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Develop and Evaluate Performance Measures for Intelligent Transportation Systems (ITS) in Louisiana

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13. Abstract

The Louisiana Department of Transportation and Development (DOTD) established Intelligent Transportation System (ITS) programs over 20 years ago. Before DOTD expands or implements new ITS programs, a study needed to be undertaken to evaluate the performance of the current ITS programs to demonstrate their benefits. The primary objective of this research was to develop a set of performance measures for each existing ITS program in Louisiana and evaluate the benefits achieved through their implementation. The scope of this study was to use insights gathered from literature reviews, qualitative surveys, and inputs from stakeholders to develop performance measures for Louisiana's ITS applications. The scope also included using data from ITS applications in Louisiana to evaluate the performance of the deployed system and determine if the ITS applications were beneficial to the taxpayer. The ITS programs were grouped under six broad areas: Arterial Management; Commercial Vehicle Operation; Electronic Payment and Congestion Pricing; Freeway Management and Traffic Management Centers; and Traveler Information. For each program area, specific objectives linked to specific transportation goals that Louisiana needed to achieve were developed, along with performance measures to evaluate the state's efforts at meeting each goal. Data mainly between 2016 and 2020 were collected and used for the assessment. Overall, the benefits achieved through the implementation of some of the ITS programs were apparent, while in other cases, further studies are required.

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Develop and Evaluate Performance Measures for Intelligent Transportation Systems (ITS) in Louisiana

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December 2022

Abstract

The Louisiana Department of Transportation and Development (DOTD) established Intelligent Transportation System (ITS) programs over 20 years ago. Before DOTD expands or implements new ITS programs, a study needed to be undertaken to evaluate the performance of the current ITS programs to demonstrate their benefits. The primary objective of this research was to develop a set of performance measures for each existing ITS program in Louisiana and evaluate the benefits achieved through their implementation. The scope of this study was to use insights gathered from literature reviews, qualitative surveys, and inputs from stakeholders to develop performance measures for Louisiana's ITS applications. The scope also included using data from ITS applications in Louisiana to evaluate the performance of the deployed system and determine if the ITS applications were beneficial to the taxpayer. The ITS programs were grouped under six broad areas: Arterial Management; Commercial Vehicle Operation; Electronic Payment and Congestion Pricing; Freeway Management and Traffic Management Centers; and Traveler Information. For each program area, specific objectives linked to specific transportation goals that Louisiana needed to achieve were developed, along with performance measures to evaluate the state’s efforts at meeting each goal. Data mainly between 2016 and 2020 were collected and used for the assessment. Overall, the benefits achieved through the implementation of some of the ITS programs were apparent, while in other cases, further studies are required.

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Implementation Statement

The study developed a set of performance measures for six different existing ITS programs in Louisiana. Such performance measures were used to evaluate the ITS applications to assess the impact of the programs on the transportation system in order to reveal the return on investment. The selected performance measures and the results from their evaluation can be used by DOTD to assess the benefits achieved through the implementation of different ITS programs within the state.

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Introduction

The Louisiana Department of Transportation and Development (DOTD) established its Intelligent Transportation System (ITS) programs over 20 years ago and has programs that include: Traffic Management Centers, Motorist Assistance Patrols, and Commercial Vehicle Operations. Future DOTD ITS programs include applications in Transportation Systems Management and Operations, Connected and Autonomous Vehicles, and expansions in current program areas [1]. It is, however, important that before Louisiana expands or implements new ITS programs, a study be undertaken to evaluate the performance of the current ITS programs to demonstrate benefit to taxpayers and serve as indicators for system operators.

Performance measures were developed for DOTD's current ITS programs in this study and were used to evaluate the ITS applications across transportation planning, traffic operation, safety, and other areas that could be evaluated. The study aimed to use the evaluation findings to assess the impact of Louisiana's ITS program on the transportation system performance and reveal the return of investment for tax dollars. Gaps in data collection for performance measures and practical performance management applications in the future are also identified. The future data collection for the performance measures program will help satisfy the Federal Highway Authority's (FHWA) increased emphasis on setting priorities and making planning, investment, and management decisions based on performance measures [1, 2].

A long list of performance measures for Louisiana's ITS program areas was developed from a literature review on the current state of practice and from results gathered through a nationwide qualitative survey that evaluated the efficiency of current performance measures. Through consultations with stakeholders in the form of workshops, a short list of performance measures was developed from the initial list. The current state of practice of the ITS programs in Louisiana based on data collected and analyzed for the short-listed performance measures is presented in this report.

The significance of this study is that it uses data and scientific methods to identify areas with the greatest need for improvement, and creates performance-driven, outcome-based indicators for decision-making regarding the need for expansion or improvements of the ITS programs in Louisiana.

