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Making Data-Driven Transportation Decisions for Freight Operations

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Abstract

Using Louisiana's Interstate system, this paper aims to demonstrate how data can be used to evaluate freight movement reliability, economy, and safety of truck freight operations to improve decision-making. Data mainly from the National Performance Management Research Data Set (NPMRDS) and the Louisiana Crash Database were used to analyze Truck Travel Time Reliability Index, commercial vehicle User Delay Costs, and commercial vehicle safety. The results indicate that while Louisiana's Interstate system remained reliable over the years, some segments were found to be unreliable, which were annually less than 12% of the state's Interstate system mileage. The User Delay Costs by commercial vehicles on these unreliable segments were, on average, 65.45% of the User Delay Cost by all vehicles on the Interstate highway system between 2016 and 2019, 53.10% between 2020 and 2021, and 70.36% in 2022, which are considerably high. These disproportionate ratios indicate the economic impact of the unreliability of the Interstate system on commercial vehicle operations. Additionally, though the annual crash frequencies remained relatively constant, an increasing proportion of commercial vehicles are involved in crashes, with segments (mileposts) that have high crash frequencies seeming to correspond with locations with recurring congestion on the Interstate highway system. The study highlights the potential of using data to identify areas that need improvement in transportation systems to support better decision-making.

Keywords

Freight, Performance Measures, TTTR Index, Crash Rate, Data-Driven, User Delay Cost

1. Introduction

Truck-borne freight movement is the backbone of many State economies, accounting for high freight tonnage and freight value movements. This has made commercial vehicle operations (CVO) and the performance of the highway system critically important to the economies of these States and, by extension, the economy, defense, and mobility of the U. S. [1] [2]. For its importance nationally, the federally backed Moving Ahead for Progress in the 21st Century Act (MAP-21) established a national freight movement and economic vitality goal to improve the national freight network and access to national and international trade markets and support regional economic growth development. The Fixing America's Surface Transportation (FAST) Act continued these policies and established freight-specific funding programs and requirements [3].

To meet these requirements, the U.S. Department of Transportation (USDOT) developed a national freight policy to improve the condition and performance of the national freight network to ensure the US competes globally. The policy requires improving safety, security, resilience, and efficiency; incorporating concepts of performance, innovation, competition, and accountability; improving economic efficiency; and reducing the environmental impacts of freight movement on the national freight network. These have necessitated the implementation of performance-driven, outcome-based programs by state Departments of Transportation (DOTs) to improve project decision-making, provide accountability for achieving measurable results on freight issues, and the efficient utilization of federal funds [4] [5] [6]. For these, the Federal Highway Administration (FHWA) adopted the federal performance management regulations (23 CFR part 490) under the Transportation Performance Management (TPM) program to meet the performance-related requirements for highways that state DOTs need to assess the performance of freight movement on the interstate highway system [3] [7] [8] [9].

For the importance of truck freight movement to Louisiana, for instance, the state's Department of Transportation and Development (DOTD), through different reports and documents, has iterated the state's goals to increase freight mobility, facilitate freight and economic growth, and reduce commercial vehicle crash rates [6] [10] [11].

1.1. Objectives

Using freight routes in Louisiana, this paper demonstrated how DOTs or MPOs could use data generated on transportation systems to evaluate an agency's performance towards meeting its goal to improve freight movement reliability, economy, and safety of truck freight operations to improve decision-making.

Scope of Study

This research analyzed transportation system data from 2016 to 2022 in order to evaluate Louisiana's freight operations goals. Despite the fact that truck freight movement in many states relies on statewide highways and regional highway systems for accessibility and mobility, the freight-significant highways considered for evaluation is the Interstate system in Louisiana, with I-10, I-12, and

I-20 providing much of the east-west movement; while I-49, I-55, and I-59 facilitate north-south movements [6] [10]. The selection of the Interstate system was notwithstanding that the highest number of crashes involving commercial vehicles in Louisiana are on rural state roadways [6].

The interstate highways in Louisiana and their mileage are shown in **Table 1** [12].

1.2. Performance Measurement

The performance monitoring of transportation systems has gained importance due to the shift towards a set of strategies, programs, and techniques to optimize the performance of transportation systems in what is referred to as Transportation Systems Management and Operations (TSMO). TSMO involves the analysis of performance from a systems perspective; coordination across jurisdictions, agencies, and modes; a collection of individual solutions; and combining the individual solutions to achieve greater performance on the entire system [13].

In freight operations, performance measures include freight demand performance measures, such as freight volume and truck parking, and freight efficiency performance measures, such as travel time index, mean travel time index, delay, speed, reliability cost, and freight bottlenecks. Other measures include safety and infrastructure conditions. FHWA data sources used to establish baseline performance conditions include truck probe data, National Performance Management Research Data Set (NPMRDS), Freight Analysis Framework (FAF) data, the Commodity Flow Survey, the Highway Performance Monitoring System (HPMS) data, and truck parking data [14].

With the advancement of innovative technologies in an era of big data, there are other approaches to evaluating performance for providing critical information on transportation systems, for instance, modeling car-following behavior under multiple performance indicators [15] and utilizing connected vehicle data to assess the performance and operation of transportation infrastructures, such as interchanges [16] and pavement conditions [14] [17] [18].

2. Methodology

Based on available data and building on previous studies that evaluated freight operations in Louisiana [19] [20] [21], this study conducted a Truck Travel Time Reliability Index analysis, commercial vehicle User Delay Cost analysis, and safety analysis with data generated on Louisiana's Interstate system between 2016 to 2022 to assess Louisiana's freight operations goals for the period studied.

Table 1. Mileage of interstate highway corridors in Louisiana.

Interstate Highway	I-10	I-12	I-20	I-49	I-55	I-59	I-110	I-210	I-220	I-310	I-510	I-610
Mileage per Direction	274.00	85.00	189.00	247.00	66.00	11.00	9.00	12.50	18.00	11.5	3.00	4.90
Direction	WB/EB	WB/EB	WB/EB	NB/SB	NB/SB	NB/SB	NB/SB	WB/EB	WB/EB	NB/SB	NB/SB	WB/EB

The Truck Travel Time Reliability Index and commercial vehicle User Delay Cost were used to deduce the reliability of freight movement and the economic impact due to the unreliability of the Interstate system. The safety analysis evaluated commercial vehicle crash rates on the Interstate system and used crash frequency, trend analysis, and pin cluster analysis [22] to make informed deductions about the safety of commercial vehicles on Louisiana's Interstate system.

An overview of the Truck Travel Time Reliability (TTTR) Index analysis, Commercial Vehicle Delay Costs analysis, and Commercial Vehicle Crash Rate analysis is briefly discussed below, including data sources.

2.1. Truck Travel Time Reliability (TTTR) Index Analysis

TTTR, defined by the PM3 federal rule—23 CFR Part 490 Subpart F Measure, is the ratio of the longer travel time (95th percentile) to a normal travel time (50th percentile) computed in 15-minute travel intervals for the interstates statewide, as expressed in Equation (1). The TTTR is computed for each interstate Traffic Messaging Channel (TMC) segment and rounded to the nearest hundredth for each applicable period for the entire year [7] [8].

$$\text{TTTR}_i = \frac{95^{\text{th}}\ \text{Percentile Travel Time}_i}{50^{\text{th}}\ \text{Percentile Travel Time}_i} \tag{1}$$

where i is the time-period:

Monday-Friday	AM Peak	6:00 am - 10:00 am
	Mid-Day	10:00 am - 4:00 pm
	PM Peak	4:00 pm - 8:00 pm
Weekends		6:00 am - 8:00 pm
Overnight (all days)		8:00 pm - 6:00 am

The maximum TTTR of all five time periods for each TMC segment is used to create the TTTR Index for the entire Interstate system. Mathematically, the TTTR Index is the sum of the maximum TTTR for each reporting TMC segment, divided by the total Interstate system miles as expressed in Equation (2).

$$\text{TTTR Index} = \frac{\sum_{i=1}^{T}\left(\text{SL}_i \times \max \text{TTTR}_i\right)}{\sum_{i=1}^{T}\left(\text{SL}_i\right)} \tag{2}$$

where:

i = an Interstate highway reporting segment

maxTTTR_i = the maximum TTTR of all five time periods for segment i

SL_i = length of segment i

T = total number of Interstate segments

The target for the TTTR Index on Louisiana highway systems is set at 1.50. Generally, a TTTR of 1.50 or less is considered reliable; conversely, a score greater than 1.50 is considered unreliable, as noted below in the general interpretations given for the TTTR score:

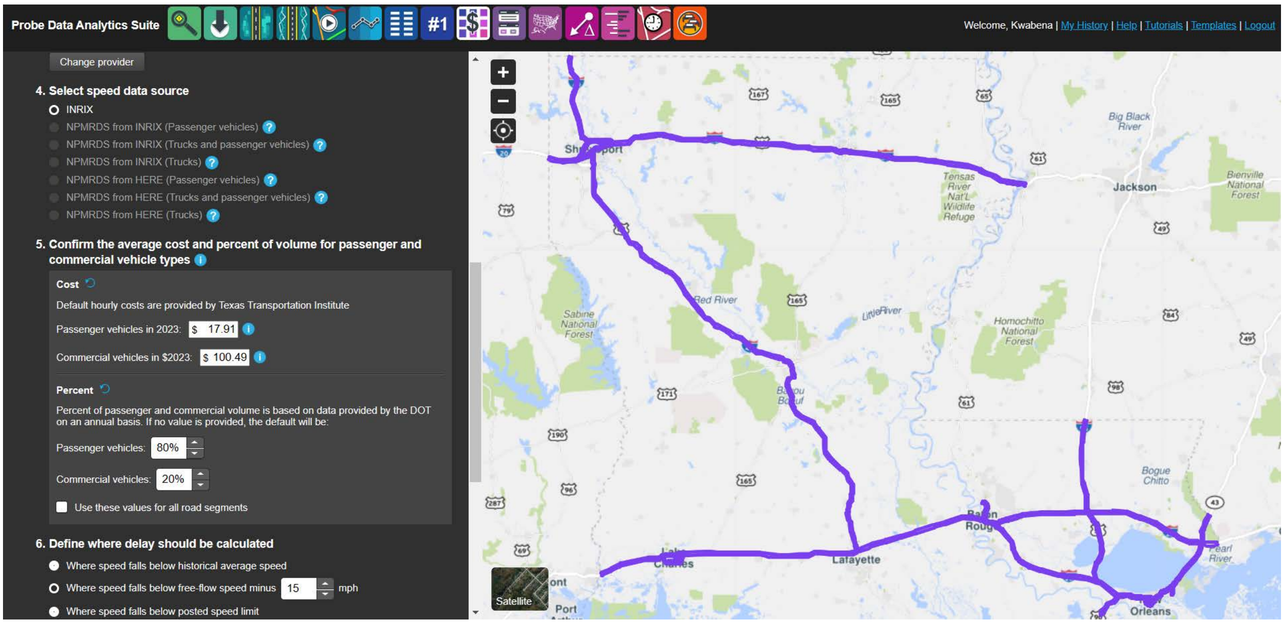
TTTR	Interpretation
Less than (<) 1.25	Very Good
1.25 - 1.40	Good

1.40 - 1.50	Barely Good
1.50 - 1.60	Barely Bad
1.60 - 1.75	Bad
Greater than (>) 1.75	Very Bad

Data for the TTTR Index estimation was sourced from the National Performance Management Research Data Set (NPMRDS) hosted on the Regional Integrated Transportation Information System (RITIS) platform [23]. Using the MAP-21 portal on the NPMRDS Analytics platform, the AM Peak, Midday, PM Peak, Weekend, Overnight, and Maximum TTTR were calculated for each TMC segment that comprised Louisiana's entire (100%) interstate highway system of 1882 miles [23]. The length (1882 miles) is synonymous with the total interstate mileage in this report, which comprised 1509 TMC segments as of 2022.

2.2. Vehicle Delay Cost Analysis

With free-flow speed defined as the mean speed in mph (capped at 65 mph) calculated based on the 85th-percentile of the observed speeds on a TMC segment for all periods, the delay is calculated for all segments whose raw speeds fall 15 mph or more than the free-flow speed of a TMC segment [23]. Applying an estimated $100.49 and $17.91 per hour value of delay time, respectively, for trucks and passenger vehicles [23] [24] and a 20% commercial vehicle mix for only single-unit and combination trucks on Louisiana's interstate system [25] [26], the delay costs were estimated with the User Delay Cost Analysis widget and with data sourced from the NPMRDS Analytics platform, a snippet of which is shown in **Figure 1**. The delay cost can be estimated at different levels of detail: total cost—experienced by all vehicles, total cost—experienced by passenger vehicles only, and total cost—experienced by commercial vehicles only [23].



4. Select speed data source
- ● INRIX
- ○ NPMRDS from INRIX (Passenger vehicles)
- ○ NPMRDS from INRIX (Trucks and passenger vehicles)
- ○ NPMRDS from INRIX (Trucks)
- ○ NPMRDS from HERE (Passenger vehicles)
- ○ NPMRDS from HERE (Trucks and passenger vehicles)
- ○ NPMRDS from HERE (Trucks)

5. Confirm the average cost and percent of volume for passenger and commercial vehicle types

Cost

Default hourly costs are provided by Texas Transportation Institute

Passenger vehicles in 2023: $ 17.91

Commercial vehicles in $2023: $ 100.49

Percent

Percent of passenger and commercial volume is based on data provided by the DOT on an annual basis. If no value is provided, the default will be:

Passenger vehicles: 80%

Commercial vehicles: 20%

☐ Use these values for all road segments

6. Define where delay should be calculated
- ○ Where speed falls below historical average speed
- ● Where speed falls below free-flow speed minus 15 mph
- ○ Where speed falls below posted speed limit

Figure 1. NPMRDS analytics for delay cost analysis [23].

The delay costs experienced by commercial vehicles and all (commercial and passenger vehicles) were calculated for the entire (100%) statewide Interstate system between 2016 and 2022. Using the annual bad-performing TMC segments (TMC segments that ever-recorded TTTR > 1.50) as a reference, a comparative analysis of the delay costs experienced on the entire Interstate highway system and the bad-performing TMC segments was also estimated for the period. Two urban locations with a high cluster of bad-performing TMC segments had delay costs resulting from the bad-performing TMC segments at these locations, also estimated for comparative analysis.

2.3. Commercial Vehicle Crash Rate Analysis

The annual commercial vehicle crash rate on each Interstate highway was calculated for every 100 million vehicle-mile of travel (100 MVMT) using the expression in Equation (3) [22]:

$$R = \frac{100000000 * C}{365 * N * \mathrm{ADT} * L} \tag{3}$$

where:

R = Commercial vehicle crash rate (crashes per 100 MVMT).

C = Number of commercial vehicles involved in crashes per period.

N = Number of years of data (annual).

ADT = Average Daily Traffic Volume (both directions).

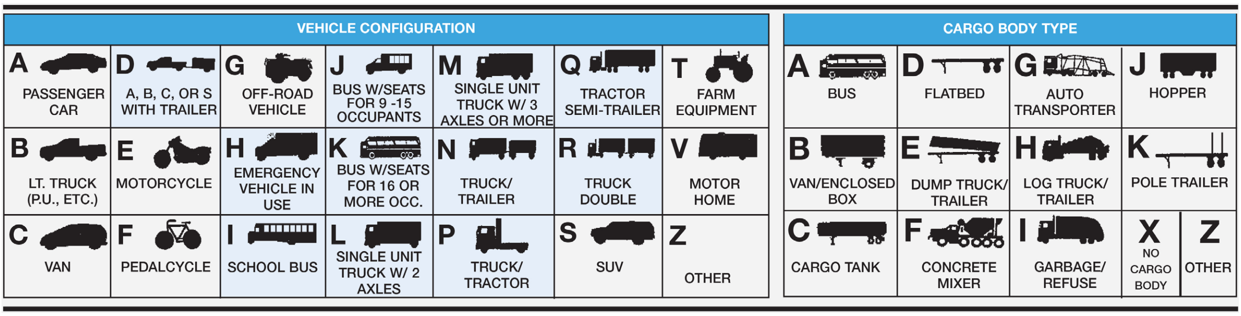
L = Length of Interstate highway segment (miles). Refer to **Table 1**.

Since there were different ADT counts on different segments of a particular Interstate highway, the ADTs reported with each crash on an Interstate highway were averaged for each year and used to estimate the crash rate on respective Interstate highways.

2.3.1. Source of Crash Data

Reported crashes on the Interstate system were sourced from the Louisiana Crash Database [27]. This statewide repository of crash reports offered a comprehensive record of reported crashes, compiled typically by state law enforcement agencies. At the time of data collection, however, the upload of crash records on individual highways for 2022 had not been completed due to the rigorous data quality control processes that are needed to ensure reliable and accurate data. Nonetheless, the available crash data on the interstate system for 2022 were explored mainly to determine the proportion of commercial vehicles involved in crashes statewide and the trends in crashes per milepost on individual highways for 2022.

