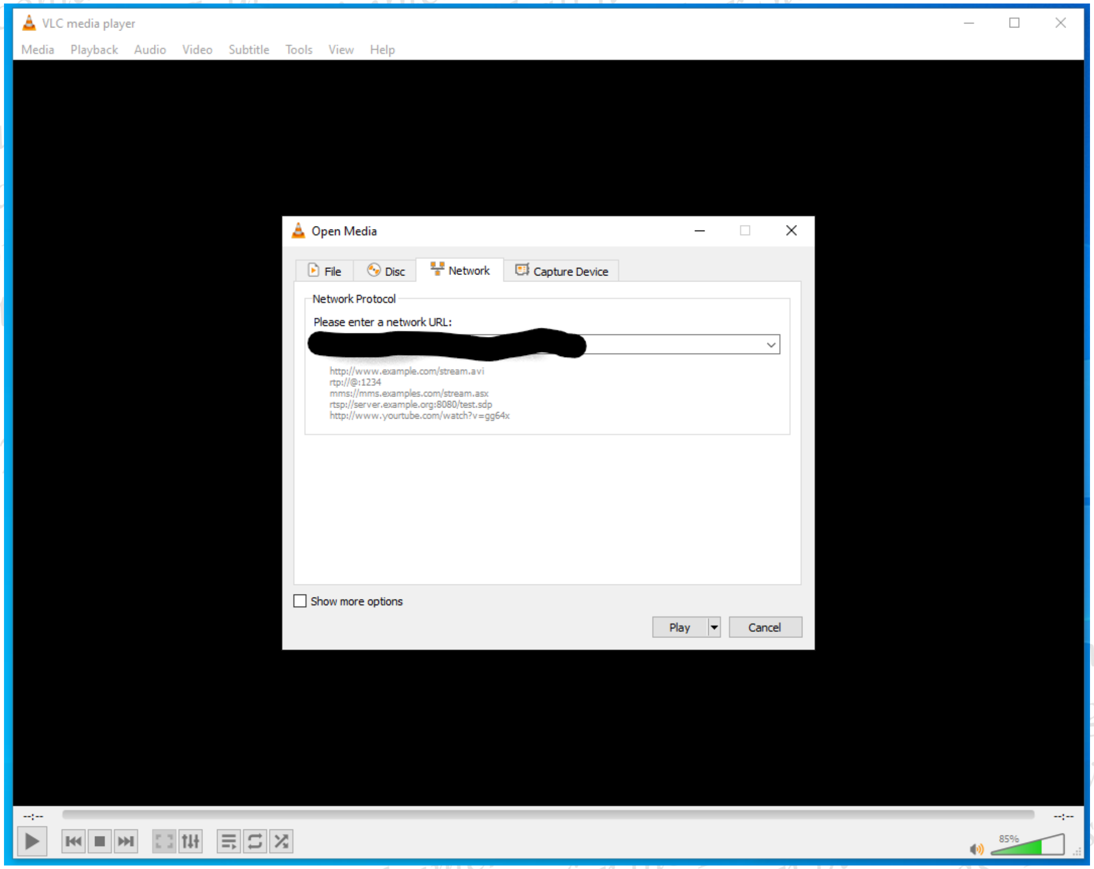
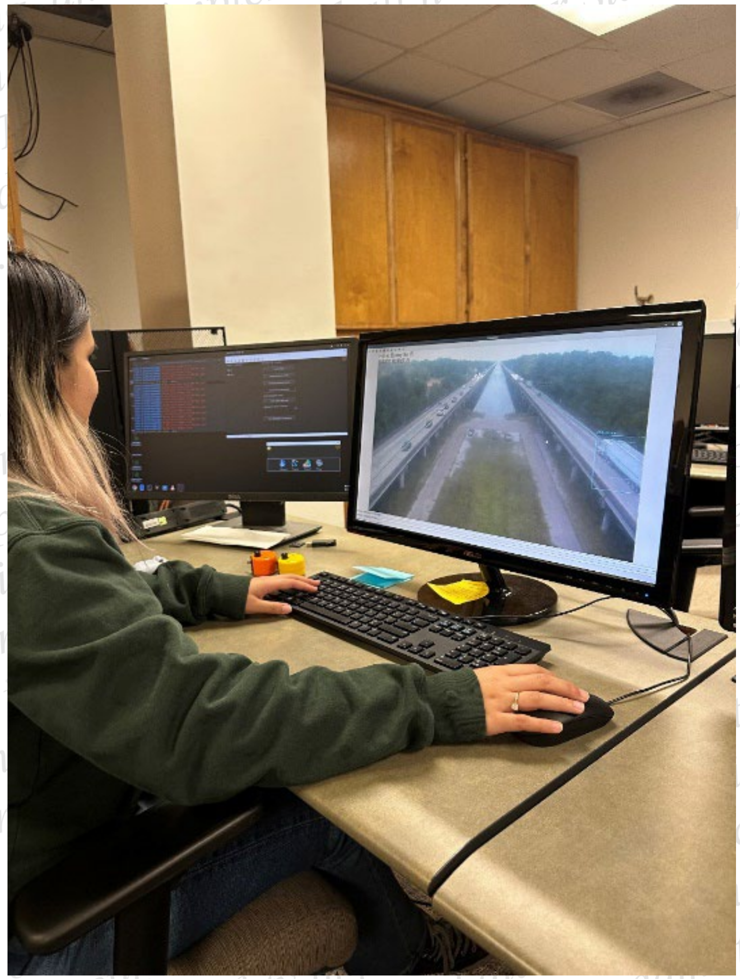