Literature Review

Performance Measurement Process

Performance measurement needs in transportation planning, and investment decision-making processes have increased for many reasons. For instance, it is required by the Moving Ahead for Progress in the 21st Century Act (MAP–21) and its replacement, the Fixing America's Surface Transportation Act (FAST Act), for agencies to have performance-driven, outcome-based programs that provide greater transparency and accountability, which are needed to improve decision-making and efficient utilization of federal funds. It is also required that states, metropolitan planning organizations (MPOs), and public transportation providers move toward performance-based strategy and program development through the performance-based planning and programming (PBPP) processes [3, 4, 5].

The PBPP process has vital elements that include establishing goals, developing objectives, developing performance measures, collecting data for evaluation, and reporting performance. A fundamental principle is that each step must be connected to the next [2, 3]. Additional considerations on how to develop performance measures and attributes of suitable performance measures are provided in the Freeway Management and Operations Handbook [6].

Developing Goals

Goals for transportation systems are to be established with a focus on the efficient management and operation of the system. Goals need to reflect agreed systems priorities and outcomes relevant to an agency and the public. Additionally, they must reflect the input of system operators and stakeholders [3, 7]. The outcome to be achieved, the roles of agencies in creating or supporting the outcomes, and the required data and analysis to develop measurable objectives are some of the factors that need to be considered in developing goals [2].

Developing Objectives

Objectives must be agreed upon with stakeholders and serve as specific, measurable, time-bound performance statements that are established on the set goals. They should accurately reflect what an agency has planned to achieve within specified periods and should include or lead to the development of performance measures that support decisions that are needed to achieve the set goals [2, 3].

Selecting Performance Measures

The performance measures selected for a transportation system must be specific, quantifiable, and provide adequate information to planners, operators, and decision-makers. A selected performance measure must be something an agency or its investments can influence, and must have the commitment of stakeholders who are crucial to the success of the measured performance. Data and forecasting tools must also be available to evaluate the performance measure [3].

Suitable performance measures should be limited in number, easy to measure, understandable, straightforward, have adequate time frames, and be sensitive such that magnitudes of measured changes reflect the magnitudes of implemented actions. Additionally, performance measures should be geographically appropriate such that they are focused on a specific geographic area where they are required. Performance measures should reflect goals and objectives, not the other way around. This approach ensures that an agency measures the right parameters and that measured success corresponds with success in terms of goals and objectives [6].

Reporting of Performance Results

In transportation, performance reports must be communicated to several different audiences. It is therefore important that reported performance are clear and concise. In the case of the public, simple graphics, scorecards, visuals, and dashboards can help ensure that understandable information is communicated. To policymakers, reports that have emphasized links to funding are important. For instance, a report on funding shortfalls relative to deficiencies in system performance can demonstrate a link [2].

National ITS Reference Architecture

The National ITS Reference Architecture (ARC-IT) has provided high-level functional requirements, goals, objectives, and proposed performance measures that can be used to monitor service packages. The proposed performance measures are from other resources, such as the U.S. Department of Transportation (DOT) and some state departments of transportation (DOTs), and metropolitan transportation commissions [8]. State and regional transportation agencies can draw on the resources and approaches used in the ARC-IT to develop their respective ITS performance measures. However, as suggested by the ARC-IT, mappings between objectives and service packages are not always straightforward and are often situation-dependent; thus, the mappings should be used only as starting points requiring further analysis to identify the best linkages for an agency's service packages [9].

ITS Performance Measurement by State DOTs

States usually group ITS into broad program areas that are designed to address transportation goals. The goals are typically outlined in two key documents: the statewide ITS architectures and the ITS strategic business plans. The vision, specific initiatives, processes, and strategies needed to achieve the goals are usually indicated at a five-year projected interval in the ITS strategic business plans. The business plans also provide a framework that is used to develop actionable goals, milestones, timelines, and performance metrics that are used to determine the success of the ITS programs [10, 11]. On the other hand, the statewide ITS architectures are used to describe the envisioned ITS, outlined programs, and the projects critical for the implementation, operation, and management of statewide ITS infrastructures, usually in a 15-to-20-year projected outlook. The statewide architectures are created in tandem with the National ITS Architecture [12, 13].

Of the 50 states, there were no publicly available state-issued ITS architectures, business plans, or performance measures for about 30 states. Some states' information was later gathered from the nationwide qualitative survey results. It was noted that there existed policies that prevented some agencies from publicly publishing their documents and performance reports. It is acknowledged that the states' web portals are updated periodically and that information that may have been absent previously would probably be later available.

An overview of the current state of Louisiana's ITS programs and performance measurement systems is provided in the following section. Additionally, an overview of how some state DOTs have structured and evaluated their ITS and performance measurement processes is summarized.