At the time of data collection, 133,704 reported crashes had been recorded on the Interstate system in Louisiana since 2016, including 10,062 recorded crashes uploaded and available for 2022. Of these, crashes involving only vehicle configurations L, M, N, P, Q, and R, respectively, for 2-axle single-unit truck, 3-axle single-unit truck, truck trailer, truck tractor, tractor semi-trailer, and truck double configurations, as shown on the snippet of the Louisiana Uniform Motor



VEHICLE CONFIGURATION						
A PASSENGER CAR	D A, B, C, OR S WITH TRAILER	G OFF-ROAD VEHICLE	J BUS W/SEATS FOR 9 -15 OCCUPANTS	M SINGLE UNIT TRUCK W/ 3 AXLES OR MORE	Q TRACTOR SEMI-TRAILER	T FARM EQUIPMENT
B LT. TRUCK (P.U., ETC.)	E MOTORCYCLE	H EMERGENCY VEHICLE IN USE	K BUS W/SEATS FOR 16 OR MORE OCC.	N TRUCK/ TRAILER	R TRUCK DOUBLE	V MOTOR HOME
C VAN	F PEDALCYCLE	I SCHOOL BUS	L SINGLE UNIT TRUCK W/ 2 AXLES	P TRUCK/ TRACTOR	S SUV	Z OTHER

CARGO BODY TYPE				
A BUS	D FLATBED	G AUTO TRANSPORTER	J HOPPER	
B VAN/ENCLOSED BOX	E DUMP TRUCK/ TRAILER	H LOG TRUCK/ TRAILER	K POLE TRAILER	
C CARGO TANK	F CONCRETE MIXER	I GARBAGE/ REFUSE	X NO CARGO BODY	Z OTHER

Figure 2. Snippet of the Louisiana uniform motor vehicle traffic crash report.

Vehicle Traffic Crash Report in **Figure 2** were considered commercial vehicle crashes by this paper. If more than one commercial vehicle was involved in a crash, each counted towards the number of commercial vehicles involved. This selection was to limit the scope of evaluation to goods-carrying vehicles, though buses are also considered commercial vehicles in Louisiana [6].

3. Data Analysis and Discussion

3.1. Truck Travel Time Reliability Index Analysis

3.1.1. Truck Travel Time Reliability

For each TMC segment, the TTTR ($95^{th}/50^{th}$ percentile travel time) scores were estimated in 15-minute travel intervals for the five reporting periods: AM Peak, Midday, PM Peak, Weekend, and Overnight throughout an entire year from 2016 to 2022. The box plots shown in **Figure 3-9** show the distribution of the TTTR scores recorded by TMC segments for the five reporting periods and the Maximum TTTR observed across the five-time periods by all TMC segments in Louisiana from 2016 to 2022.

From observation, distributions of TTTR scores for the five reporting periods were skewed towards 1.00, with central tendencies below the 1.50 target. Overall, PM peak periods contributed to the maximum TTTR scores across the years except during 2019, where the Weekend contributed the maximum TTTR score of 17.50, possibly due to a non-recurrent incident. Also, besides 2019 where a maximum third quartile TTTR of 1.52 was observed, three-quarters of the maximum TTTR recorded across the study years were all on or below the 1.50 target threshold. Accordingly, it is deduced that less than one-quarter of the TMC segments recorded bad scores (TTTR > 1.50) over the reporting periods. These bad-performing TMC segments are responsible for the unreliability of the Interstate system.

3.1.2. Truck Travel Time Reliability Index

On a monthly basis, the TTTR Index scores recorded across the years were less on or below 1.50, except for August 2016, March 2021, and August 2021. Notwithstanding the bad TTTR Index scores for these months, the annual TTTR Index remained reliable throughout the study period, with the best performance of 1.26 in 2020, possibly due to the reduced vehicle miles traveled (VMT) in

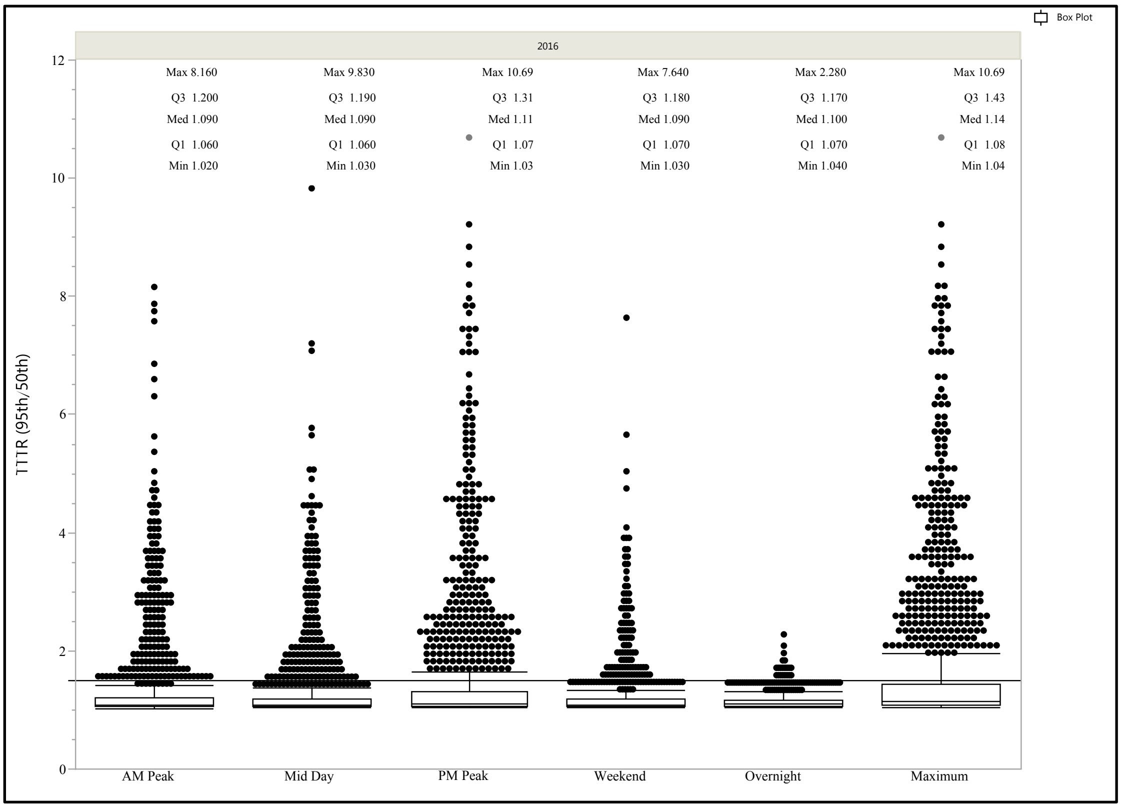


Figure 3. TTTR—Louisiana interstate highway system, 2016.

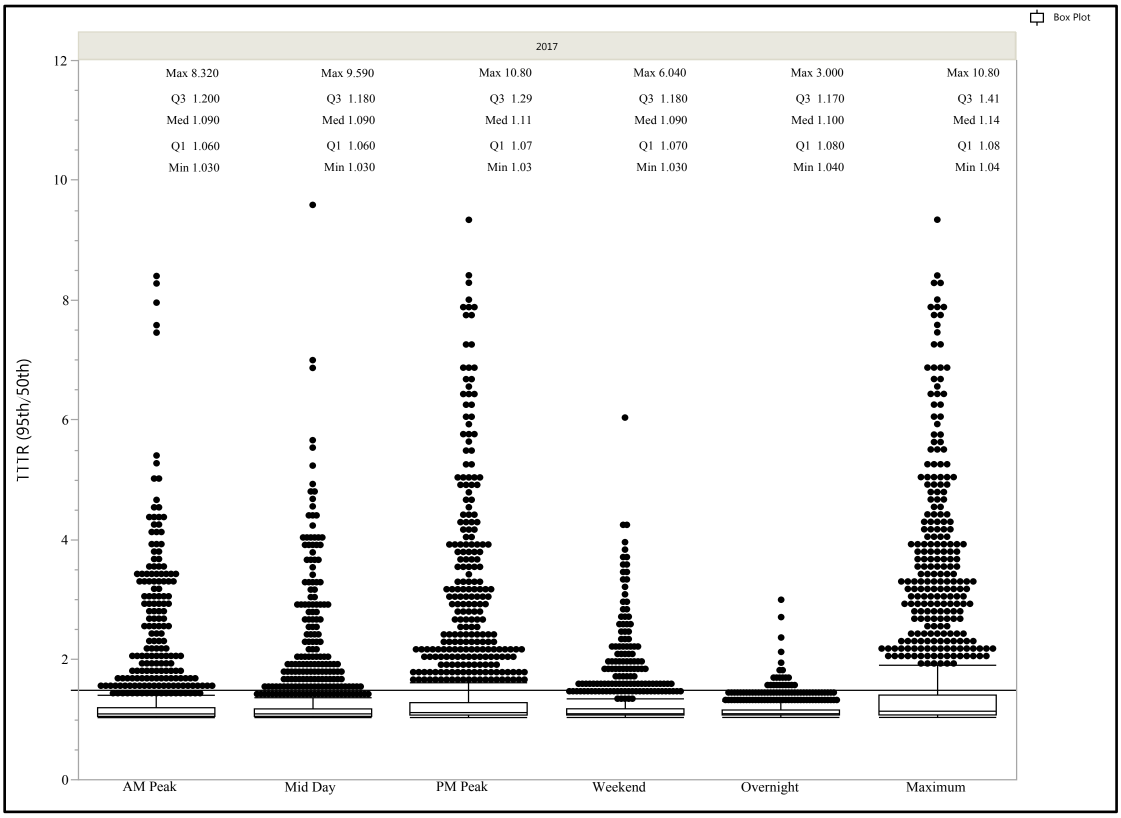


Figure 4. TTTR—Louisiana interstate highway system, 2017.

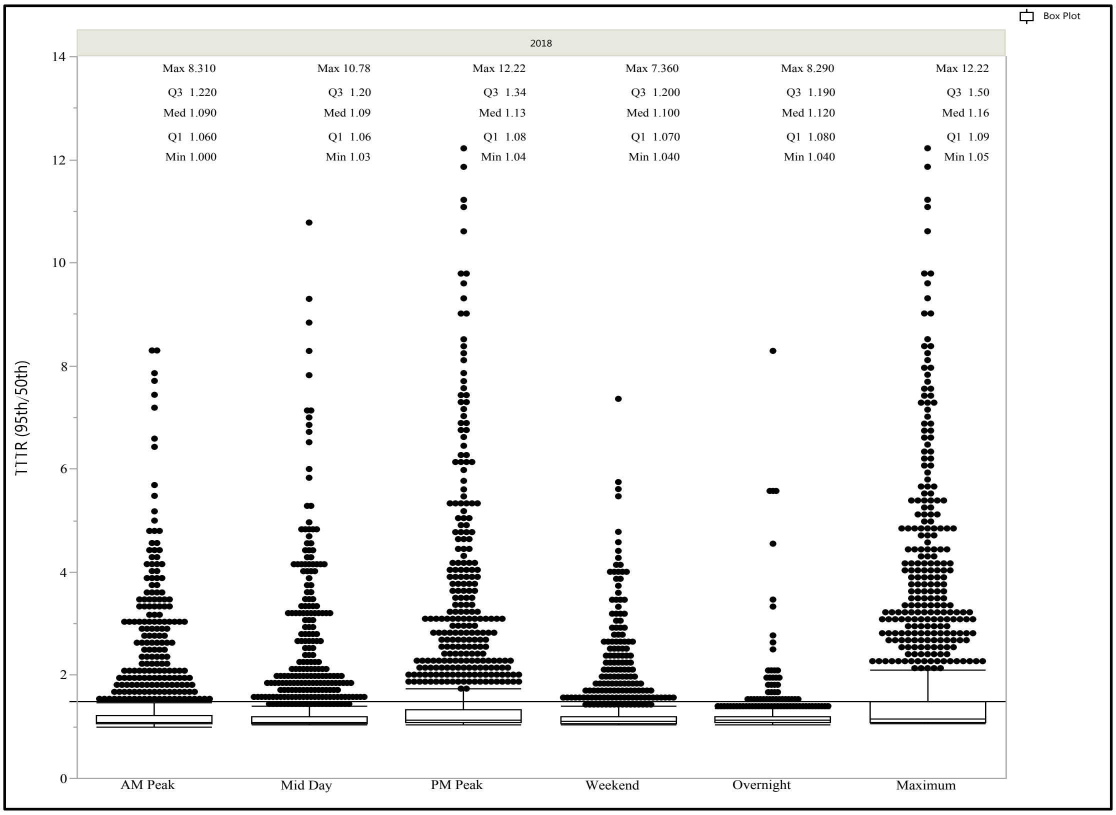


Figure 5. TTTR—Louisiana interstate highway system, 2018.

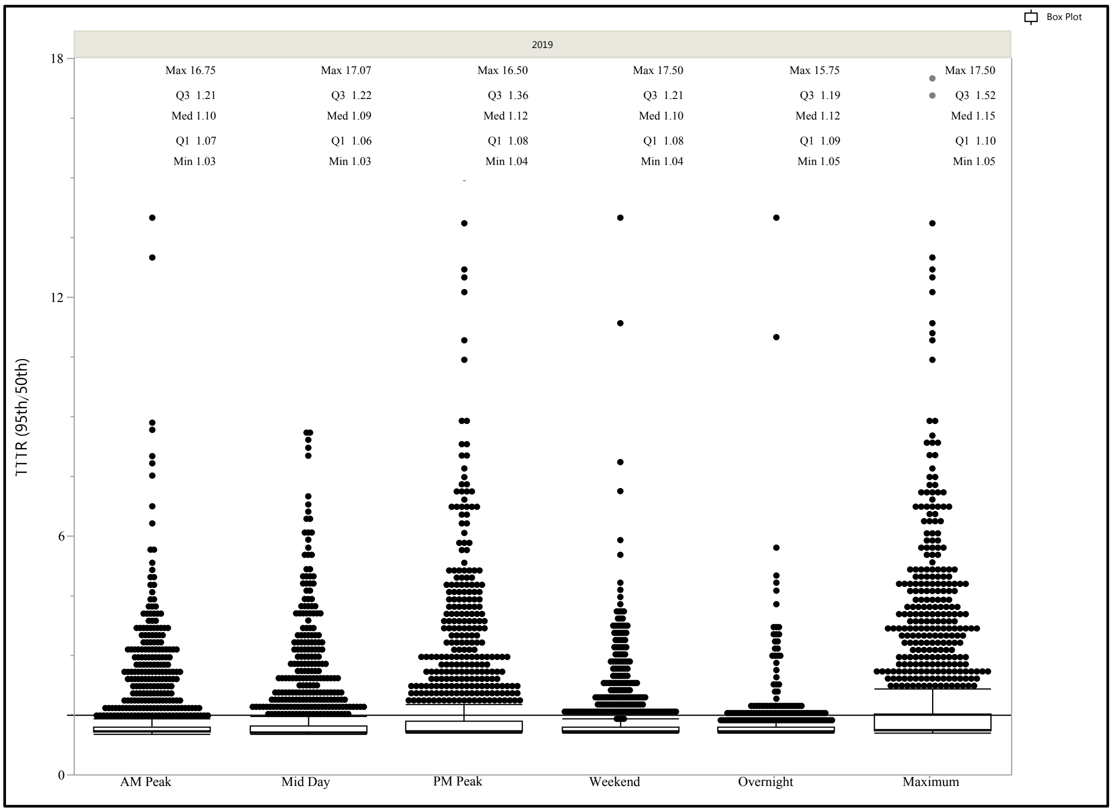


Figure 6. TTTR—Louisiana interstate highway system, 2019.