Figure B3. Ongoing stream recording using media player

Figure B4. A student using the DeepMetrics system to count vehicles



Appendix C: Hotspots

Table C1. Hotspot ranking on all 8 sites

Site	Hotspot No.	Hotspot Rankings
Site 1 West	10	18
	11	19
	12	17
Site 1 East	13	10
	14	15
	15	13
	16	16
Site 2 East	1	43
	2	23
	3	29
	4	28
Site 2 West	5	39
	6	25
	7	40
	8	20
	9	27
Site 3 North	17	10
	18	15
	19	13
Site 3 South	20	16
	21	12
Site 4 North	22	8
	23	11
Site 4 South	24	7
	25	6
	26	33
Site 5 East	27	32
	28	24
	29	37
	30	22
	31	26
Site 5 West	32	21
	33	38
	34	35
Site 6 North	35	30
	36	34
	37	31

	38	36
	39	50
	40	48
	41	46
Site 6 South	42	42
	43	57
	44	47
	45	54
	46	55
	47	45
	48	52
	49	56
	50	51
Site 7 North	51	49
Site 7 South	52	41
Site 8 East	53	44
	54	53
	55	9
Site 8 West	56	14
	57	4

Appendix D: Hotspot Maps

Figure D1. Site 1 eastbound hotspot map

Figure D2. Site 1 westbound hotspot map

Figure D3. Site 3 northbound hotspot map

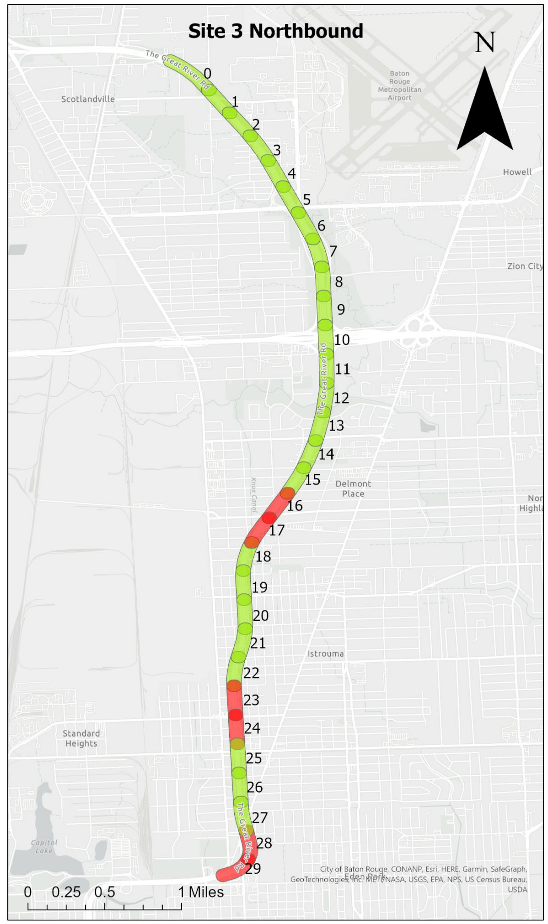


Figure D4. Site 3 southbound hotspot map

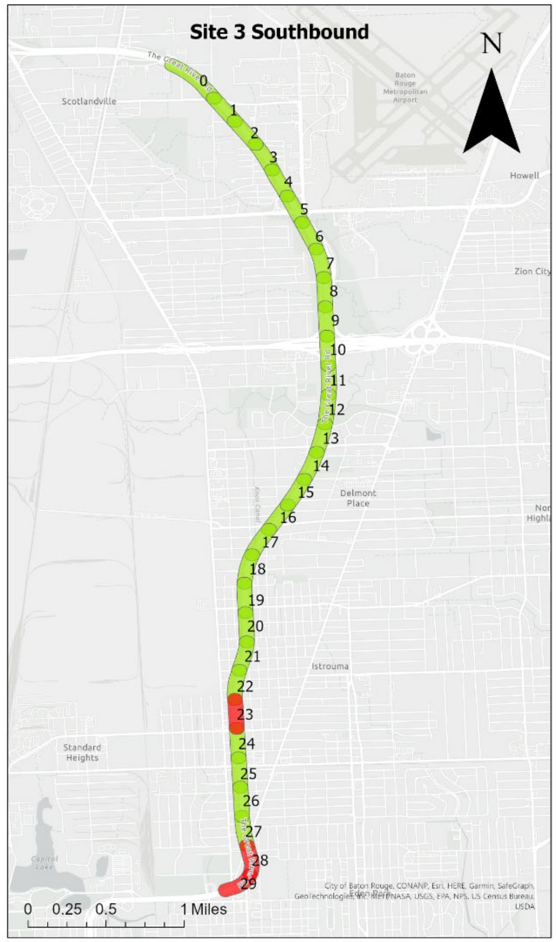


Figure D5. Site 4 northbound hotspot map

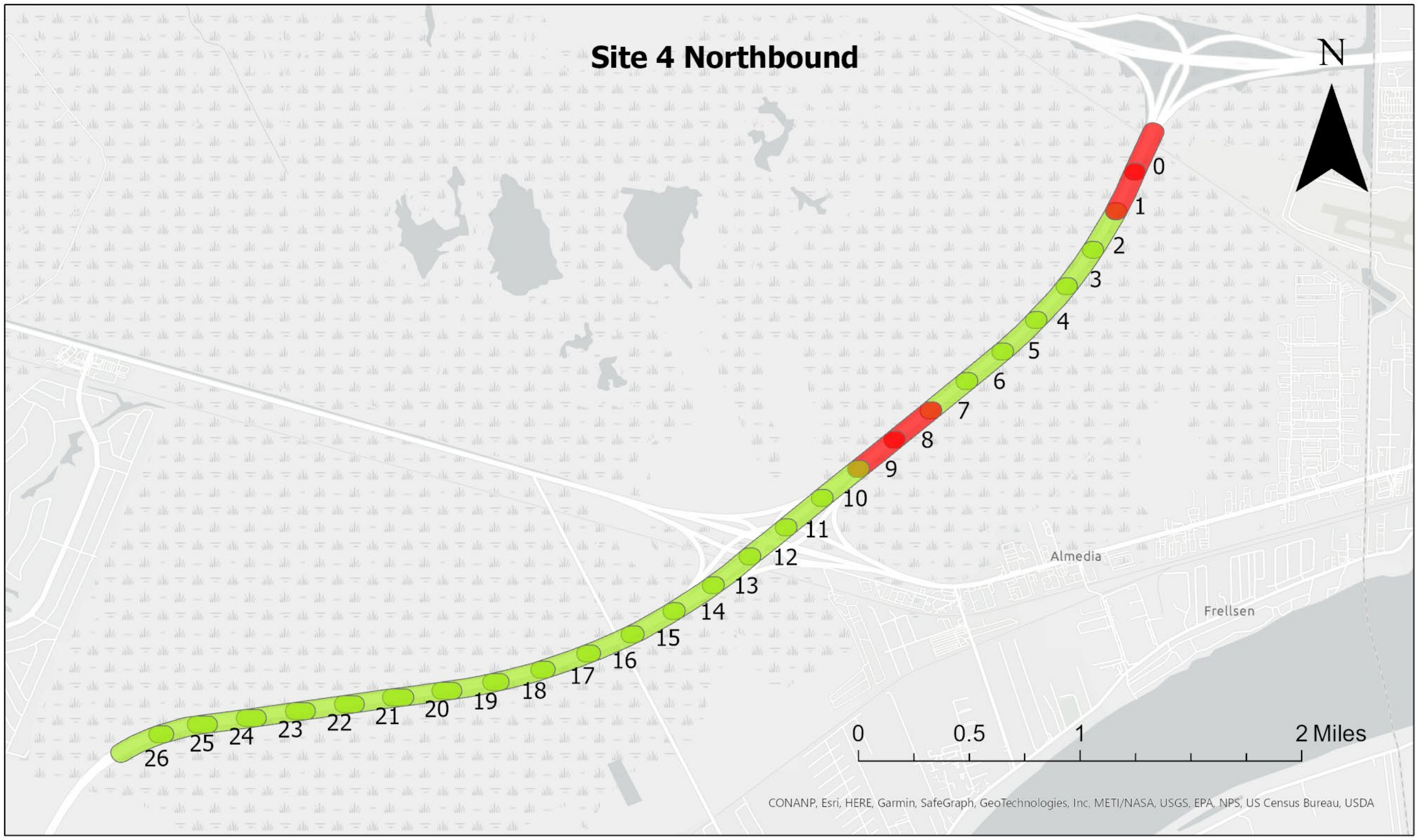


Figure D6. Site 4 southbound hotspot map

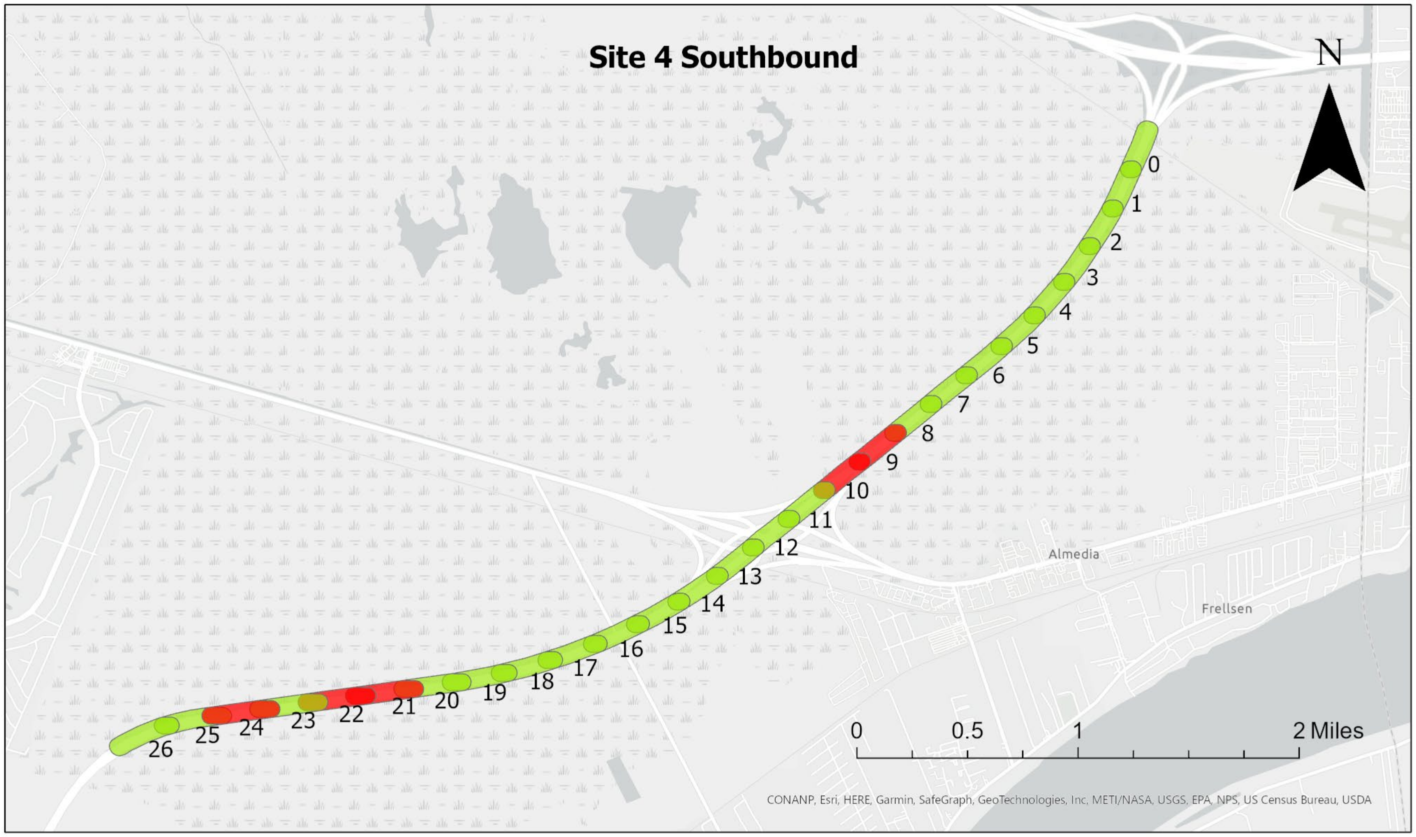


Figure D7. Site 5 northbound hotspot map

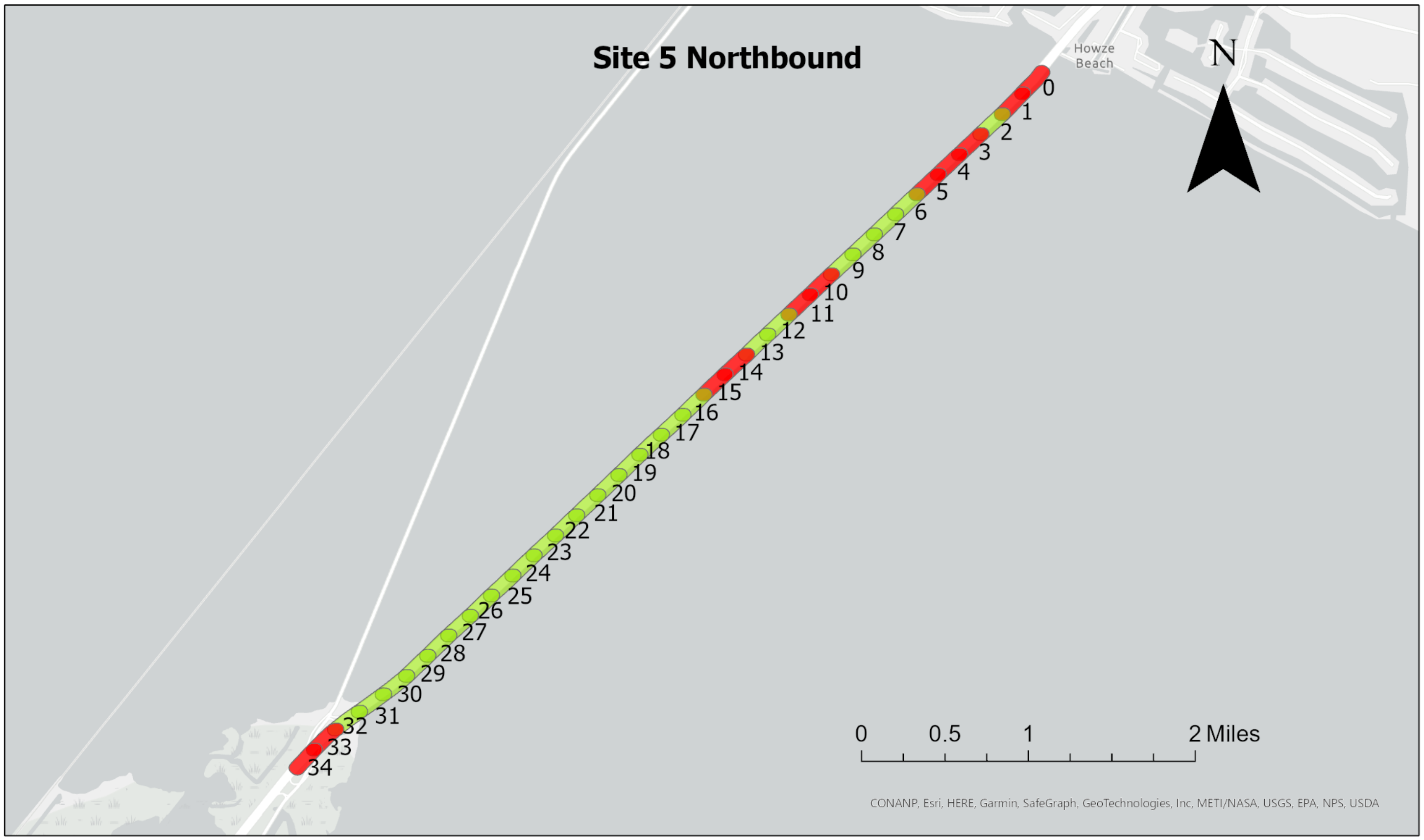


Figure D8. Site 5 southbound hotspot map

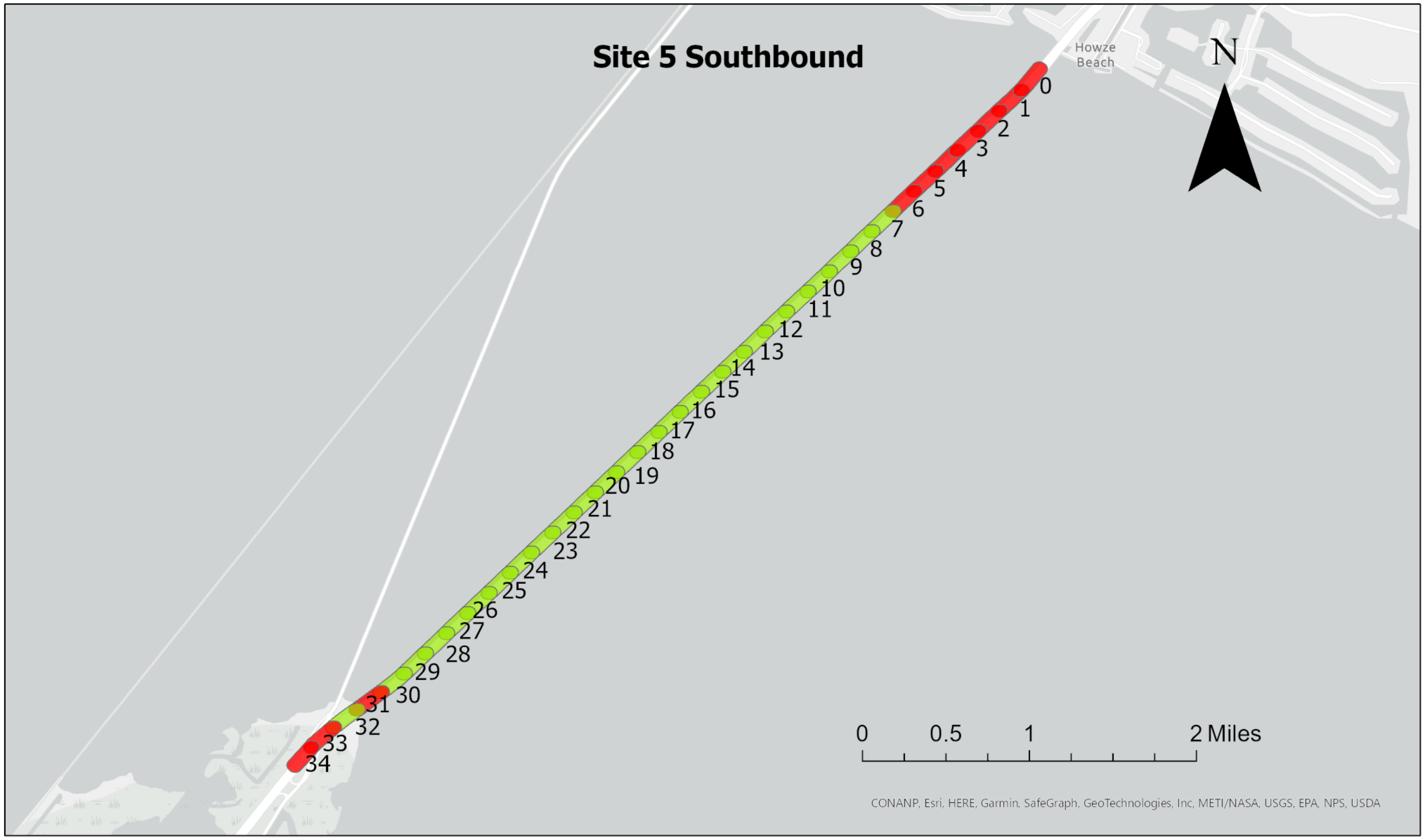