Louisiana ITS and Performance Measures

The DOTD existing and desired ITS program areas are summarized in Table 1 with the following three program statuses: existing, planned, and planned addition. The "existing" is an ITS program area that is currently practiced. The "planned" is a proposed ITS program area that is not currently practiced and is not expected to expand on existing program areas. The "planned addition," on the other hand, is a proposed ITS Program area that is not currently practiced but is expected to expand on an "existing" program [1, 14]. For instance, Arterial Management and Commercial Vehicle Operations (CVO) are some program areas that have already been deployed and exist in Louisiana.

Table 1. ITS program areas [1]

No.	Area: System/ Service	Description	Status
1	Arterial Management	Operational strategies for signal systems to increase traffic demand, reduce delays, and enhance safety.	Existing
2	Commercial Vehicle Operations (CVO)	ITS strategies to enhance commercial vehicle operations.	Existing
3	Electronic Payment and Congestion Pricing	Ability to collect tolls electronically and detect and process violations	Existing
4	Emergency Management	Systems to provide emergency services	Existing
5	Freeway Management	ITS for freeway surveillance, incident detection, response, driver advisory systems, lane control, and other operational strategies to improve traffic flow on freeways.	Existing
6	Incident Management	ITS for rapid incident detection, verification, and clearance. It also involves agency coordination such as public safety and emergency services	Existing
7	Maintenance of ITS Devices	Maintenance of deployed ITS.	Existing
8	Motorist Assistance Patrol	Manage critical roadways during incidents to reduce congestion and secondary incidents.	Existing
9	Traffic Management Centers (TMCs)	Strategies to share and disseminate traffic information to improve freeway mobility, safety, and reliability.	Existing
10	Traveler Information	Systems for rapid dissemination of traffic information to roadway users	Existing
11	Advanced Vehicle Systems	Strategies to support vehicle and roadside systems that communicate and share information collaboratively and use the information to enhance safety and mobility	Planned Addition
12	Information Management	Systems to facilitate collaboration between stakeholders to ensure transportation system data required for planning and operations are available	Planned
13	Infrastructure Monitoring and Security	Systems to monitor the condition of transportation-related infrastructure	Planned
14	Travel Demand Management	Systems and strategies to support travel demand by optimizing roadway mobility	Planned
15	Work Zone ITS	Improve work crew safety and reduce collisions between the motoring public and maintenance and construction vehicles	Planned

The statewide ITS goals, objectives, and their relationship to planning are summarized in Table 2. The performance measures for the goals are categorized under crashes, incident clearance time, delays, travel time reliability, modal connectivity, and freight travel time. For instance, to assess "improved traffic management," "vehicle hours of travel" (VHT) is used as a performance measure, which is categorized under delays.

Table 2. Louisiana's ITS goals and objectives and their relationship to planning [14].

No.	Name	Description	Performance Measure Category	Performance Measure
1	Improved Transportation Network Safety	Improve the safety of transportation systems and reduce crashes and other incidents in work zones and high-incident locations.	Crashes	Crashes/Million Vehicle Miles
			Incident Clearance Time	Time
2	Improved Traffic Management	Reduce delays and reduce travel time variability.	Delay	Vehicle Hours of Travel (VHT)
3	Reduced Non-Recurring Congestion	Minimize the effects of the causes of congestion.	Travel Time Reliability	Planning Time Index, Buffer Time Index
4	Effective Dissemination of Traffic Information	Increase the number of people receiving accurate traveler information.	Delay	Vehicle Hours of Travel (VHT)
5	Improved Emergency Management	Continuously monitor and manage traffic and communicate best routes.	Delay	Vehicle Hours of Travel (VHT)
6	More Efficient Modal Utilization	Increase the number of people that receive transit schedule information.	Modal Connectivity	Connectivity, Wait Time
7	Improved Administrative Efficiency, Operational Safety, and Productivity for Commercial Vehicles	Decrease state resources on routine administrative tasks, increase revenues, reduce motor carrier regulatory compliance costs, reduce commercial vehicle crash rate, implement cost-effective inspections	Freight Travel Time	Hours
8	Amber Alert	Issue of child abduction via radio, TV, email, SMS, Text, and DMS.	Delay	Minutes

From the information provided in the two preceding tables above, it was clear that the statewide ITS goals, objectives, and performance measures did not have a clear relationship with the state's existing and desired ITS programs. Additionally, no ITS performance reports were cited for Louisiana. It was, therefore, to be assumed that no statewide ITS performance measures have been established for the state's ITS applications, and as such, no performance reports based on established metrics existed.