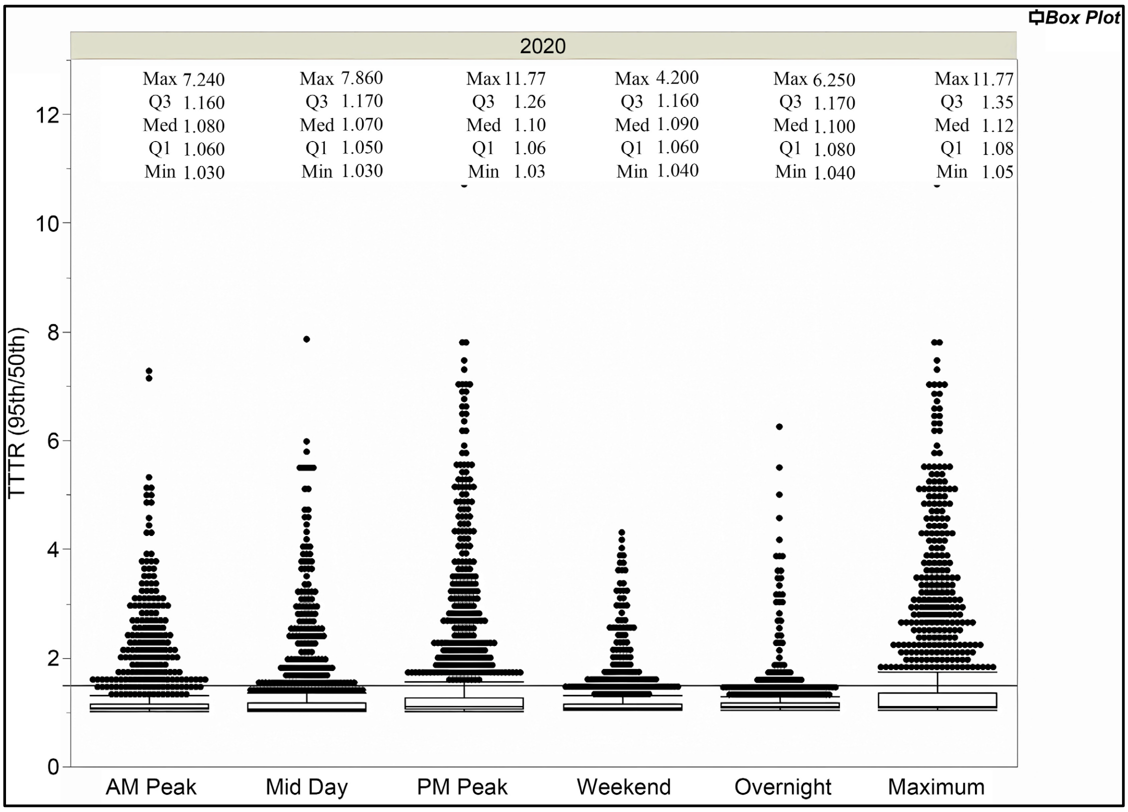


Figure 7. TTTR—Louisiana interstate highway system, 2020.

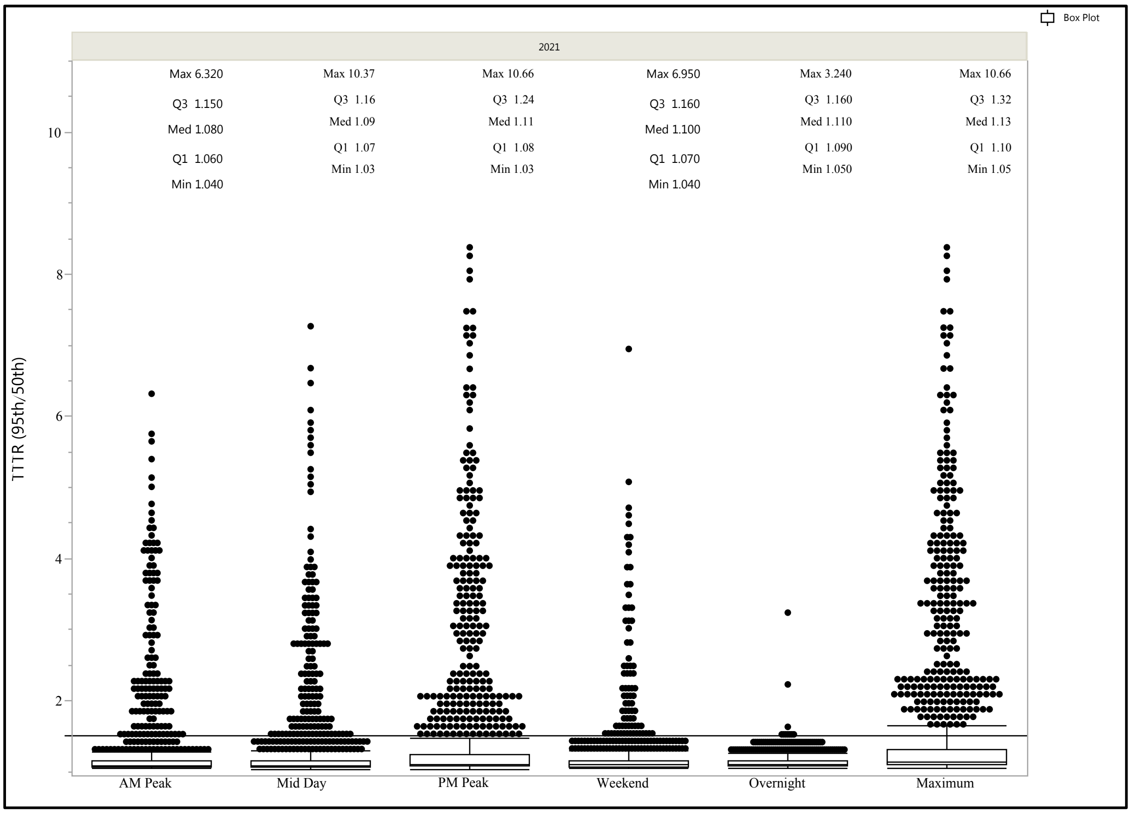


Figure 8. TTTR—Louisiana interstate highway system, 2021.

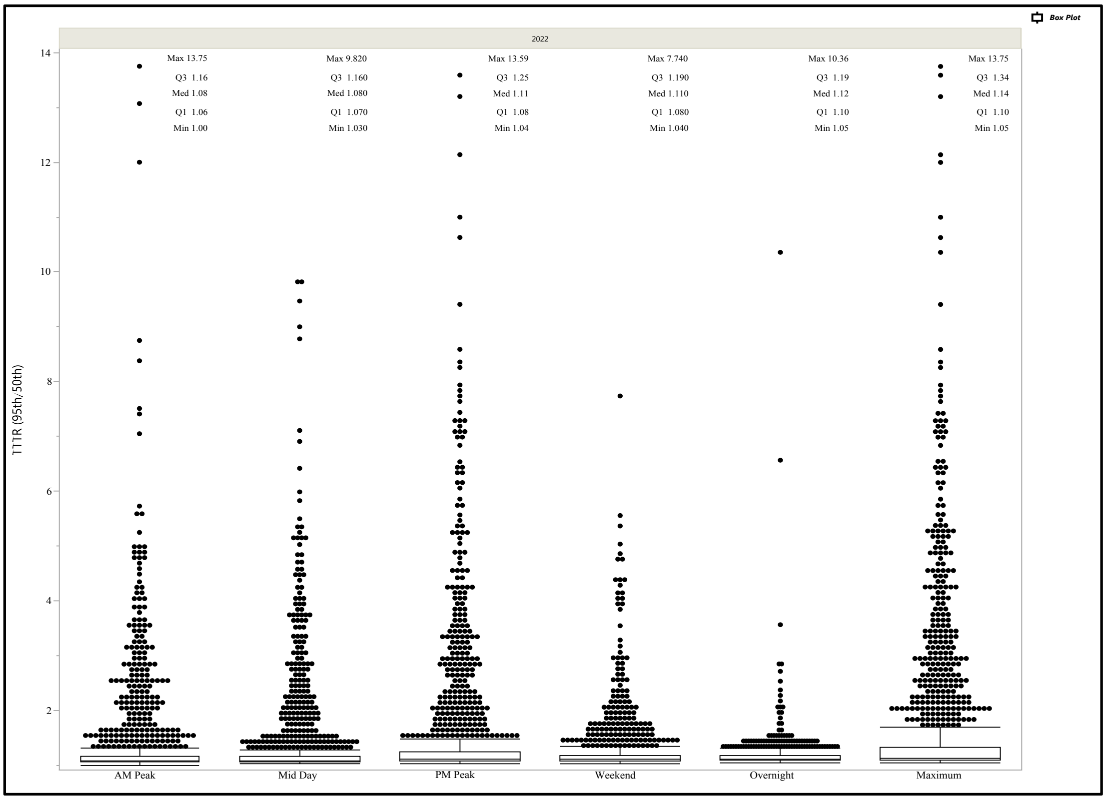


Figure 9. TTTR—Louisiana interstate highway system, 2022.

response to COVID-19 regulations. The worst yearly score was 1.35, registered in 2018 and 2019, which was still considered a good score with respect to the target set by Louisiana. The historical monthly and yearly TTTR Index from 2016 to 2022 is shown in Table 2.

From the table, for instance, in terms of freight movement travel time, a commercial vehicle needed to estimate 15.60 minutes extra for a trip that would take 60 minutes in free-flow conditions to ensure a 95 percent reliability of on-time arrival in 2020 compared to 21 minutes in 2018 and 2019.

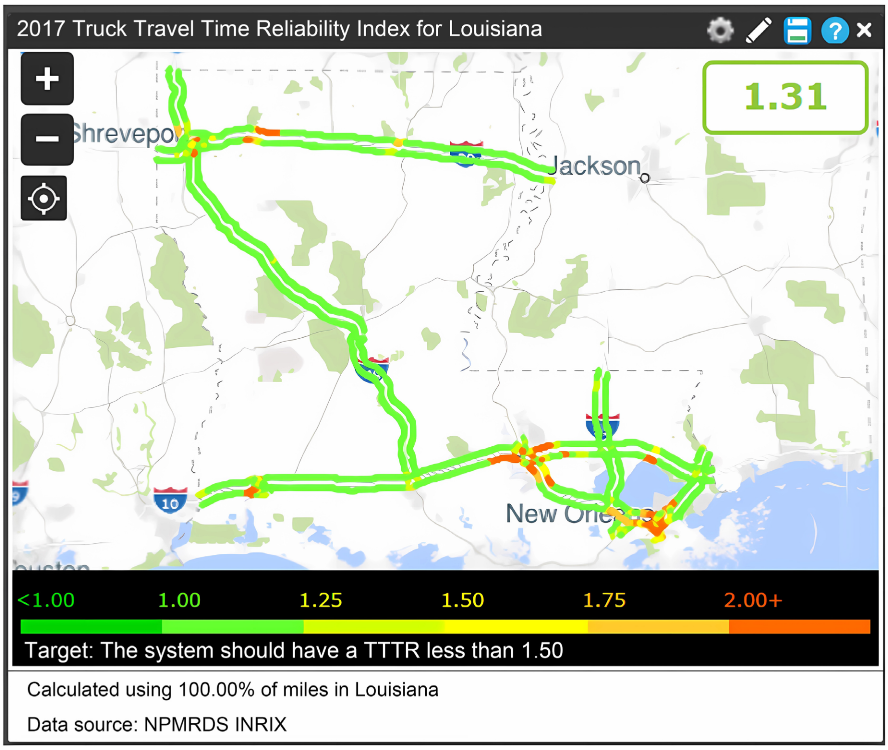
3.1.3. Bad Performing (Unreliable) TMC Segments (TTTR > 1.50)

The scorecard shown in Figure 10 depicts the reliable and unreliable TMC segments in 2017. As shown, some TMC segments recorded TTTR scores higher than the state threshold. These TMC segments that recorded a maximum TTTR score greater than 1.50 between 2016 and 2022 are mainly clustered in and around New Orleans, Baton Rouge, Shreveport, and Lake Charles, with a few dotted along I-12, I-20 and I-49, as shown in Figure 11.

In all, 435 different TMC segments recorded TTTR scores greater than 1.50 between 2016 and 2022. These added up to 315.78 miles (16.78%) of the 1882 total TMC mileage that makes up 100% of the Interstate highway system. Of these 435 TMC segments, 159 and 100 were in and around New Orleans and Baton Rouge, respectively. These TMC segments added to 80.79 miles in and around New Orleans and 71.62 miles in and around Baton Rouge, which were

Table 2. TTTR index—Louisiana interstate highway systems (2016-2020).

Monthly TTTR Index							
Month\Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
January	1.31	1.31	1.34	1.42	1.31	1.20	1.24
February	1.37	1.38	1.35	1.41	1.36	1.89	1.32
March	1.45	1.36	1.42	1.47	1.27	1.32	1.40
April	1.38	1.35	1.42	1.37	1.11	1.27	1.33
May	1.37	1.41	1.38	1.40	1.14	1.35	1.32
June	1.36	1.38	1.42	1.40	1.23	1.46	1.37
July	1.42	1.34	1.37	1.42	1.22	1.35	1.33
August	1.53	1.36	1.37	1.40	1.26	1.60	1.28
September	1.39	1.39	1.42	1.33	1.40	1.40	1.31
October	1.38	1.34	1.42	1.39	1.40	1.33	1.31
November	1.44	1.40	1.42	1.40	1.33	1.37	1.40
December	1.36	1.33	1.38	1.39	1.30	1.34	1.41
Yearly TTTR Index							
Year	2016	2017	2018	2019	2020	2021	2022
TTTR Index	1.33	1.31	1.35	1.35	1.26	1.29	1.29



Target: The system should have a TTTR less than 1.50

Calculated using 100.00% of miles in Louisiana

Data source: NPMRDS INRIX

Figure 10. 2017 Louisiana TTTR index scorecard (map).

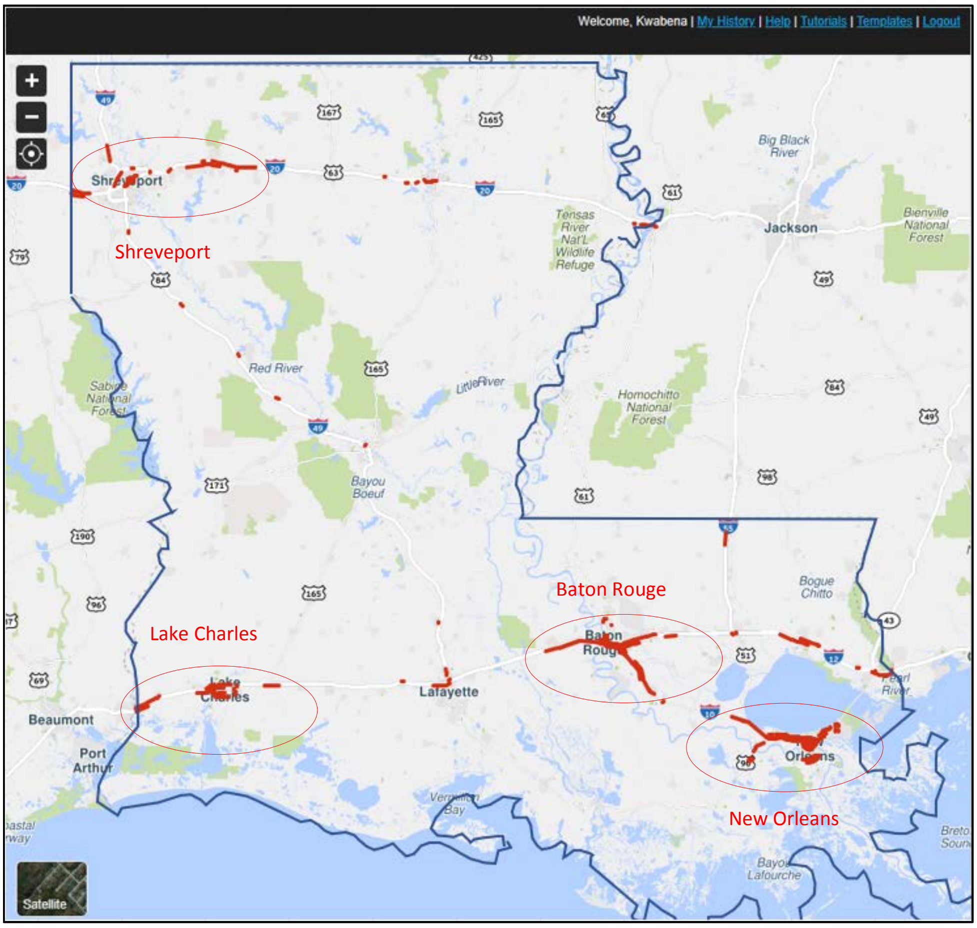


Figure 11. Bad performing TMC segments in Louisiana (TTTR > 1.50) from 2016-2022.

4.29% and 3.81% of the entire (100%) Interstate highway mileage, respectively. These TMCs segments were mainly on I-10, I-12, and I-110 in Baton Rouge and I-10, I-610, and I-310 in New Orleans, as shown in **Figure 12**.

Aggregated yearly, the numbers of TMC segments that recorded bad TTTR scores statewide totaled less than 12% of the statewide TMC mileage, with the least of 7.66% (187.99 miles) recorded in 2020 and the high of 11.18% (210.42 miles), recorded in 2016. In terms of the two urban locations with the high cluster of bad-performing TMC segments, the annual proportion of the statewide Interstate highway mileage in Baton Rouge that registered TTTR greater than 1.50 ranged between 2.14% (2020) and 3.71% (2016). In New Orleans, the proportions were less than 4% of statewide Interstate highway mileage, the same as in Baton Rouge, and ranged from 2.37% (2020) to 3.50% (2022). The number of TMC segments that recorded unreliable TTTR scores (TTTR > 1.50) statewide and in and around Baton Rouge and New Orleans between 2016 and 2022 is shown in **Table 3**, along with the respective mileages and proportion of the statewide Interstate highway mileage that they represent.

The subsequent sections present an analysis of the User Delay Costs on Louisiana's Interstate highway system between 2016 and 2022.