Figure D9. Site 6 northbound hotspot map

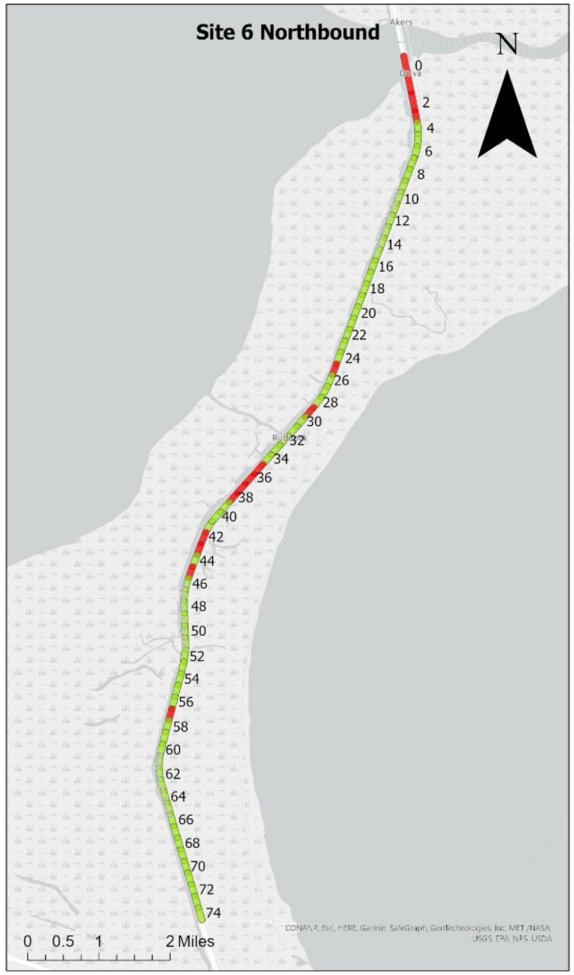


Figure D10. Site 6 southbound hotspot map

Figure D11. Site 7 northbound hotspot map

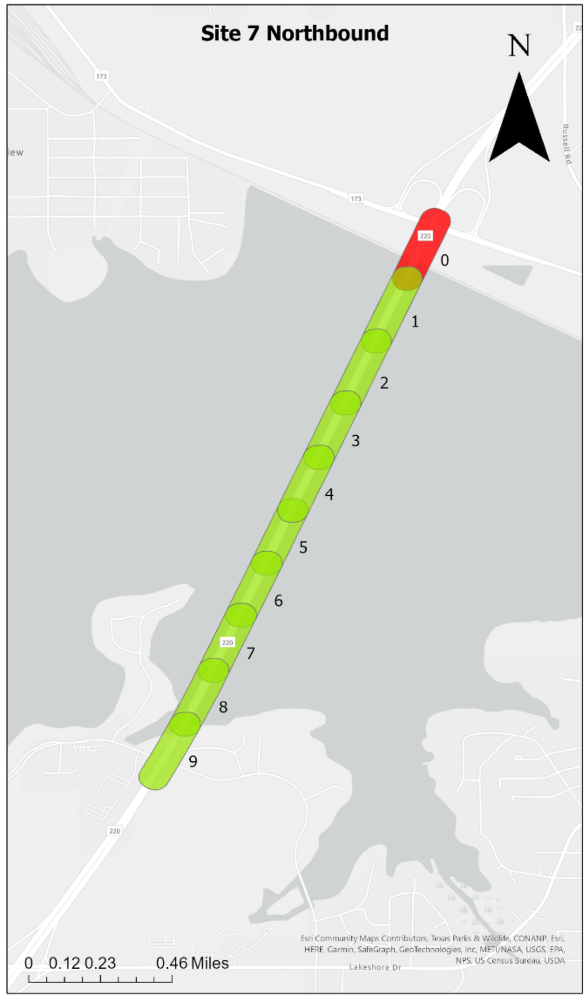


Figure D12. Site 7 southbound hotspot map

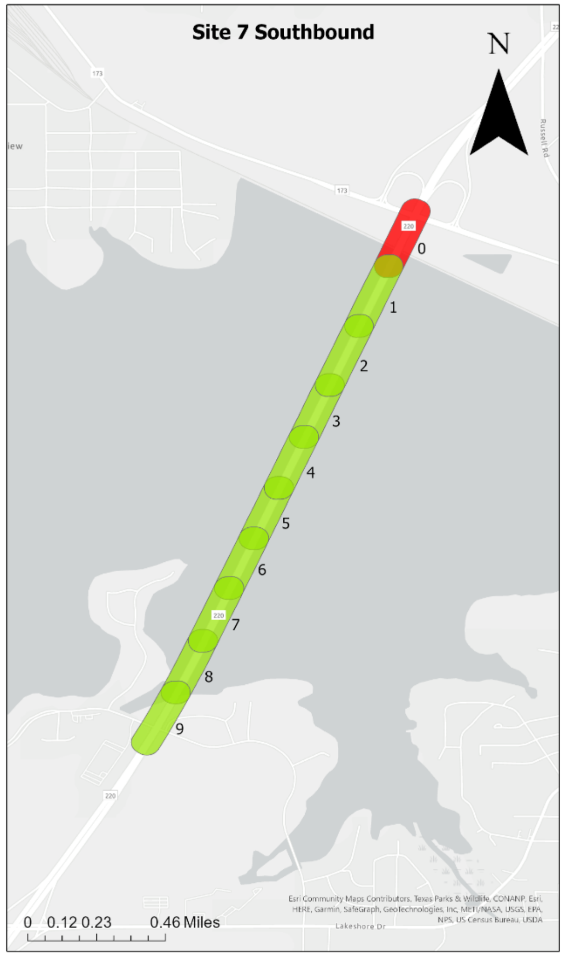


Figure D13. Site 8 eastbound hotspot map

Figure D14. Site 8 westbound hotspot map

Appendix E: Vehicle Counts on Site 2 with DPM Algorithm and Manually

Table E1. Eastbound vehicle counts on site 2 with dpm algorithm and manually

Eastbound	S/N	DPM Truck (left lane)	DPM Truck (total)	DPM Vehicles (total)	DPM % Lane Compliance	Manual Truck (left lane)	Manual Truck (total)	Manual Vehicles (total)	Manual % Lane Compliance