Other State's ITS and Performance Measures

Alabama. Alabama's ITS programs aim to improve safety and reduce traffic fatalities. Eight ITS service areas have been outlined to achieve the goals, which include Travel and Traffic Management and Public Transportation Management. The strategic business plan provided performance measures, reporting, and tracking matrices. These performance measures are grouped under Traffic Management Centers (TMCs) operational measures, Alabama Service Assistance Patrol, and System Performance Measures [10, 15].

Florida. Florida has eight ITS service areas which include Traffic Management, Traveler Information, and Emergency Management, and 52 existing and planned service packages which include Traffic Incident Management System and Intersection Safety Warning [16]. The operational performance and outcomes for the Total Annual 511 Calls; Road Ranger Stops; ITS Miles Managed; Incident Duration; Total Time Reliability, and Customer Satisfaction were reported in the state's 2015/2016 ITS Performance Measure Annual Report [17]. The purpose, objectives, and methodologies for assessing each service area were detailed in the report.

Iowa. The state's Transportation System Management and Operation (TSMO) programs are centered on eight strategies that include ITS and communications, which are aimed to preserve capacity and improve transportation systems' security, safety, and reliability [18, 19]. The plan for each focus area has proposed performance management strategies to evaluate the effectiveness of the strategic area and support decisions related to resource allocation, technology deployment, and actions to achieve the objectives.

Minnesota. The overview volume of Minnesota Statewide Regional ITS Architecture, version 2018, summarized the purpose, general descriptions, objectives, and performance measures for the state's ITS program. The objectives are service-specific and aimed to enhance transportation through safe and efficient movement of people, goods, and information while focusing on increased mobility, fuel efficiency, reduced pollution, and increased operating efficiency [12]. The development objectives, strategies, and associated performance measures for all goal areas are summarized in the state's 2018 Regional Architecture Development for Intelligent Transportation output [20].

Performance Measures from Other Relevant Related Sources

Besides the information gathered from the state's performance measurement approaches, other FHWA, DOT, and other agencies have provided useful resources. For instance, the National Transportation Coalition has identified and defined a set of key operations performance measures of national significance. These measures can be used to identify and implement intra-agency network performance measures that support planning and operations functions [21]. Additionally, the FHWA has addressed work zone performance measures needs through its issued reports that agencies can access in developing related performance measurement programs [22, 23]. The performance measures that are focused on incident management are provided in DOT and FHWA resources [24, 25]. The general descriptions, objectives to reference, performance measures, anticipated data needs, management and operations strategies to consider, and safety-related impacts on TSMO strategies are provided in factsheets in the related desk reference [26].

Definition of Terminology

Terminologies related to ITS are occasionally used interchangeably in some literature. ARC-IT developed a glossary of definitions of terms encountered in ITS to have a common understanding of relevant terminologies. There is also the use of terminologies that have been discontinued; for instance, market packages instead of service packages. The discontinued terminologies were particularly cited in statewide ITS architectures, especially those yet to be updated to reflect updates and changes in the ARC-IT.

A list of interchangeably used terminologies in ITS is shown in Table A1 in Appendix A. This list is expected to give the user a quick reference.

Summary of Literature Review

Responsible organizations like the FHWA and DOT through ARC-IT have provided sufficient guidance and information to develop or incorporate performance measurement strategies into respective ITS programs. The findings on the availability of relevant state-issued documents, including performance reports, pointed to a gap between requirements for state DOTs to increase emphasis on performance measurements in their transportation systems, including ITS, and the actual implementation. In the case of Louisiana, the state's ITS goals, objectives, and performance measures did not have a clear relationship with the state's existing and desired ITS programs. Additionally, no ITS performance reports existed for the state. These findings necessitated the nationwide survey and provided key information for the formulated questionnaire.

Objective

The primary objective of this research was to develop a set of performance measures for each existing ITS program in Louisiana and evaluate benefits achieved through their implementation across transportation planning, traffic operation, safety, environmental quality and sustainability, and any other areas that can be evaluated.

Specifically, the research needed to determine:

1. ITS terminologies and whether their meanings are the same across transportation agencies;
2. Existing ITS applications and how they are currently evaluated;
3. If the existing performance measures were consistent with FHWA expectations, and what other state agencies use;
4. The performance measures that DOTD should use for each ITS program;
5. If the current ITS applications are beneficial to Louisiana's taxpayers; and
6. The processes that DOTD must follow to make performance measures data accessible.

The research objective and the required details were addressed through literature search, surveys, and stakeholder workshops. Briefly, the information required for the ITS terminologies was addressed through literature review, while that for the existing application was through literature review and surveys. A stakeholder workshop was used to determine the performance measures for the state's ITS programs.