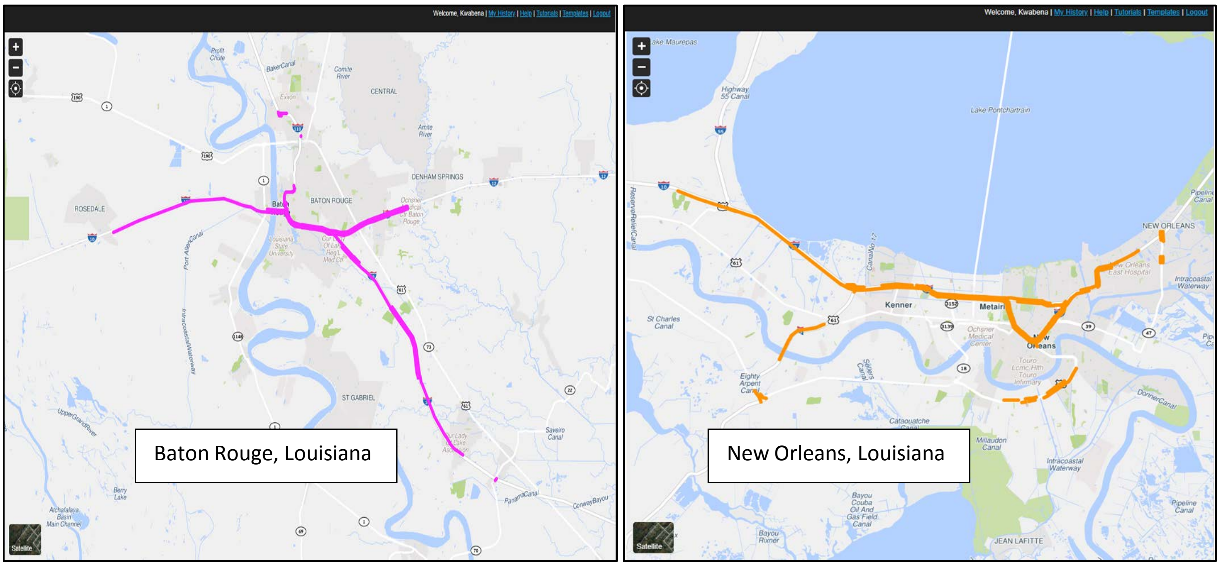


Figure 12. Bad performing TMC segments in New Orleans and baton rouge 1.50 (2016-2020).

Table 3. Unreliable TMC segments (2016-2022).

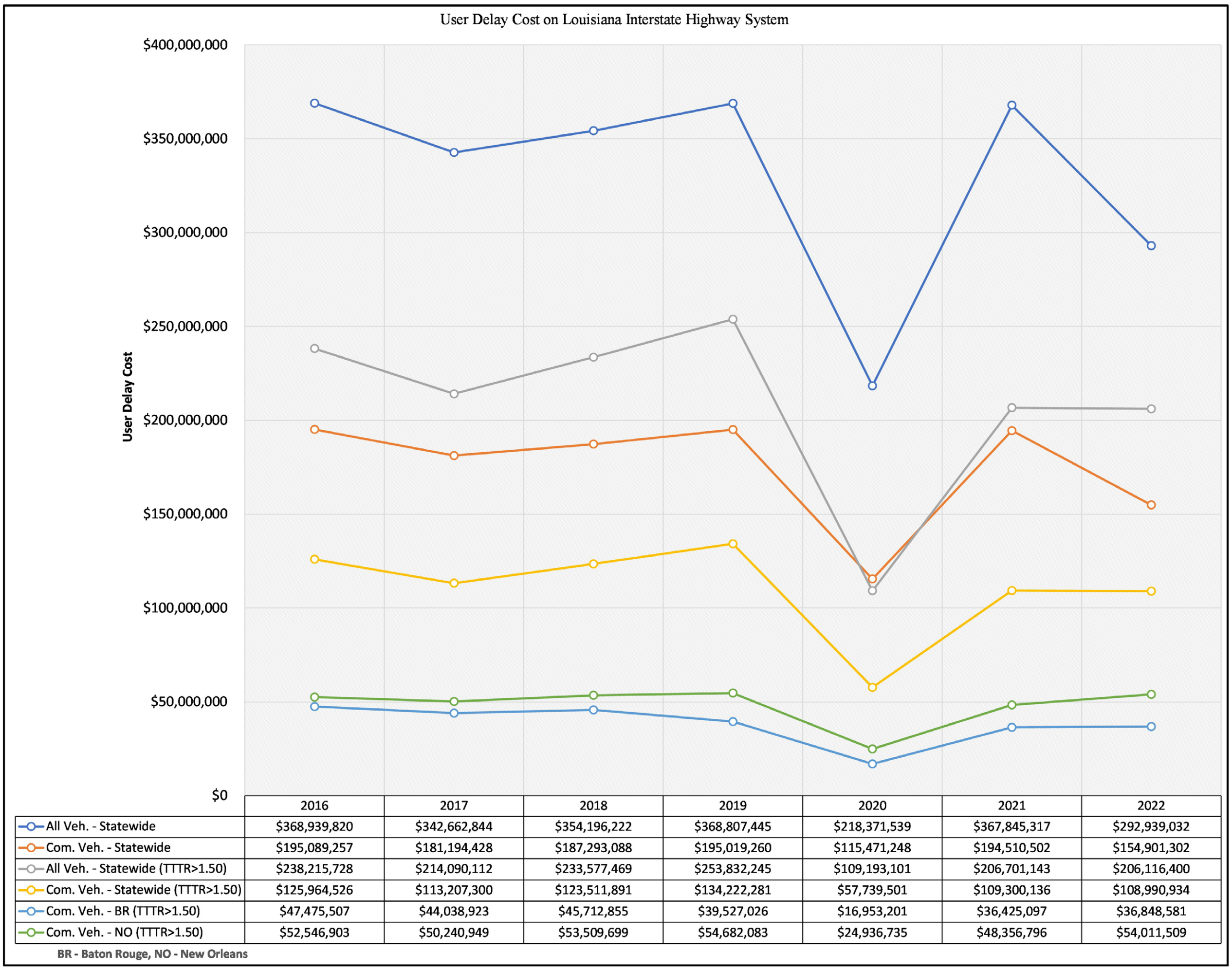
Year	Description	Statewide	Baton Rouge (BR)	New Orleans (NO)
2016	No. of TMCs	322	94	117
	Total mileage	210.42	69.87	63.62
	% of Interstate Sys.	**11.18%**	**3.71%**	**3.38%**
2017	No. of TMCs	284	83	117
	Total mileage	196.92	65.58	59.97
	% of Interstate Sys.	**10.46%**	**3.48%**	**3.19%**
2018	No. of TMCs	308	88	123
	Total mileage	203.68	66.95	60.21
	% of Interstate Sys.	**10.82%**	**3.56%**	**3.20%**
2019	No. of TMCs	305	80	133
	Total mileage	187.99	52.74	64.39
	% of Interstate Sys.	**9.99%**	**2.80%**	**3.42%**
2020	No. of TMCs	262	75	111
	Total mileage	144.20	40.30	44.64
	% of Interstate Sys.	**7.66%**	**2.14%**	**2.37%**
2021	No. of TMCs	280	78	121
	Total mileage	172.64	45.72	61.87
	% of Interstate Sys.	**9.17%**	**2.43%**	**3.29%**
2022	No. of TMCs	259	73	127
	Total mileage	163.47	51.81	65.80
	% of Interstate Sys.	**8.69%**	**2.75%**	**3.50%**

3.2. Truck Delay Cost Analysis

The trends of annual User Delay Costs experienced by all vehicles and by commercial vehicles on the entire (100%) Interstate highway system between 2016 and 2022 are presented in **Figure 13**, along with the annual User Delay Costs experienced (by all vehicles and by commercial vehicles) on the proportion of Interstate highway system with unreliable TMC segments (TTTR > 1.50), between 2016 and 2022, referred to in **Table 3**. Also shown in **Figure 13** are the trends of annual User Delay Costs experienced by commercial vehicles on the proportions of the Interstate highway system in and around Baton Rouge and New Orleans responsible for unreliability (TTTR > 1.50) at these two urban locations.

From observation, the annual User Delay Costs experienced by all vehicles and by only commercial vehicles on the entire Interstate highway system remained relatively constant between 2016 and 2019, dipped in 2020 due to reduced VMT, and returned to the usual (pre-2020) trend in 2021. The trend, however, dropped in 2022 below pre-2020 and 2021 levels, an indication of relatively improved travel conditions in 2022 in terms of travel time and congestion compared to conditions observed pre-2020 and 2021.

The User Delay Cost experienced by all vehicles and by commercial vehicles



	2016	2017	2018	2019	2020	2021	2022
All Veh. - Statewide	$368,939,820	$342,662,844	$354,196,222	$368,807,445	$218,371,539	$367,845,317	$292,939,032
Com. Veh. - Statewide	$195,089,257	$181,194,428	$187,293,088	$195,019,260	$115,471,248	$194,510,502	$154,901,302
All Veh. - Statewide (TTTR>1.50)	$238,215,728	$214,090,112	$233,577,469	$253,832,245	$109,193,101	$206,701,143	$206,116,400
Com. Veh. - Statewide (TTTR>1.50)	$125,964,526	$113,207,300	$123,511,891	$134,222,281	$57,739,501	$109,300,136	$108,990,934
Com. Veh. - BR (TTTR>1.50)	$47,475,507	$44,038,923	$45,712,855	$39,527,026	$16,953,201	$36,425,097	$36,848,581
Com. Veh. - NO (TTTR>1.50)	$52,546,903	$50,240,949	$53,509,699	$54,682,083	$24,936,735	$48,356,796	$54,011,509

BR - Baton Rouge, NO - New Orleans

Figure 13. User delay cost on Louisiana interstate highway system (2016-2022).

on the bad-performing TMC segments followed a similar trend as on the entire Interstate highway system, except that the User Delay Costs remained about the same between 2021 and 2022. Besides, the User Delay Cost experienced by all vehicles on the bad-performing TMC segments statewide reduced below the User Delay Cost experienced by commercial vehicles on the entire Interstate highway system for the first time in 2020. In New Orleans and Baton Rouge, the delay costs on the bad-performing TMC segments in 2022 were, on average, similar to pre-2020 trends, indicating that travel conditions did not improve on these segments.

Comparative ratios of the vehicle delay costs in **Figure 13** are presented in **Table 4**.

From the comparative ratios:

- The annual User Delay Costs by commercial vehicles on the entire (100%) Interstate highway system were, on average, 52.88% of the User Delay Cost experienced by all vehicles statewide between 2016 and 2022. The comparative ratios between the User Delay Cost experienced by commercial vehicles and all vehicles on the bad-performing TMC segments statewide between 2016 and 2022 were also 52.88%, as seen in **Table 4** (A and B). These ratios observed are mainly by virtue of the estimated proportion of commercial vehicles on Louisiana's Interstate highways and the estimated hour value of delay time for trucks and passenger vehicles and by definition of delay.
- The annual User Delay Costs by all vehicles on the bad-performing TMC segments statewide were, on average, 65.45% of the User Delay Cost by all vehicles on the entire (100%) Interstate highway system between 2016 and 2019. The proportion dropped to 50.00% in 2020 and increased to 56.19% in 2021 and 70.36% in 2022, the highest, similar to the comparative ratios between the User Delay Cost by commercial vehicles on the bad-performing TMC segments statewide to the User Delay Cost by commercial vehicles on the entire (100%) Interstate highway, as observed in **Table 4** (C and D). These proportions are extremely high considering that the annual Interstate highway system mileage responsible for unreliability from 2016 to 2022 was below 12% of the entire (100%) Interstate highway system mileage, as seen in **Table 3**. This disproportion ratio indicates the economic impact of the unreliability of the Interstate system on commercial vehicle (freight) operations in Louisiana and, by extension, on passenger vehicles too.
- The total annual User Delay Cost by commercial vehicles on the bad-performing TMC segments in and around Baton Rouge and New Orleans between 2016 and 2022 were, on average:
  - 41.30% of the corresponding annual User Delay Cost by all vehicles on the respective annual bad-performing TMC segments statewide, as seen in **Table 4** (E).
  - 78.10% of the corresponding annual User Delay Cost by commercial vehicles on the respective annual bad-performing TMC segments statewide, as seen in **Table 4** (F).

Table 4. Comparative ratios of delay costs (2016-2022).

User Delay Cost	Ratio	2016	2017	2018	2019	2020	2021	2022
A								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
All Veh. - Statewide	A	$368,939,820	$342,662,844	$354,196,222	$368,807,445	$218,371,539	$367,845,317	$292,939,032
Com. Veh. - Statewide	B	$195,089,257	$181,194,428	$187,293,088	$195,019,260	$115,471,248	$194,510,502	$154,901,302
Ratio (%)	B:A	52.88	52.88	52.88	52.88	52.88	52.88	52.88
B								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
All Veh. - Statewide (TTTR>1.50)	A	$238,215,728	$214,090,112	$233,577,469	$253,832,245	$109,193,101	$206,701,143	$206,116,400
Com. Veh. - Statewide (TTTR>1.50)	B	$125,964,526	$113,207,300	$123,511,891	$134,222,281	$57,739,501	$109,300,136	$108,990,934
Ratio (%)	B:A	52.88	52.88	52.88	52.88	52.88	52.88	52.88
C								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
All Veh. - Statewide (TTTR>1.50)	A	$238,215,728	$214,090,112	$233,577,469	$253,832,245	$109,193,101	$206,701,143	$206,116,400
All Veh. - Statewide	B	$368,939,820	$342,662,844	$354,196,222	$368,807,445	$218,371,539	$367,845,317	$292,939,032
Ratio (%)	A:B	64.57	62.48	65.95	68.83	50.00	56.19	70.36
D								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Com. Veh. - Statewide (TTTR>1.50)	A	$125,964,526	$113,207,300	$123,511,891	$134,222,281	$57,739,501	$109,300,136	$108,990,934
Com. Veh. - Statewide	B	$195,089,257	$181,194,428	$187,293,088	$195,019,260	$115,471,248	$194,510,502	$154,901,302
Ratio (%)	A:B	64.57	62.48	65.95	68.83	50.00	56.19	70.36
E								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Com. Veh. - BR (TTTR>1.50)	A	$47,475,507	$44,038,923	$45,712,855	$39,527,026	$16,953,201	$36,425,097	$36,848,581
Com. Veh. - NO (TTTR>1.50)	B	$52,546,903	$50,240,949	$53,509,699	$54,682,083	$24,936,735	$48,356,796	$54,011,509
All Veh. - Statewide (TTTR>1.50)	C	$238,215,728	$214,090,112	$233,577,469	$253,832,245	$109,193,101	$206,701,143	$206,116,400
Ratio (%)	(A+B):C	41.99	44.04	42.48	37.11	38.36	41.02	44.08
F								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Com. Veh. - BR (TTTR>1.50)	A	$47,475,507	$44,038,923	$45,712,855	$39,527,026	$16,953,201	$36,425,097	$36,848,581
Com. Veh. - NO (TTTR>1.50)	B	$52,546,903	$50,240,949	$53,509,699	$54,682,083	$24,936,735	$48,356,796	$54,011,509
Com. Veh. - Statewide (TTTR>1.50)	C	$125,964,526	$113,207,300	$123,511,891	$134,222,281	$57,739,501	$109,300,136	$108,990,934
Ratio (%)	(A+B):C	79.41	83.28	80.33	70.19	72.55	77.57	83.36
G								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Com. Veh. - BR (TTTR>1.50)	A	$47,475,507	$44,038,923	$45,712,855	$39,527,026	$16,953,201	$36,425,097	$36,848,581
Com. Veh. - NO (TTTR>1.50)	B	$52,546,903	$50,240,949	$53,509,699	$54,682,083	$24,936,735	$48,356,796	$54,011,509
Com. Veh. - Statewide	C	$195,089,257	$181,194,428	$187,293,088	$195,019,260	$115,471,248	$194,510,502	$154,901,302
Ratio (%)	(A+B):C	51.27	52.03	52.98	48.31	36.28	43.59	58.66
H								
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Com. Veh. - BR (TTTR>1.50)	A	$47,475,507	$44,038,923	$45,712,855	$39,527,026	$16,953,201	$36,425,097	$36,848,581
Com. Veh. - NO (TTTR>1.50)	B	$52,546,903	$50,240,949	$53,509,699	$54,682,083	$24,936,735	$48,356,796	$54,011,509
All Veh. - Statewide	C	$368,939,820	$342,662,844	$354,196,222	$368,807,445	$218,371,539	$367,845,317	$292,939,032
Ratio (%)	(A+B):C	27.11	27.51	28.01	25.54	19.18	23.05	31.02

- 49.02% of the corresponding User Delay Cost by commercial vehicles on the entire Interstate highway system, as seen in Table 4 (G).
- 25.92% of the annual User Delay Cost by all vehicles on the entire (100%)

Interstate highway system, as seen in **Table 4** (H), all of which are extremely high considering that the proportions of the statewide interstate system in and around these urban locations responsible for unreliability annually were altogether less than 7.5% of the statewide interstate system.