LAF-CAM-047	1	185	897	3,081	20.6%	189	957	3,361	19.7%
	2	161	890	2,796	18.1%	169	977	2,990	17.3%
	3	184	809	2,635	22.7%	196	948	2,839	20.7%
	4	97	762	3,062	12.7%	104	743	3,211	14.0%
	5	180	889	2,845	20.2%	173	978	3,089	17.7%
	6	183	773	2,934	23.7%	160	866	3,182	18.5%
Subtotal		990	5,020	17,353	19.7%	991	5,469	18,672	18.1%
LAF-CAM-061	1	253	1,141	3,435	22.2%	247	1,058	3,563	23.3%
	2	208	954	1,642	21.8%	225	983	1,589	22.9%
	3	225	1,013	2,843	22.2%	230	1,025	2,865	22.4%
	4	186	864	3,068	21.5%	189	935	3,097	20.2%
Subtotal		872	3,972	10,988	22.0%	891	4,001	11,114	22.3%
Total		**1,862**	**8,992**	**28,341**	**20.7%**	**1,882**	**9,470**	**29,786**	**19.9%**

Table E2. Westbound Vehicle Counts on Site 2 with DPM algorithm and manually

Westbound	DPM					Manual			
	S/N	Truck (left lane)	Truck (total)	Vehicles (total)	% Lane Compliance	Truck (left lane)	Truck (total)	Vehicles (total)	% Lane Compliance
LAF-CAM-007	1	73	619	2,798	11.80%	73	622	3,117	11.70%
	2	191	928	2,721	20.60%	187	1,002	2,975	18.70%
	3	144	1,019	3,201	14.10%	134	934	3,465	14.30%
	4	151	851	2,796	17.70%	155	879	2,803	17.60%
	5	248	1,116	3,294	22.20%	217	1,087	3,315	20.00%
	6	225	945	3,261	23.80%	217	974	3,304	22.30%
	7	181	878	2,965	20.60%	190	889	2,939	21.40%
	8	185	966	3,186	19.20%	178	1,003	3,241	17.70%
	9	191	1,027	3,583	18.60%	187	1,002	3,524	18.70%