Scope

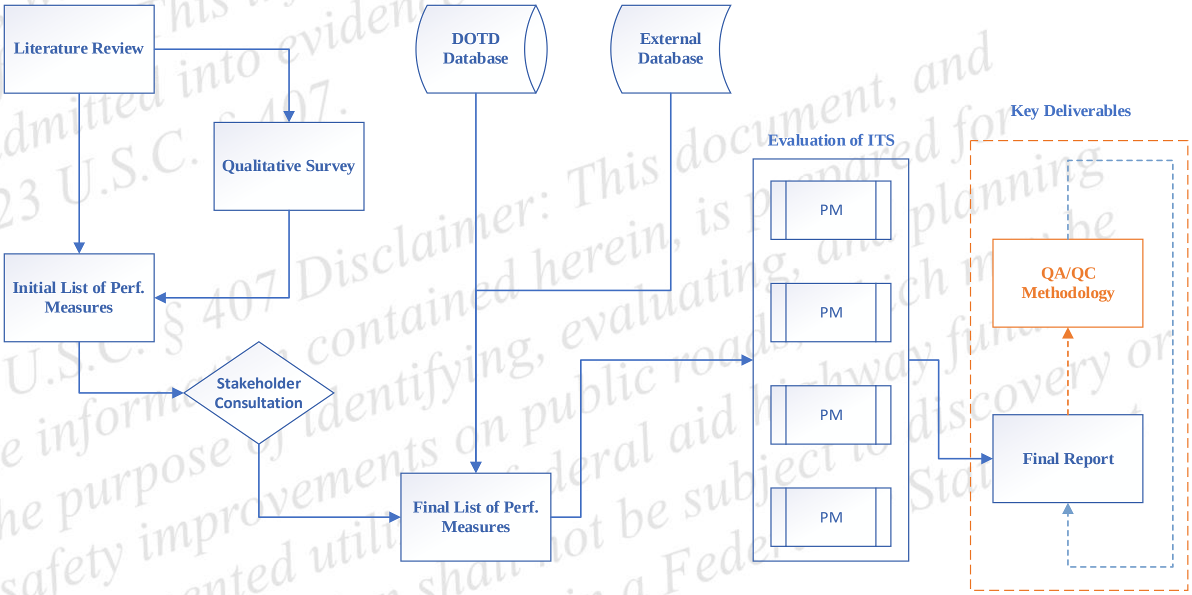
The scope of this study was to use insights gathered from literature reviews, qualitative surveys, and inputs from stakeholders to develop performance measures for Louisiana's ITS applications. The scope also included using data from sampled ITS applications deployed in Louisiana to evaluate the performance of deployed ITS application and determine if the ITS applications were beneficial to the taxpayer. The data used for the evaluation were mainly collected for periods between 2016 and 2020.

The research was scheduled to be carried out from 2020 to 2022. It is expected to be significant as it uses data and scientific methods to identify areas with the greatest need for improvement and create performance-driven, outcome-based indicators for decision-making regarding the need for expansion or improvements of the ITS programs in Louisiana.

Methodology

The methodologies for evaluating the individual ITS programs were different and are stated under the respective sections; but overall, the methodology for this research followed the framework shown in Figure 1.

Figure 1. Framework of methodology



Literature Review

The literature review investigated how performance targets specific to ITS have been tracked, measured, and reported statewide by DOTs. Publicly available sources were used to gather the required literature and data. Specifically, information from ARC-IT, statewide ITS architectures, strategic business plans, and issued newsletters were used.

Qualitative Survey

A survey and protocol were designed to obtain information on how well existing performance measurements have been assimilated into ITS programs of respective agencies. The final survey questionnaire consisted of 9 questions designed to be completed in less than 10 minutes. The target audience for the research survey were

Louisiana MPOs and nationwide DOT ITS departments. The survey questionnaire allowed a total of 21 days to respond.

Initial List of Performance Measures

An initial list of performance measures for each DOTD ITS program was developed from information gathered from the literature review and qualitative survey. Information of relevance was the reported shortfalls of existing performance measures and those reported to be highly efficient.

Final List of Performance Measures

Following a stakeholder consultation in the form of a workshop, a final list of agreed performance measures for DOTD ITS programs was developed. The stakeholders consisted of the Project Review Committee, whose responsibilities included providing inputs and helping to validate the situation analysis findings from the initial survey; filling any information gaps identified during the situation analysis; and ensuring broader buy-in of the proposed final list of performance measures.

Data Collection and Data Analysis

An analysis of data availability for the agreed performance measures was conducted to identify where Louisiana lacked data for evaluating ITS performance on the selected performance measures. For those applications where data exists, the data were collected mainly from the DOTD database, ITS equipment, and external sources. Details of the data type and sources are subsequently provided for each ITS program evaluation.