These disproportionally high ratios indicating the economic impact of the unreliability of the Interstate system on freight operations can form the basis of investment decisions to improve travel conditions at locations with high clusters of unreliable TMC segments (TTTR > 1.50) in Louisiana.

3.3. Commercial Vehicle Safety in Louisiana (2016-2022)

3.3.1. Commercial Vehicle Crash Frequencies

The annual frequency of all vehicle crashes over the study period on the Interstate system remained similar between 2016 and 2019, declined marginally in 2020, and returned to the usual trend in 2021. While there were fewer vehicle crashes in 2020, the proportion of commercial vehicles involved in crashes saw an increasing trend from 12.79% in 2016 to 15.84% in 2021. Even on the 10062 crash records (preliminary) available for 2022 to date, the proportion of commercial vehicles involved in these crashes was 17.75% for that year. The increasing trend of the proportion of commercial vehicles involved in crashes annually indicates critical safety conditions that must be investigated and addressed in order to improve safe freight operations in Louisiana.

The annual frequency of all crashes, the number of commercial vehicles involved, and the ratio of the number of commercial vehicles involved to the annual frequency of all crashes on Louisiana's Interstate system between 2016 and 2022 are shown in **Figure 14**.

3.3.2. Commercial Vehicle Crash Rates

Excluding the preliminary crash records on individual highways in 2022, I-110 had three worst performances in 2016, 2019, and 2020 in terms of commercial vehicle crash rate, expressed in 100 MVMT, of the six years. Other worst performers were the I-610, with two of the worst crash rates in 2017 and 2021, while an unusually high crash rate on the I-510 in 2018 made the other, all of which have mileages of less than 12 miles. Other interstate highways with moderate to moderately high crash rates were I-220 and I-210, with 18.0 and 12.5 miles, respectively. Likewise, I-10, I-12, and I-20, with 274, 85, and 189 miles in the north-south bound directions, respectively, also had moderate-to-moderately high crash rates, with I-20 having a relatively lower rate among these three highways as shown in **Figure 15**.

In terms of relatively safer commercial vehicle interstate highways, I-49, with 247 miles in the north-south direction, had the lowest crash rates in three of the six years studied, while I-510, with 3.0 miles in the north-south direction, had the lowest crash rates in the other three years. Also, I-55 and I-59, in the north-south bound directions, with 66.0 and 11.0 miles, respectively, had moderately lower crash rates over the studied period.

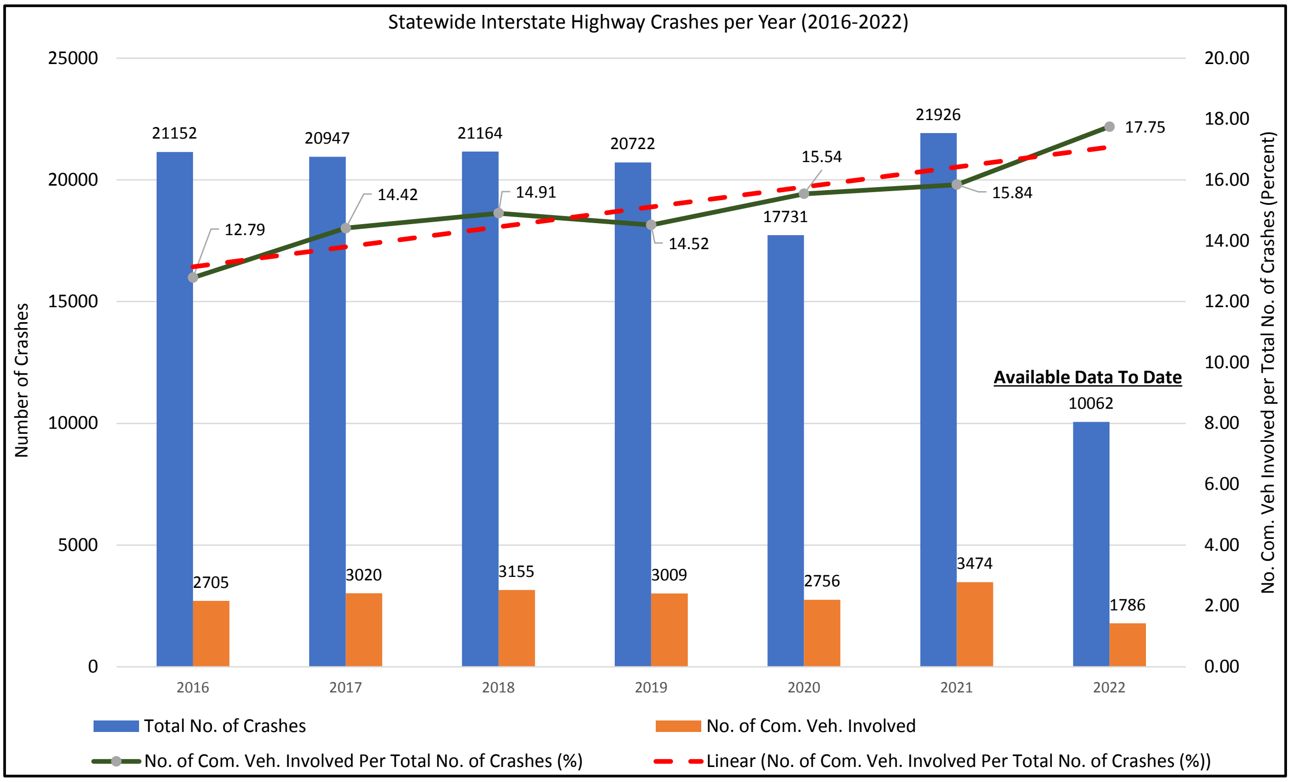
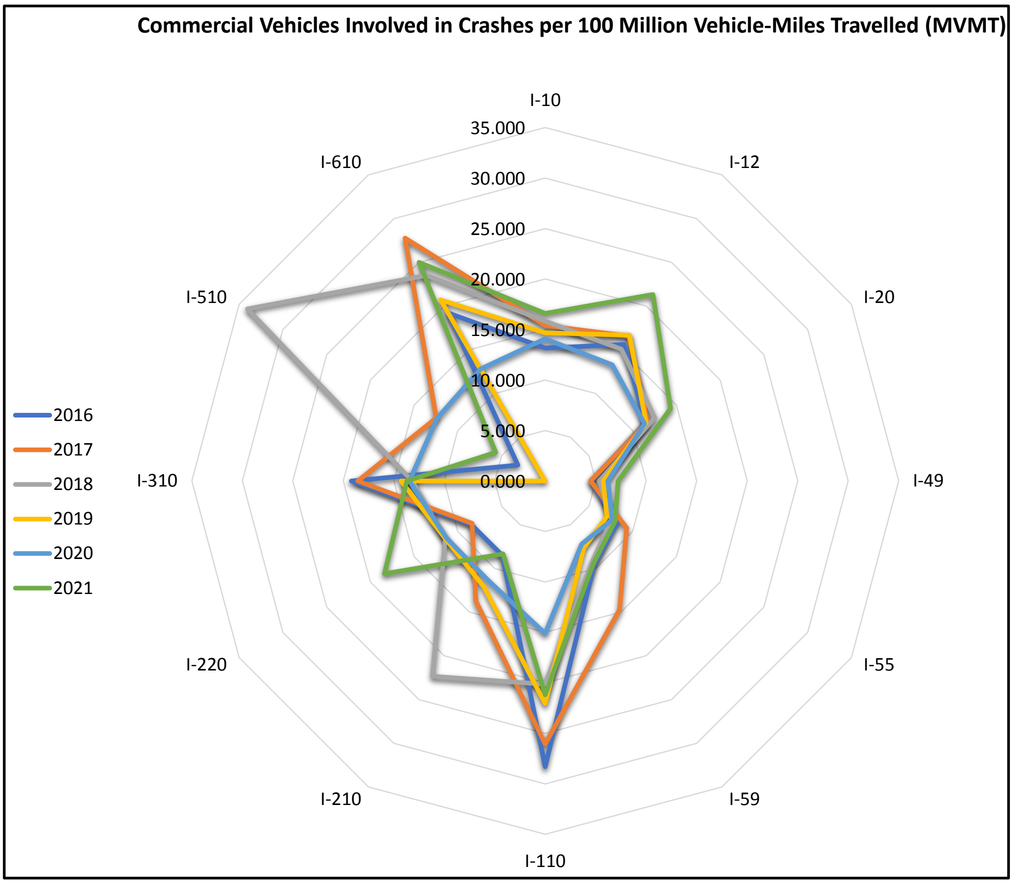
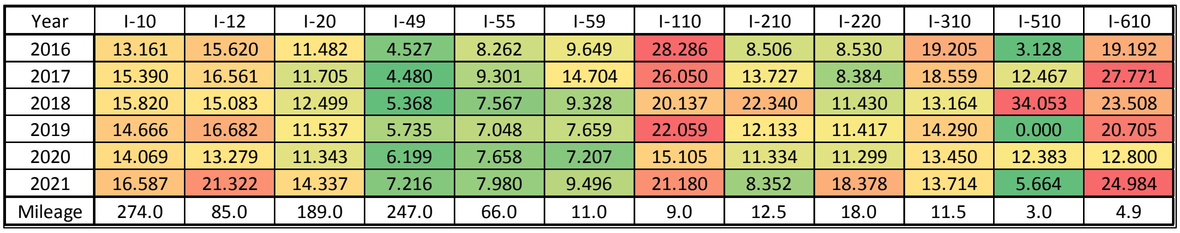


Figure 14. Annual crashes on Louisiana's interstate highway system (2016-2022).





Year	I-10	I-12	I-20	I-49	I-55	I-59	I-110	I-210	I-220	I-310	I-510	I-610
2016	13.161	15.620	11.482	4.527	8.262	9.649	28.286	8.506	8.530	19.205	3.128	19.192
2017	15.390	16.561	11.705	4.480	9.301	14.704	26.050	13.727	8.384	18.559	12.467	27.771
2018	15.820	15.083	12.499	5.368	7.567	9.328	20.137	22.340	11.430	13.164	34.053	23.508
2019	14.666	16.682	11.537	5.735	7.048	7.659	22.059	12.133	11.417	14.290	0.000	20.705
2020	14.069	13.279	11.343	6.199	7.658	7.207	15.105	11.334	11.299	13.450	12.383	12.800
2021	16.587	21.322	14.337	7.216	7.980	9.496	21.180	8.352	18.378	13.714	5.664	24.984
Mileage	274.0	85.0	189.0	247.0	66.0	11.0	9.0	12.5	18.0	11.5	3.0	4.9

Figure 15. Commercial vehicle crash rates in 100 MVMT (2016-2021).

3.3.3. Overview of Crashes on Individual Interstate Highways

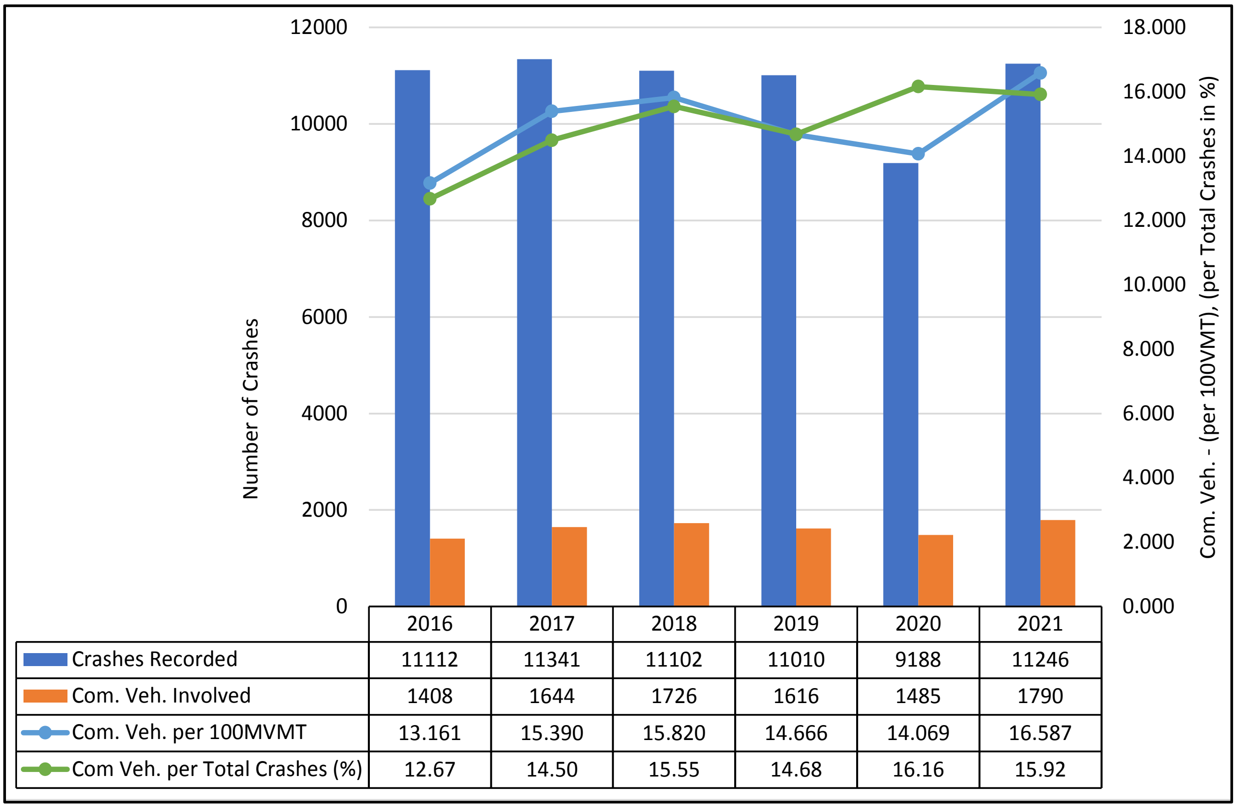
In terms of crash frequencies and proportions of commercial vehicles involved, as presented below in Figure 16-27, the individual interstate highways followed different trends from the statewide estimations presented in Figure 14. In reference to the proportion of commercial vehicles involved, it is observed that, even though the statewide proportions were between 12.79% recorded in 2016 and 15.84% recorded in 2021, some interstates highways recorded proportions higher than the estimated statewide proportions in some of the years, such as I-59 in 2016 and 2017, and I-310 in 2017, and 2020, as shown in Figure 21 and Figure 25, respectively.

Also, even though I-20 had relatively moderate crash rates, the proportions of commercial vehicles involved in crashes annually were higher than the statewide proportion in all the years evaluated, as shown in Figure 18, pointing to unsafe conditions that must be investigated and resolved on this highway to improve safe commercial vehicle operations. Additionally, for the worst-performing I-110 and I-610 in terms of crash rates, these interstate highways were observed to have a relatively lower proportion of commercial vehicles involved in crashes for those years compared to the state averages, as shown in Figure 22 and Figure 27.

These observations suggest that using a single performance measure to assess safety on Louisiana's highway system may not be enough to make sound determinations. For this, there is the need to set individual performance targets for each interstate highway instead of a blanket target for the statewide highway system. Additionally, there may be a need to compare or benchmark the safety performance of individual subsystems (highways) with another in order to make informed decisions.