	10	170	1,004	3,136	16.90%	164	991	3,160	16.50%
	11	169	956	3,055	17.70%	156	976	3,096	16.00%
	12	108	604	3,151	17.90%	99	607	3,162	16.30%
	13	166	1,011	3,192	16.40%	160	977	3,204	16.40%
	14	209	943	3,510	22.20%	190	981	3,550	19.40%
	Subtotal	2,411	12,867	43,849	18.70%	2,307	12,924	44,855	17.90%
LAF-CAM_011	1	198	1,012	3,141	19.60%	189	971	2,850	19.50%
	2	182	1,028	3,585	17.70%	161	987	3,480	16.30%
	3	161	947	2,990	17.00%	164	892	2,781	18.40%
	4	170	1,044	3,185	16.30%	164	991	3,080	16.50%
	5	184	1,039	3,309	17.70%	181	1,007	3,100	18.00%
	Subtotal	895	5,070	16,210	17.70%	859	4,848	15,291	17.70%
LAF-CAM-047	1	196	956	2,968	20.50%	168	956	3,003	17.60%
	2	156	977	2,933	16.00%	153	932	2,951	16.40%
	3	156	720	2,123	21.70%	153	932	2,181	16.40%
	4	126	1,007	3,331	12.50%	128	929	3,427	13.80%
	5	213	997	3,098	21.40%	205	1,043	3,049	19.70%
	6	308	1,049	3,601	29.40%	207	996	3,679	20.80%

	Subtotal	1,155	5,706	18,054	20.20%	1,014	5,788	18,290	17.50%
LAF-CAM-060	1	253	1,258	3,353	20.10%	221	1,096	3,231	20.20%
LAF-CAM-061	1	258	1,055	2,797	24.50%	279	994	3,009	28.10%
	2	119	548	1,600	21.70%	108	548	1,734	19.70%
	3	237	1,048	2,912	22.60%	236	1,002	3,016	23.60%
	4	228	1,100	2,698	20.70%	231	1,002	2,946	23.10%
	5	273	1,110	3,256	24.60%	277	1,012	2,415	27.40%
Subtotal		1,368	6,119	16,616	22.40%	1,352	5,654	16,351	23.90%
Total		**4,927**	**25,314**	**80,028**	**19.50%**	**4,739**	**24,522**	**79,728**	**19.30%**