The data analysis was aimed to evaluate whether the existing DOTD ITS applications have been beneficial. It involved a quantitative analysis of collected data to demonstrate the benefits of the respective ITS applications and report on aspects that needed improvement.

Final Report

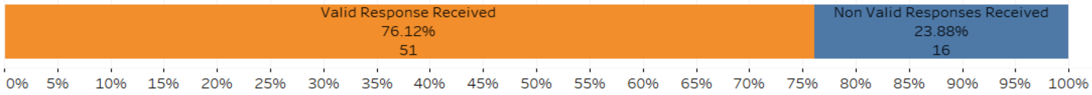
This final report documents the research effort needed to complete the research and provides a detailed description of all research tasks accomplished. It includes a copy of a qualitative survey questionnaire in Appendix B and all steps (methodology) implemented for the various analyses undertaken.

Discussion of Results

Qualitative Survey Findings

Overall, 67 responses were received, with 16 (23.88%) having blank inputs for all questions, as shown in Figure 2. The 16 blank responses were considered invalid and were excluded; thus, only 51 (76.12%) responses were considered for the analysis. The findings of the survey are synthesized in the following section.

Figure 2. Survey respondents



Information about Respondents

Question 1: Which of the following best describes the type of organization you represent?

Of the 51 valid responses, 84.32% (n=43) represented state DOTs, 7.84% (n=4) represented MPOs, and 1.96% (n=1) represented the FHWA. Two representatives from county-level DOTs and one representative from a nationwide data and software provider, together, made up the "Other" category with 5.88% (n=3).

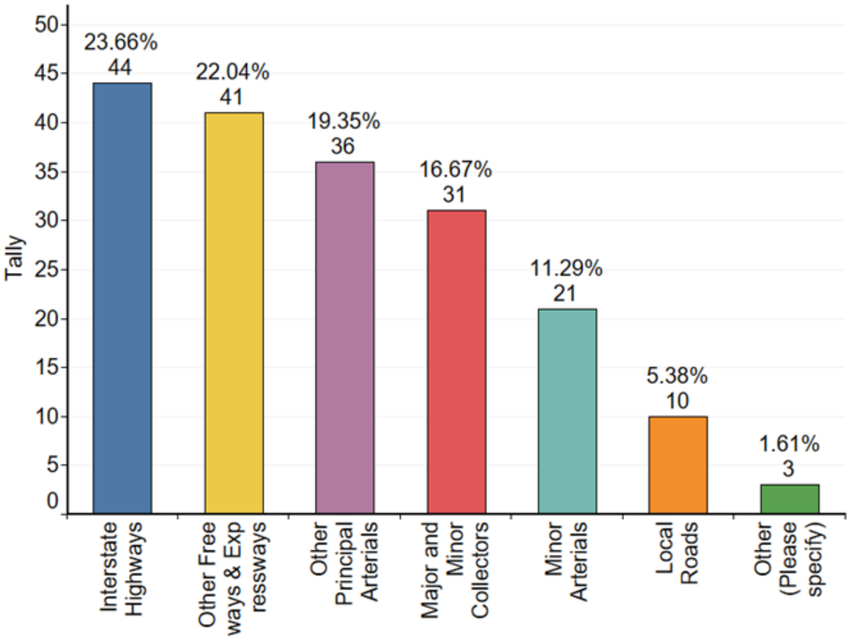
Question 2: How would you classify the extent of the ITS deployment that is under your organization's control?

Out of 57 tallied responses received from 51 respondents, 70.18% (n=40) indicated a statewide deployment of their organizations' ITS; 14.03% (n=8) indicated regional extent; 3.51% (n=2) indicated municipal extent; and 3.51% (n=2) indicated a nationwide extent of deployment. Deployment on metropolitan extent was 7.02% (n=4), with 1.75%(n=1) as city extent of deployed ITS.

Question 3: What roadway network do you operate on?

The types of road networks operated by respondents' organizations are shown in descending order in Figure 3. Out of 186 tallied responses from 51 respondents, interstate highways, expressways, and principal arterials were the most operated, indicated respectively by 23.66% (n=44), 22.04% (n=41), and 19.35% (n=36) of the tallied responses. Major and minor collectors, minor arterials, and local roads respectively had 16.67% (n=31), 11.29% (n=21), and 5.38% (n=10) of the tallied responses. Three tallied responses indicated “other”. Two failed to specify details, while one indicated that its organization owned roadway infrastructure, which made it function as a regional transportation planning agency under an agreement.