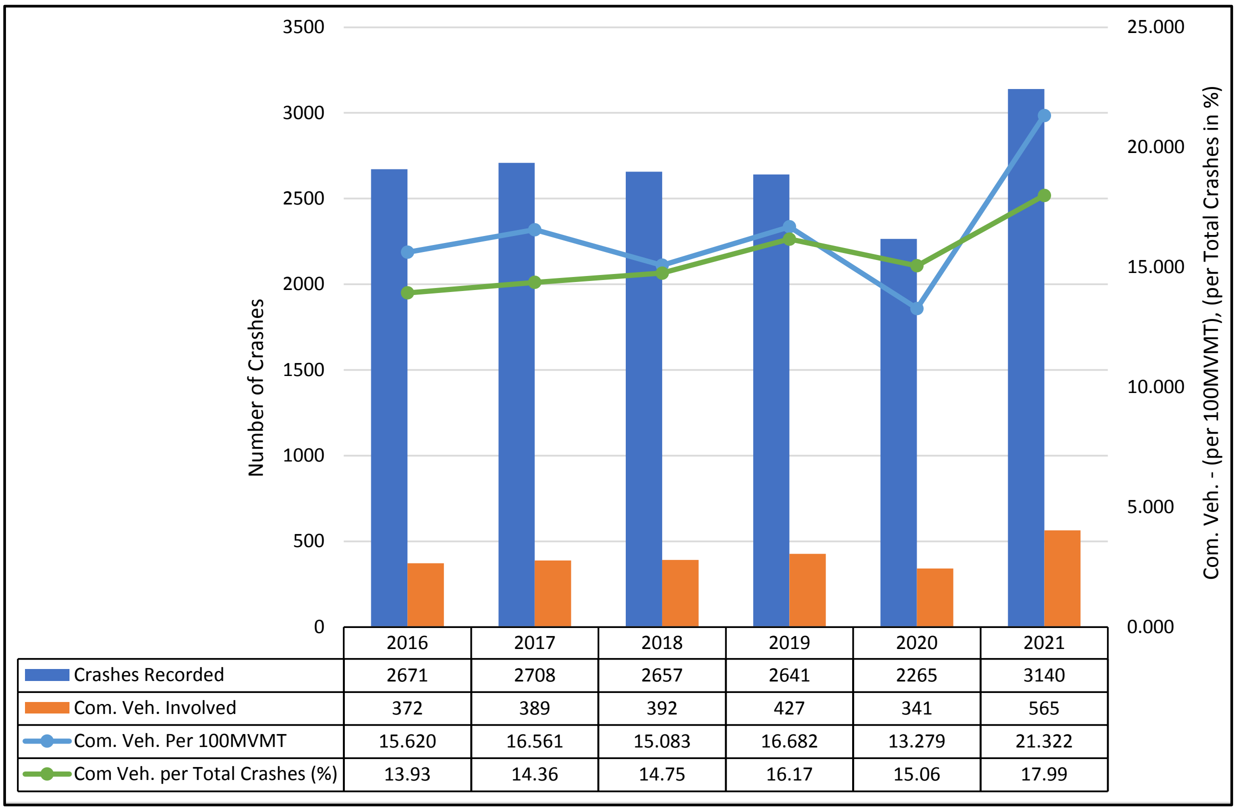
3.3.4. Crash Clustering Analysis

Plotting the trend of crashes per milepost over the study period, locations with recurring clusters of crashes on each interstate highway were identified. For instance, for I-10, mileposts with unusually high frequency were in Lake Charles, Baton Rouge, and New Orleans, with an emerging mound shape on mileposts in Lafayette, even with the preliminary crash records for 2022, as shown in Figure 28. Plotting the GPS coordinates of crashes on mileposts with high clustering on all interstate highways, the pin map cluster in Figure 29 is created, indicating segments on the interstate highway system that experienced multiple crashes



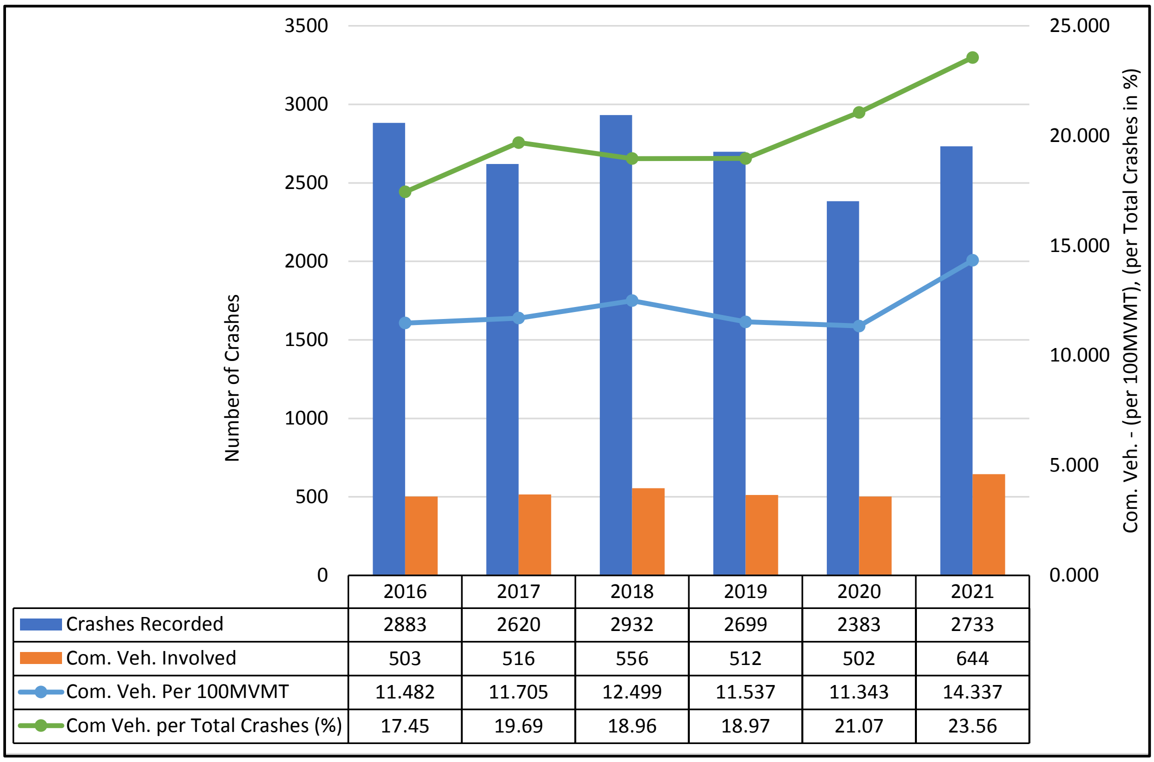
	2016	2017	2018	2019	2020	2021
Crashes Recorded	11112	11341	11102	11010	9188	11246
Com. Veh. Involved	1408	1644	1726	1616	1485	1790
Com. Veh. per 100MVMT	13.161	15.390	15.820	14.666	14.069	16.587
Com Veh. per Total Crashes (%)	12.67	14.50	15.55	14.68	16.16	15.92

Figure 16. Crashes on interstate I-10.



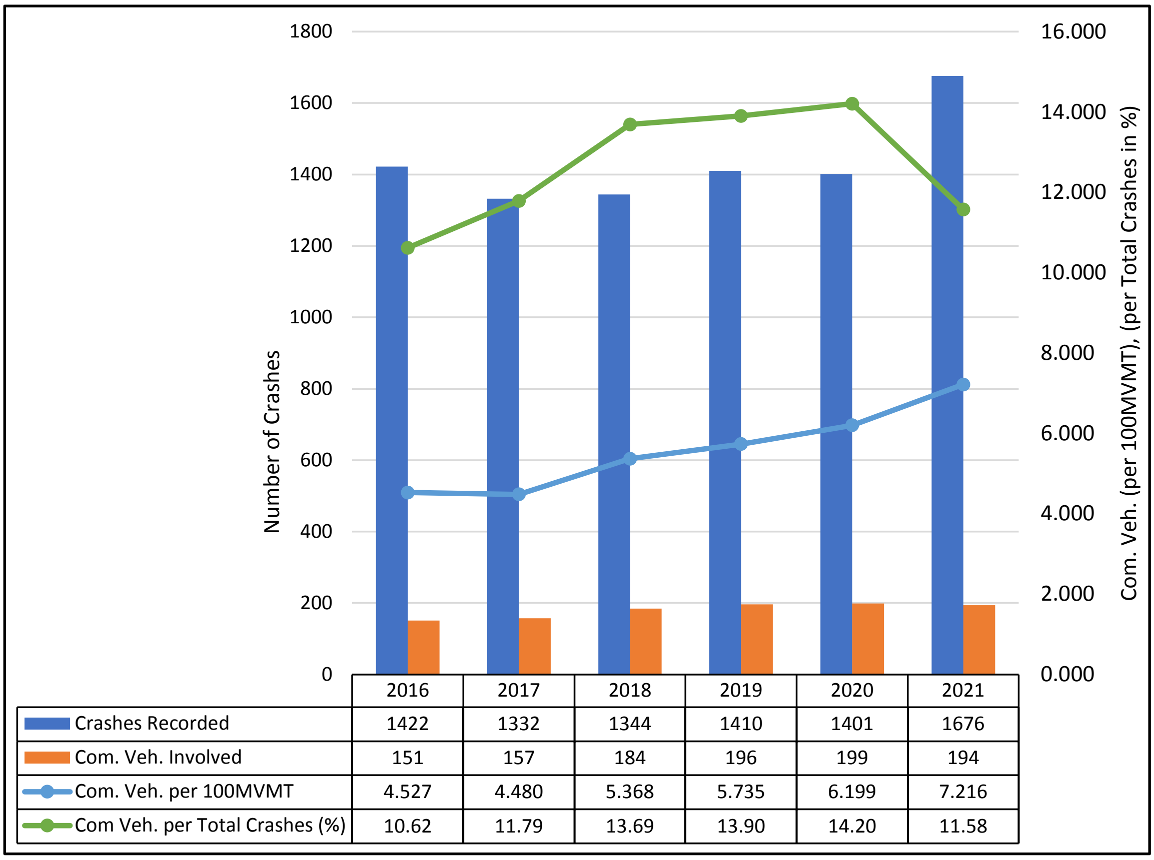
	2016	2017	2018	2019	2020	2021
Crashes Recorded	2671	2708	2657	2641	2265	3140
Com. Veh. Involved	372	389	392	427	341	565
Com. Veh. Per 100MVMT	15.620	16.561	15.083	16.682	13.279	21.322
Com Veh. per Total Crashes (%)	13.93	14.36	14.75	16.17	15.06	17.99

Figure 17. Crashes on interstate I-12.



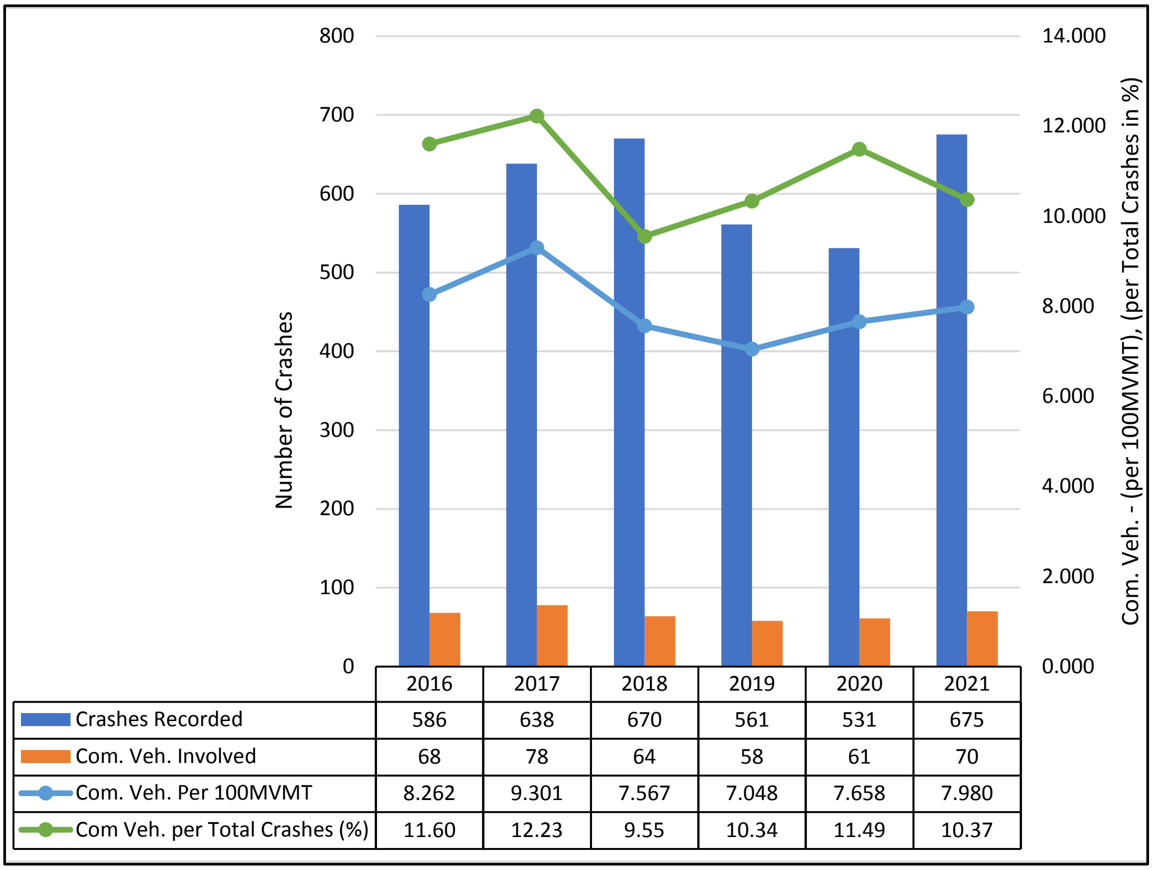
	2016	2017	2018	2019	2020	2021
Crashes Recorded	2883	2620	2932	2699	2383	2733
Com. Veh. Involved	503	516	556	512	502	644
Com. Veh. Per 100MVMT	11.482	11.705	12.499	11.537	11.343	14.337
Com Veh. per Total Crashes (%)	17.45	19.69	18.96	18.97	21.07	23.56

Figure 18. Crashes on interstate I-20.



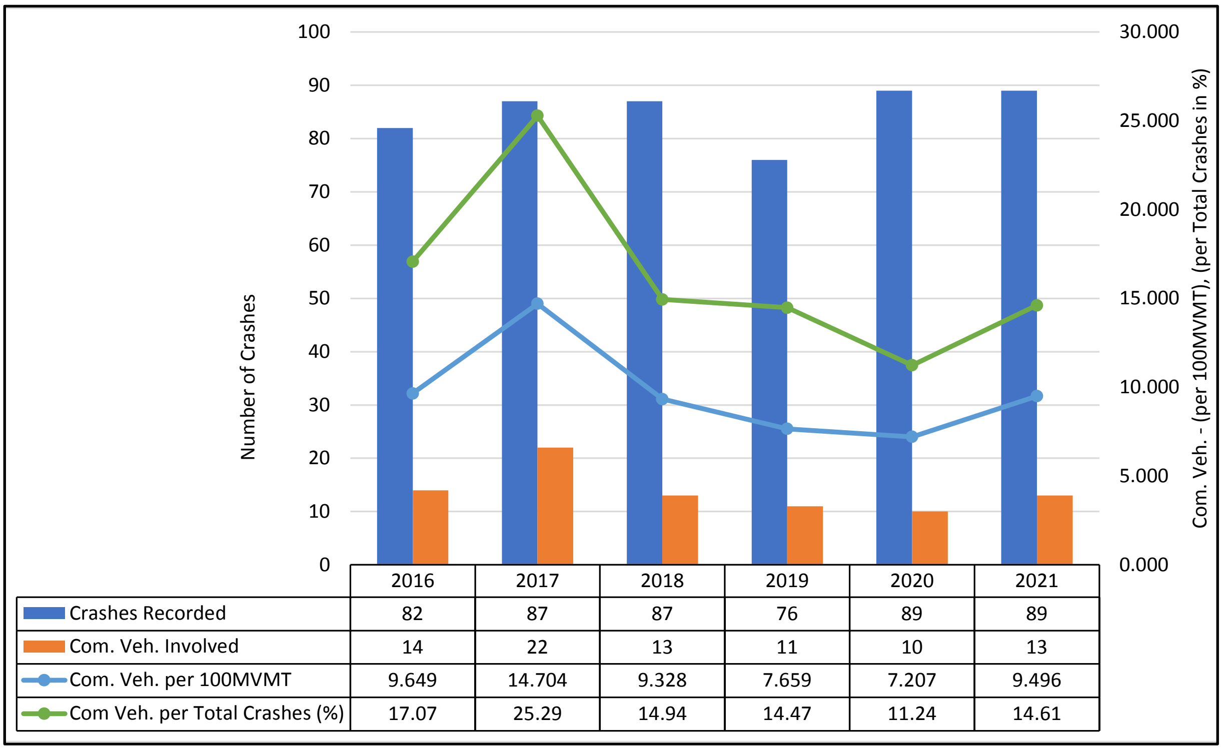
	2016	2017	2018	2019	2020	2021
Crashes Recorded	1422	1332	1344	1410	1401	1676
Com. Veh. Involved	151	157	184	196	199	194
Com. Veh. per 100MVMT	4.527	4.480	5.368	5.735	6.199	7.216
Com Veh. per Total Crashes (%)	10.62	11.79	13.69	13.90	14.20	11.58

Figure 19. Crashes on interstate I-49.



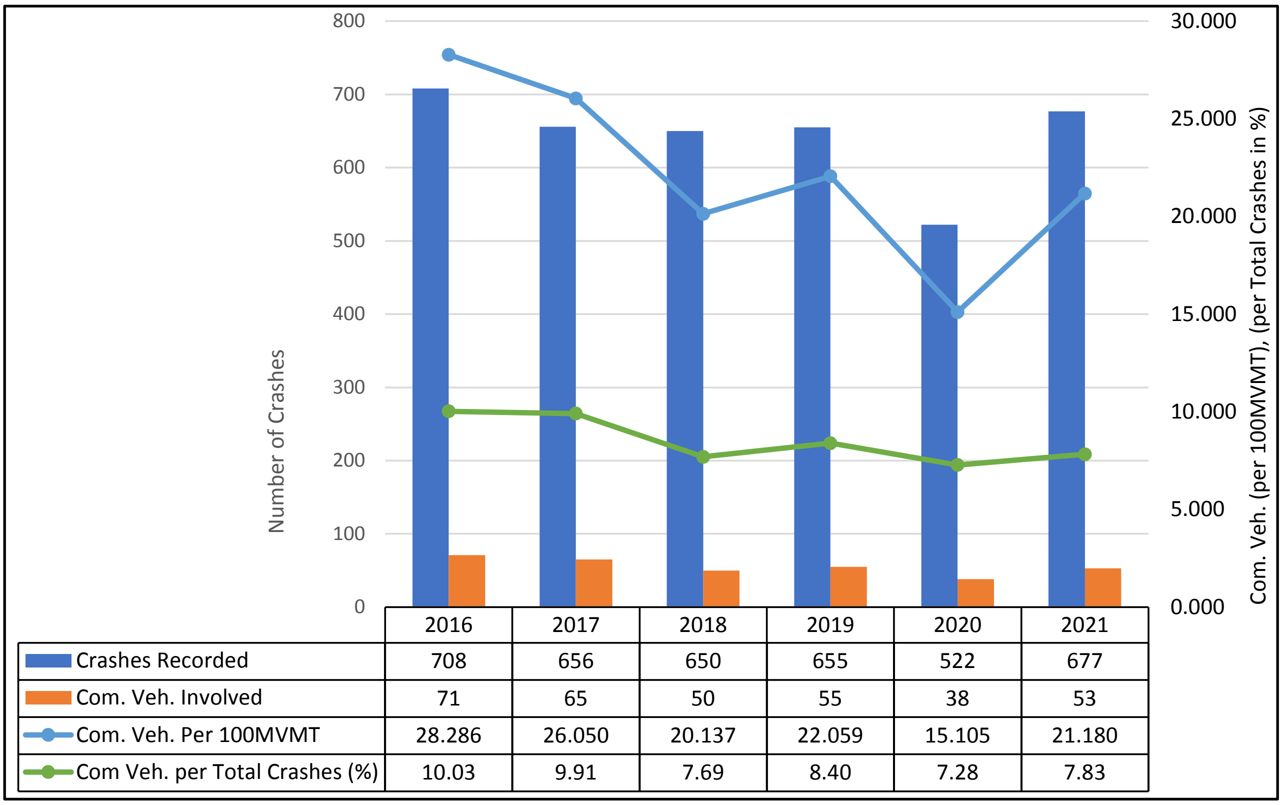
	2016	2017	2018	2019	2020	2021
Crashes Recorded	586	638	670	561	531	675
Com. Veh. Involved	68	78	64	58	61	70
Com. Veh. Per 100MVMT	8.262	9.301	7.567	7.048	7.658	7.980
Com Veh. per Total Crashes (%)	11.60	12.23	9.55	10.34	11.49	10.37

Figure 20. Crashes on interstate I-55.



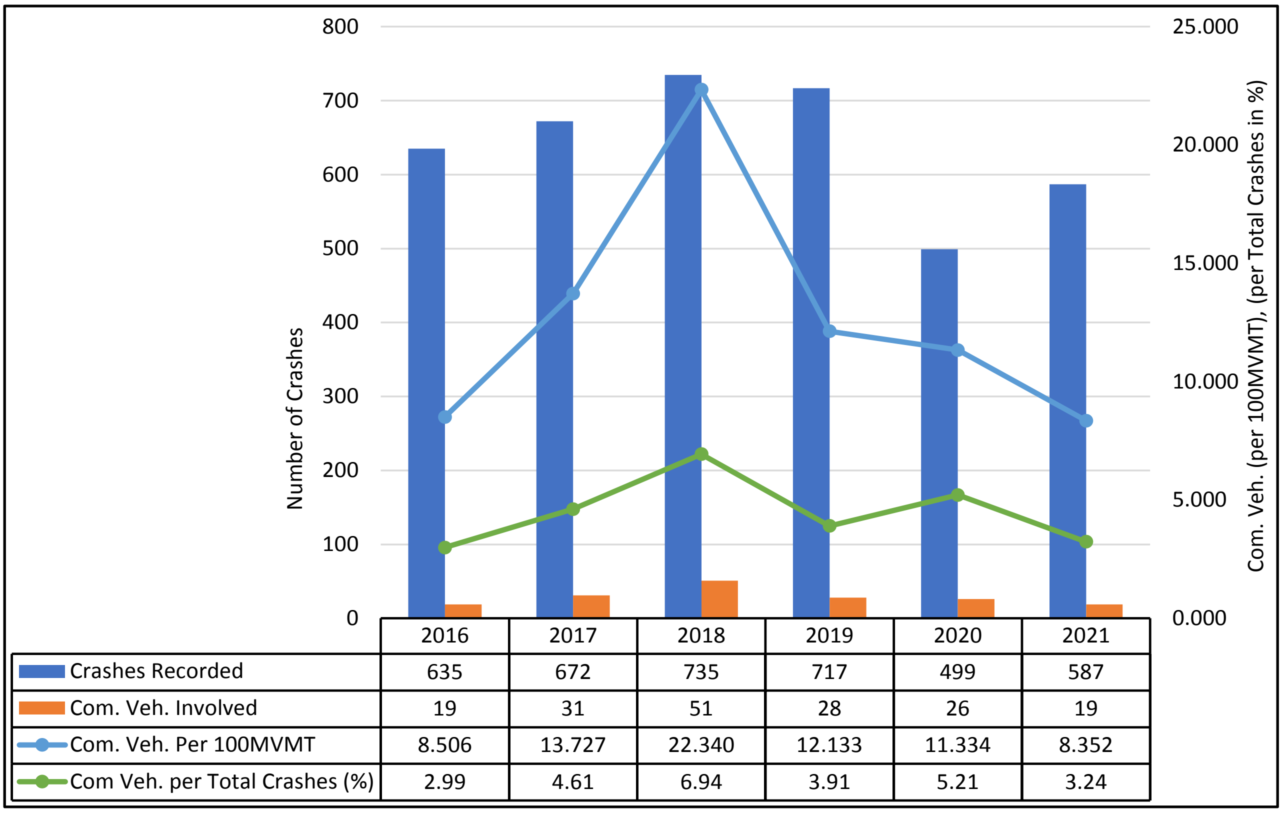
	2016	2017	2018	2019	2020	2021
Crashes Recorded	82	87	87	76	89	89
Com. Veh. Involved	14	22	13	11	10	13
Com. Veh. per 100MVMT	9.649	14.704	9.328	7.659	7.207	9.496
Com Veh. per Total Crashes (%)	17.07	25.29	14.94	14.47	11.24	14.61

Figure 21. Crashes on interstate I-59.



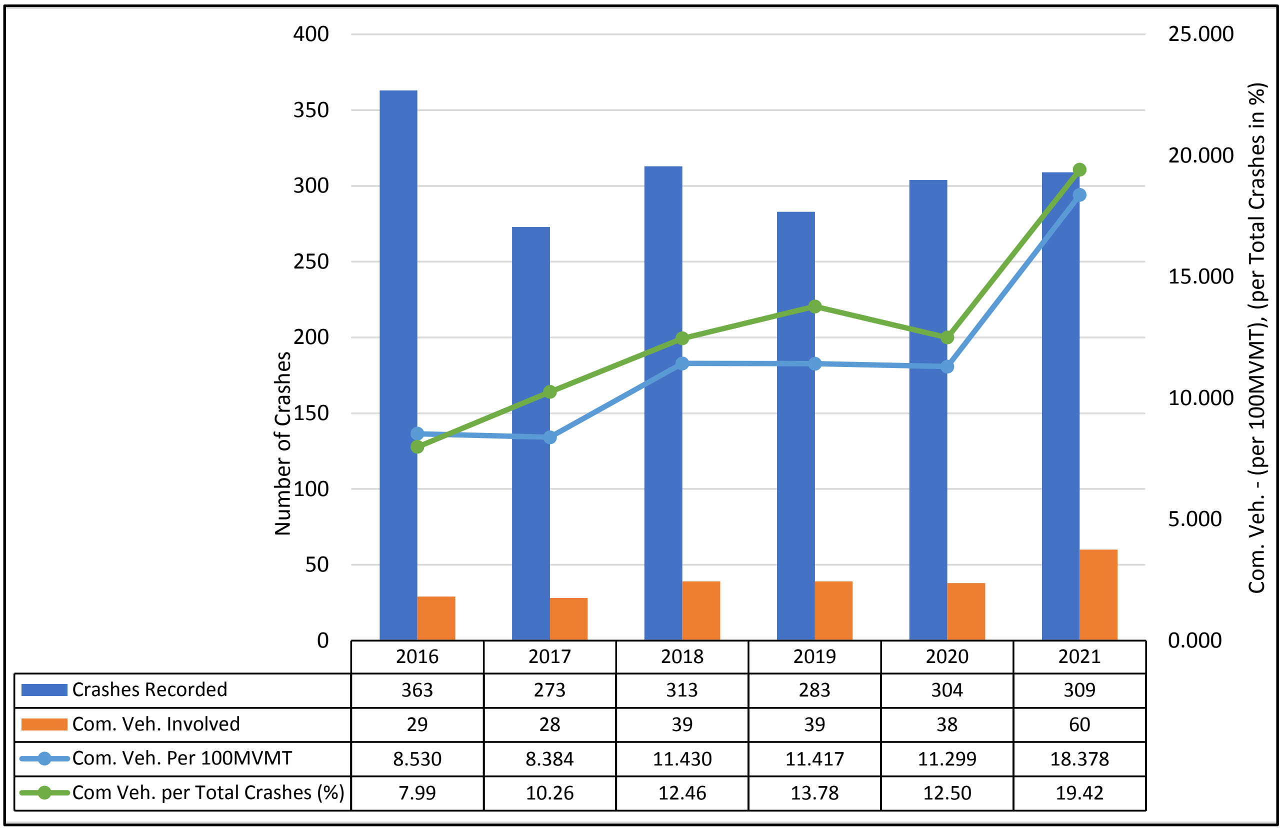
	2016	2017	2018	2019	2020	2021
Crashes Recorded	708	656	650	655	522	677
Com. Veh. Involved	71	65	50	55	38	53
Com. Veh. Per 100MVMT	28.286	26.050	20.137	22.059	15.105	21.180
Com Veh. per Total Crashes (%)	10.03	9.91	7.69	8.40	7.28	7.83

Figure 22. Crashes on interstate I-110.



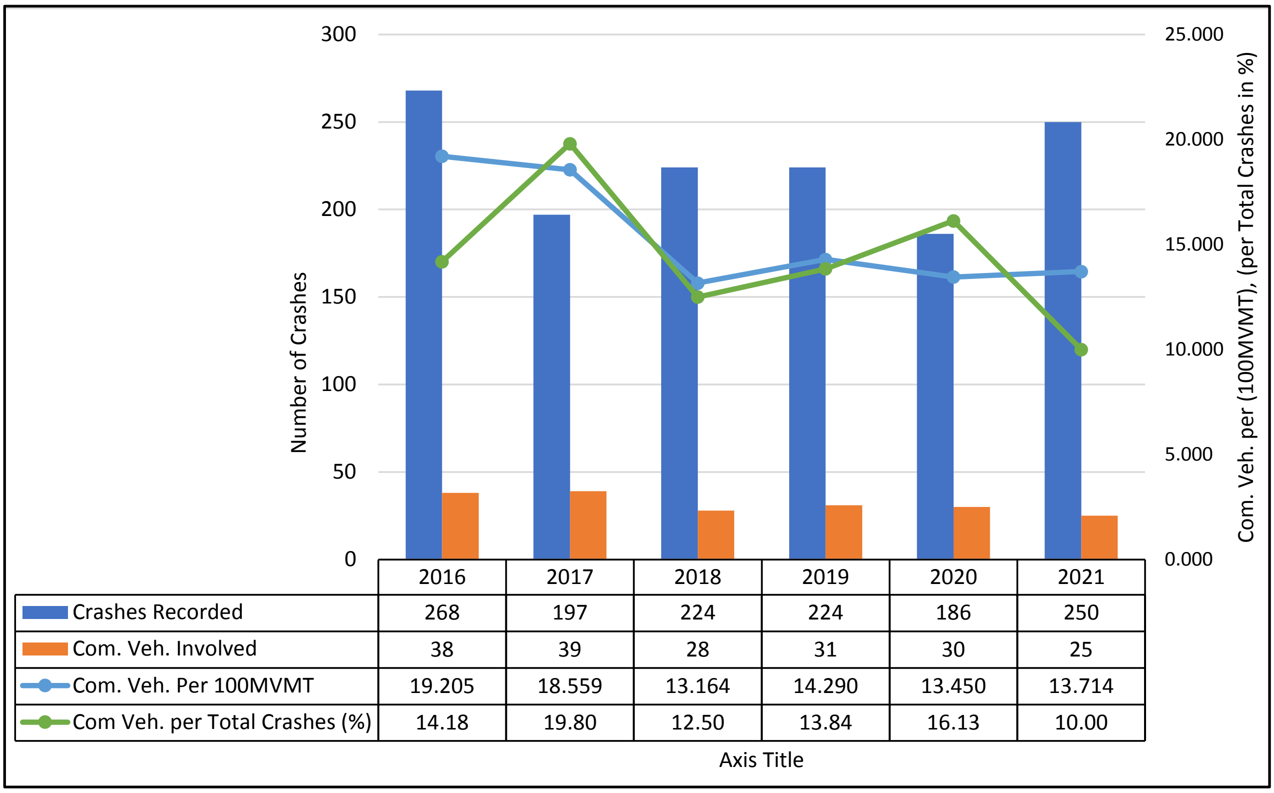
	2016	2017	2018	2019	2020	2021
Crashes Recorded	635	672	735	717	499	587
Com. Veh. Involved	19	31	51	28	26	19
Com. Veh. Per 100MVMT	8.506	13.727	22.340	12.133	11.334	8.352
Com Veh. per Total Crashes (%)	2.99	4.61	6.94	3.91	5.21	3.24

Figure 23. Crashes on interstate I-210.



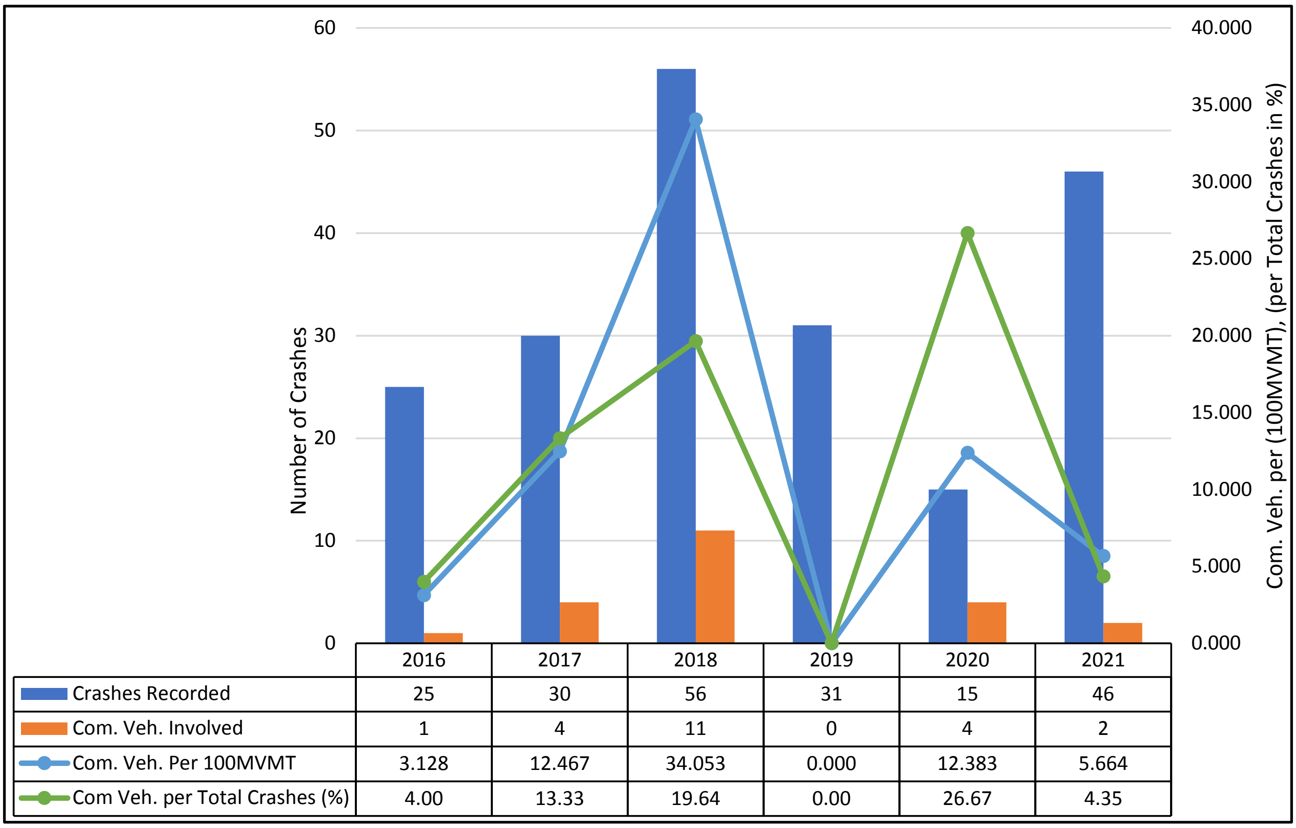
	2016	2017	2018	2019	2020	2021
🟦 Crashes Recorded	363	273	313	283	304	309
🟧 Com. Veh. Involved	29	28	39	39	38	60
-●- Com. Veh. Per 100MVMT	8.530	8.384	11.430	11.417	11.299	18.378
-●- Com Veh. per Total Crashes (%)	7.99	10.26	12.46	13.78	12.50	19.42

Figure 24. Crashes on interstate I-220.