Figure 3. Type of roadway network operated



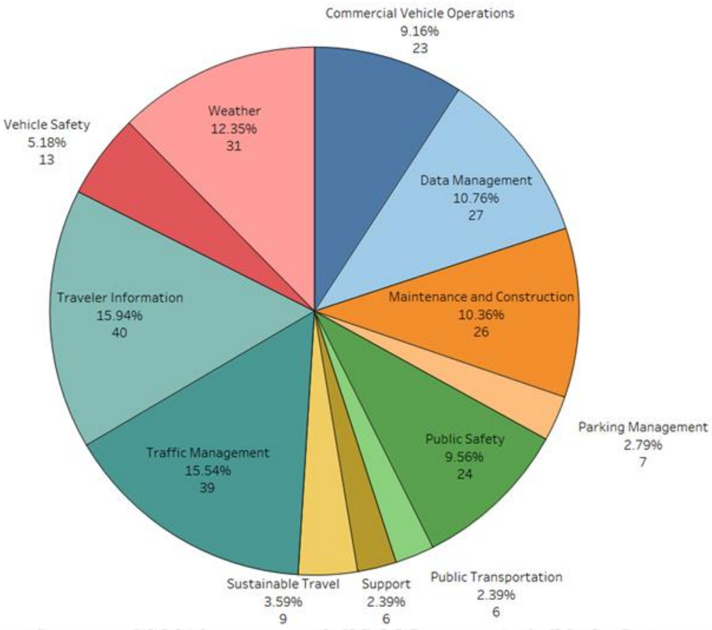
Performance Measurement Practice

Question 4: Which of the following best describes the Intelligent Transportation Systems (ITS) service areas currently deployed by your organization?

Traveler Information and Traffic Management were the most deployed service areas, as indicated by 15.94% (n=40) and 15.54% (n=39), respectively, of the 251 tallied responses of 46 respondents. Weather, Data Management, Maintenance and Construction were indicated by 12.35% (n=31), 10.76% (n=27), and 10.36% (n=26), respectively as deployments. Public Safety and Commercial Vehicle Operations polled 9.56% (n=24) and 9.16% (n=23), with Vehicle Safety at 5.18% (n=13). Sustainable Travel, Parking

Management, Support, and Public Transportation polled percentages less than 5% (<n=12) extent of deployments, as shown in Figure 4.

Figure 4. Types of ITS service areas deployed



Number of respondents: 46; Number of tallies: 251

Question 5. Do you currently monitor the performance of your organization's ITS programs?

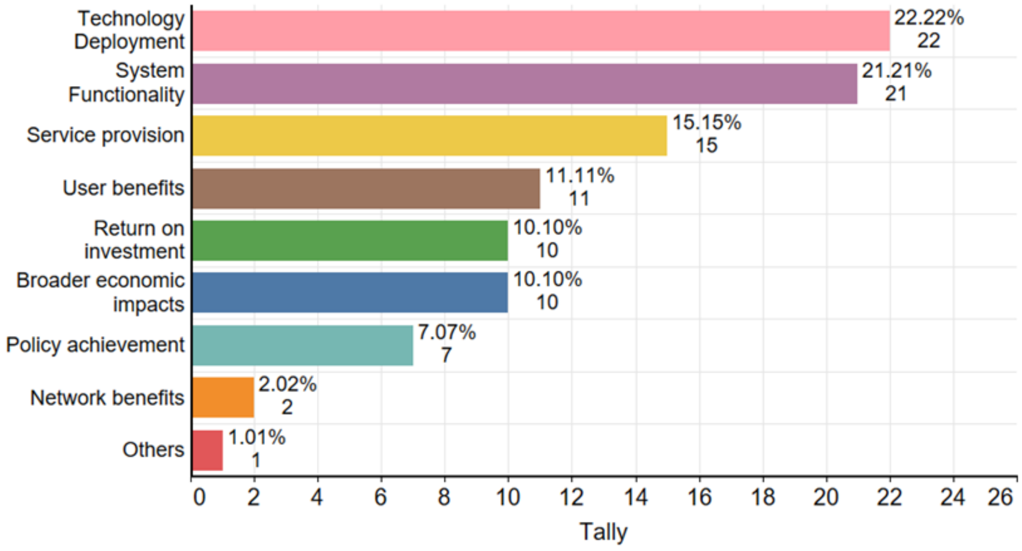
Out of the 46 responses to the specific question, 36 (78.26%) indicated their organizations currently monitored ITS programs' performance, with 10 (21.74%) indicating the contrary.

Question 6: Which of the following best describes the levels at which your organization's ITS performance is monitored?

Out of 99 tallied responses from 25 respondents, technology deployment (22.22%, n=22), system functionality (21.21%, n=21), and service provision (15.15%, n=15) were the three most common areas ITS is monitored, as shown in Figure 5. Performance monitoring on technology deployment would monitor the number or extent to which a particular system is deployed in a jurisdiction, such as the number of speed cameras installed. Monitoring a system’s functionality would, for instance, monitor the time a system is in service or out of service while the level of service provision would monitor, for instance, the quality or the level of service provided.