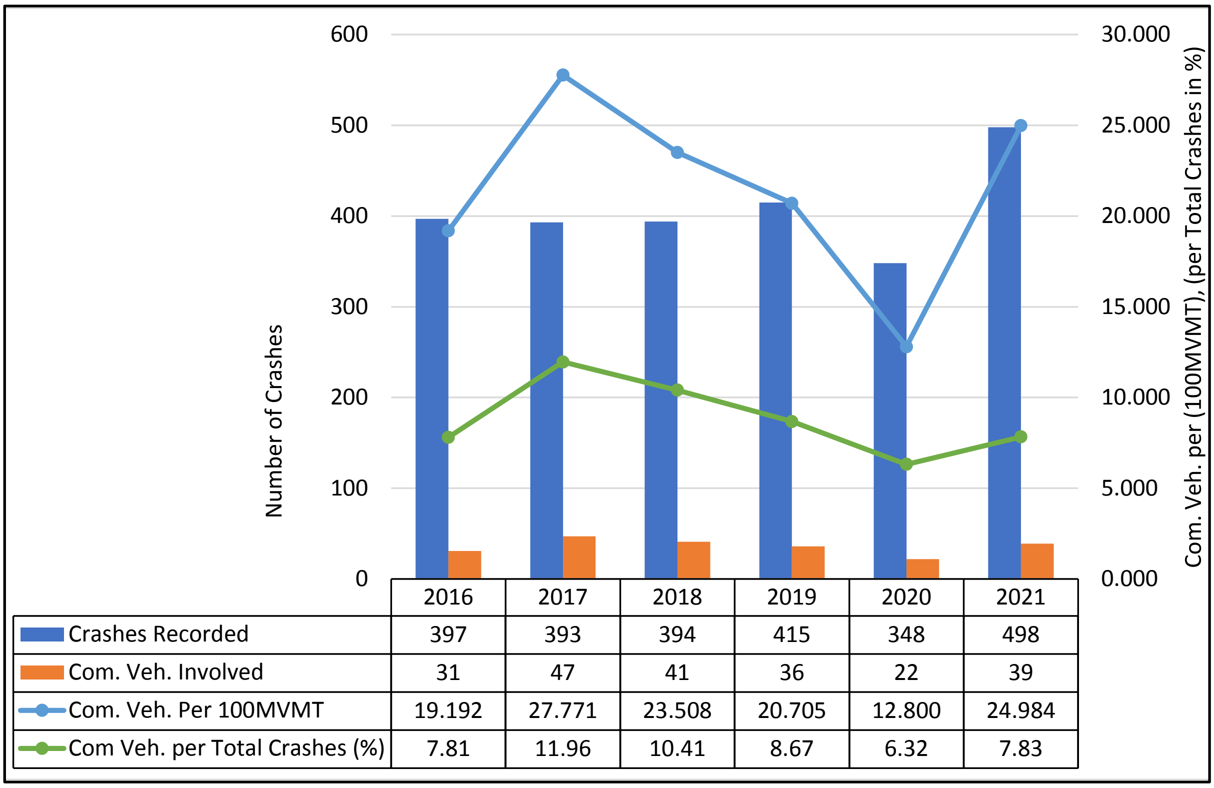
	2016	2017	2018	2019	2020	2021
🟦 Crashes Recorded	268	197	224	224	186	250
🟧 Com. Veh. Involved	38	39	28	31	30	25
-●- Com. Veh. Per 100MVMT	19.205	18.559	13.164	14.290	13.450	13.714
-●- Com Veh. per Total Crashes (%)	14.18	19.80	12.50	13.84	16.13	10.00

Figure 25. Crashes on interstate I-310.



	2016	2017	2018	2019	2020	2021
🟦 Crashes Recorded	25	30	56	31	15	46
🟧 Com. Veh. Involved	1	4	11	0	4	2
● Com. Veh. Per 100MVMT	3.128	12.467	34.053	0.000	12.383	5.664
● Com Veh. per Total Crashes (%)	4.00	13.33	19.64	0.00	26.67	4.35

Figure 26. Crashes on interstate I-510.



	2016	2017	2018	2019	2020	2021
🟦 Crashes Recorded	397	393	394	415	348	498
🟧 Com. Veh. Involved	31	47	41	36	22	39
● Com. Veh. Per 100MVMT	19.192	27.771	23.508	20.705	12.800	24.984
● Com Veh. per Total Crashes (%)	7.81	11.96	10.41	8.67	6.32	7.83

Figure 27. Crashes on interstate I-610.

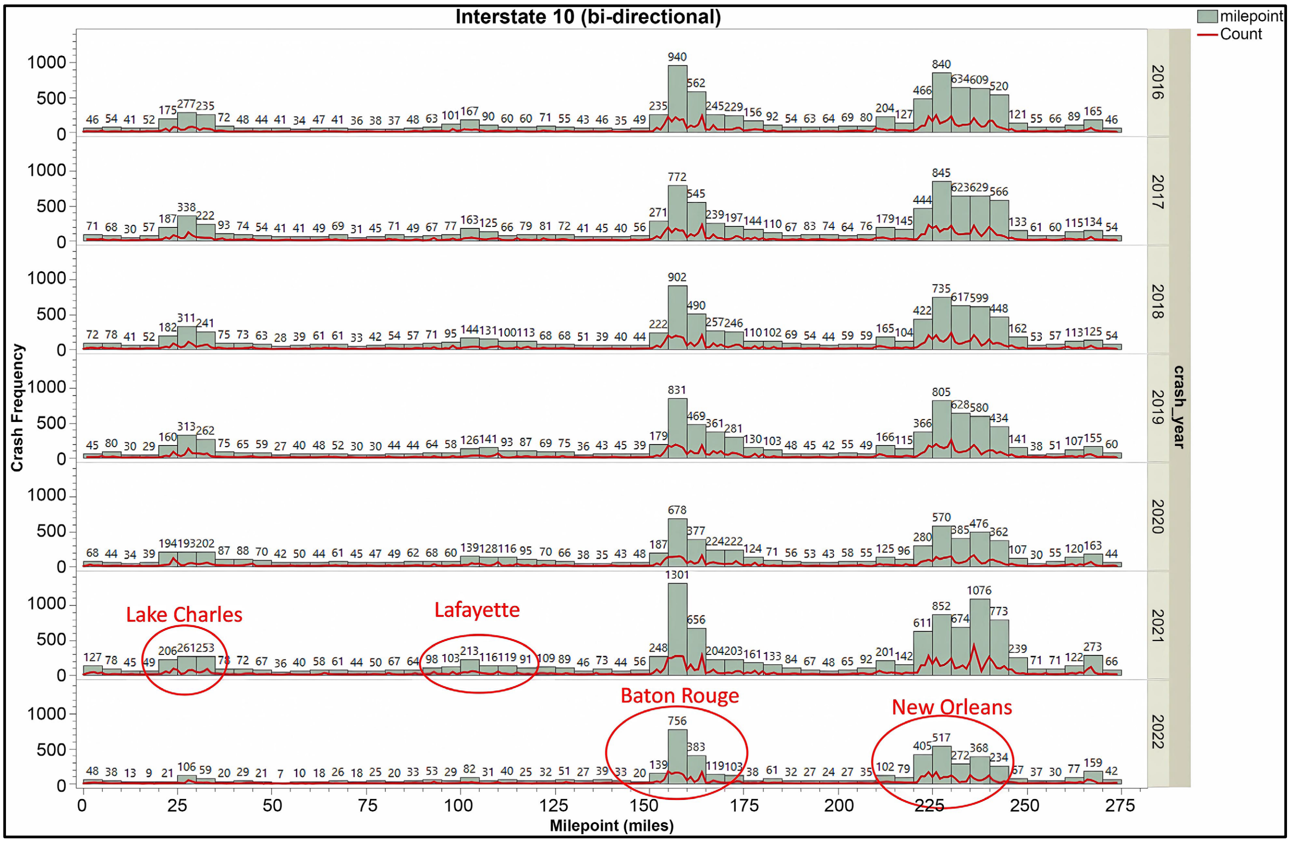


Figure 28. Yearly crash frequencies per milepost on I-10 Louisiana (2016-2022).

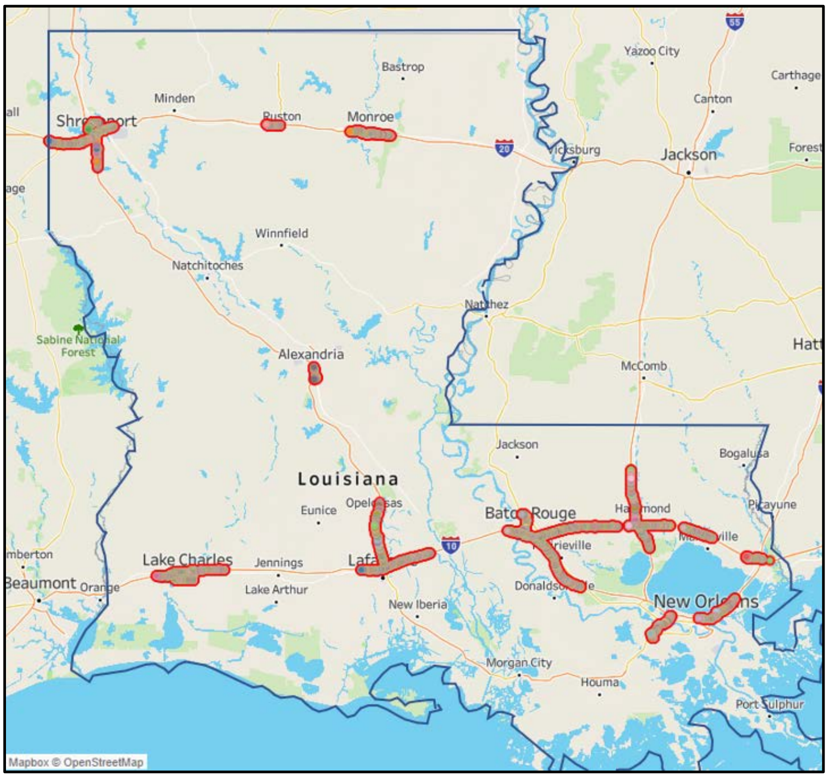


Figure 29. Segment with high crash frequencies (2016-2022).

over the study period. With these multiple crash locations identified, robust analyses can be performed if additional information on exposure and roadway characteristics can be linked to the location.

Additionally, the segments with clusters of crashes in **Figure 28** seem to correspond to locations with clusters of unreliable TMC segments (TTTR Index > 1.50), shown in **Figure 11**. Further investigation is required to identify factors contributing to the multiple crashes and the recurring congestion at these locations and to determine if the recurring congestion is responsible for the multiple crashes or the other way around.

4. Conclusions

This paper demonstrated how transportation agencies could use transportation data to evaluate freight operation goals to improve reliability, economy, and safety using Truck Travel Time Reliability (TTTR) Index, User Delay Cost, and Safety Analyses on Louisiana's Interstate System between 2016 and 2022. The safety analysis evaluated the commercial vehicle crash rate, crash frequency, trends, and clusters. TTTR Index and user delay cost data were sourced from the National Performance Management Research Data Set (NPMRDS), while the crash data were retrieved from the Louisiana Crash Database.

From evaluation, the Interstate system in Louisiana remained reliable over the period per the set TTTR Index threshold. However, segments of the Interstate highway system (bad-performers) recorded unreliable TTTR scores above the threshold, which were statewide altogether less than 12% of the total Interstate highway mileage annually. These were mainly clustered in and around New Orleans, Baton Rouge, Shreveport, and Lake Charles. The segments clustered in and around New Orleans and Baton Rouge were annually less than 4% of the total statewide Interstate mileage at these locations.

The annual User Delay Costs by commercial vehicles on the unreliable segments (bad-performers) statewide were, on average, 65.45% of the User Delay Cost by all vehicles on the entire (100%) interstate highway system between 2016 and 2019 and 50.00%, 56.19%, and 70.36% in 2020, 2021, and 2022, respectively. These proportions are extremely high considering that the annual Interstate highway system mileage responsible for unreliability from 2016 to 2022 was annually less than 12%. In Baton Rouge and New Orleans, total annual User Delay Costs by commercial vehicles on the unreliable segments between 2016 and 2022 were, on average, 49.02% of the corresponding User Delay Cost by commercial vehicles on the entire Interstate highway system. These disproportionate ratios indicate the economic impact of the unreliability of the Interstate system on commercial vehicle (freight) operations in Louisiana, which can form the basis of investment decisions to improve travel conditions at these locations in Louisiana.

Though the statewide annual crash frequencies of all vehicles on the Interstate system remained relatively stable between 2016 and 2021 (except for the dip in

2020), the proportions of commercial vehicles involved saw an increasing trend from 12.79% to 15.84% over the study period indicating the existence of critical safety conditions that must be investigated and addressed to improve safe freight operations in Louisiana. This situation is even emerging with the preliminary data for 2022. Additionally, though the annual proportions of commercial vehicles involved in crashes between 2016 and 2021 were between 12.8% and 15.84% statewide, some Interstate highways recorded annual proportions higher than some corresponding statewide proportions. For instance, I-59 in 2016 and 2017, I-310 in 2017 and 2020, and I-20 in all the evaluated years. Contributing factors to these unusually high proportions on individual highways must be investigated and addressed.

In terms of commercial vehicle crash rate (100MVMT), I-110 recorded the worst performance in three of the six years evaluated, followed by I-610 in two and I-510 in one. Interstate highways I-49, I-55, and I-59 were relatively safer in terms of commercial vehicle crash rate. Interstate Highway 10, I-12, and I-20, with 274, 85, and 189 miles, respectively, had moderate-to-moderately high crash rates, with I-20 having a relatively lower rate among these three highways. Even though I-20 had relatively moderate crash rates, the proportions of commercial vehicles involved in crashes annually on this highway were higher than the statewide proportion in all the years evaluated, pointing to unsafe conditions that must be investigated and resolved to improve safe freight operations on this highway.

Additionally, for the worst-performing I-110 and I-610 in terms of crash rates, these interstate highways were observed to have a relatively lower proportion of commercial vehicles involved in crashes for those years compared to the state averages. These observations suggest that using a single performance measure to assess safety on Louisiana's highway system may not be enough to make sound determinations. For this, there is the need to set individual performance targets for each interstate highway instead of a blanket target for the statewide highway system. Additionally, there may be a need to compare or benchmark the safety performance of individual subsystems (highways) with another in order to make informed decisions. Lastly, the segments with multiple crashes seemed to correspond with locations with recurring congestion on the Interstate highway system. Further investigation is required to identify factors contributing to the multiple crashes and congestion at these locations and to determine if the high congestion is responsible for the multiple crashes or the other way around. Further research could build upon these findings to understand the issues.

Recommendation for Future Studies

Future investigation is required to identify factors contributing to the seeming correlation between the location of segments with multiple crashes and locations with recurring congestion. The research could involve investigating the roadway features contributing to congestion and unsafe conditions and proposed countermeasures. To improve truck freight operations, the increasing statewide proportion of commercial vehicles involved in crashes must be investigated and addressed. Also, unsafe conditions responsible for the more than usual proportion of commercial vehicles in crashes on I-20 must be investigated, and countermeasures proposed to improve safe freight operations on this highway. Additionally, the research could involve collaboration with policymakers and stakeholders across jurisdictions to develop and implement effective solutions. The additional research could provide insight into the application of innovative technologies, including Intelligent Transportation Systems, for providing improvements.

Significance of Study

The paper provides valuable insights into how transportation system-generated data could be used to identify significant freight system trends, needs, and issues and guide decision-making, contributing to the existing body of knowledge in the Transportation System Management and Operations (TSMO), which the USDOT is currently promoting.

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Author Contributions

The authors confirm the paper's contribution: paper conception and design; data collection: K. Abedi; analysis and interpretation of results: K. Abedi, R. Thapa, J. Codjoe & V. Gopu; draft manuscript preparation: K. Abedi, R. Thapa, J. Codjoe, & V. Gopu. All authors reviewed the results and approved the final version of the manuscript.

Conflicts of Interest

This paper contains information prepared solely to identify, evaluate, and plan safety and operational improvements on public roads in Louisiana and is exempt from discovery or admission into evidence.

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