Further, ITS performance monitored on levels of user benefits, returns on investments, and economic impacts were somehow fairly represented with 11.11% (n=11), 10.10% (n=10), and 10.10% (n=10), respectively, as indicated by the tallied response. ITS performance monitored on policy achievement, and network benefits were insufficiently indicated by 7.07% (n=7) and 2.02% (n=2), respectively. A respondent indicated resource allocation as an "other" level that ITS performance is monitored.

Figure 5. Level of monitoring ITS performance



Question 7: Do you consider the ITS performance monitoring by your organization beneficial to operations and taxpayers?

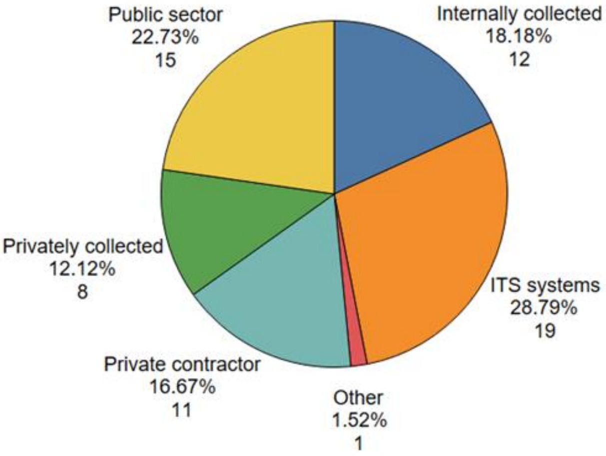
Of 25 respondents, 92% (n=23) indicated ITS performance monitoring was beneficial to their organization's operations and the taxpayers. Two respondents indicated "not sure" about the benefits.

Question 8: Who collects the data your organization uses in monitoring performance?

Considerable data is sourced directly from ITS systems, as indicated by 28.79% (n=19) of the 66 tallied responses, as shown in Figure 6. The data that is directly collected by the ITS systems are expected to be immediately available to agencies at no additional cost, though the storage, processing, transmission, and data analysis may attract a cost.

Generally, the cost of data and availability depend on who owns the data, public or private. As indicated from the survey, privately collected data (12.12%, n=8) and private contractors (16.67%, n=11) account for 28.79% of the data used to monitor ITS performance. Also, data collected internally by agencies and public sectors accounted for 18.18% (n=12) and 22.73% (n=15), respectively. One tallied response indicated university support for data collection.

Figure 6. Agency or source of data collected



Question 9a: Do you publish the findings of the performance monitoring you describe?

Out of 25 respondents, 8% (n=2) do not publish performance monitoring reports, while 28% (n=7) published only internally. Agencies that publish only publicly were 12% (n=3), while 52% (n=13) published both internally and externally.

While the replies indicate that reports are likely to be widely accessible if the statistical significance of the small sample size is ignored, the difficulty in citing agency performance measures through the literature search cannot be explained.

Question 9b: If possible, please provide a URL link to your published reports.

URL links to published ITS performance reports, dashboards, and other information provided by respondents are shown in Table 3. The information provided additional resources as most of the published reports were not cited through the literature search, such as the reports of Georgia, Arizona, and North Carolina.

Table 3. URL links to published reports

Name of organization	URL link
PennDOT	https://www.penndot.gov/ProjectAndPrograms/operations/Pages/default.aspx
Maricopa County DOT	http://aztech.org/About/PerfIndicators
Georgia DOT	http://sigopsmetrics.com/main/
Virginia DOT	https://www.virginiadot.org/business/resources/OperationsDivision/FY2020_Operations_Performance_Report.pdf
Arizona DOT	http://aztech.org/about/performance-indicators-book.htm
FHWA	https://ops.fhwa.dot.gov/publications/fhwahop19089/index.htm
Illinois DOT	https://www.travelmidwest.com/lmiga/traveltimes.jsp
Missouri DOT	https://www.modot.org/tracker-measures-departmental-performance
MnDOT	http://www.dot.state.mn.us/measures/
North Carolina DOT	https://www.ncdot.gov/about-us/our-mission/Documents/2019-annual-report-interactive-fullscreen.pdf
Maryland DOT	https://www.roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=711

Question 10: Do you consult or find the suggested Performance Measures listed for individual service packages described in the ARC-IT helpful in developing your organization's ITS performance measures?

From the survey, 51.52% (n=17) of the 33 respondents indicated their organizations did not consult or find these recommendations helpful. The number of responses, however, was insufficient to conclude if the feedback could be generalized across agencies.

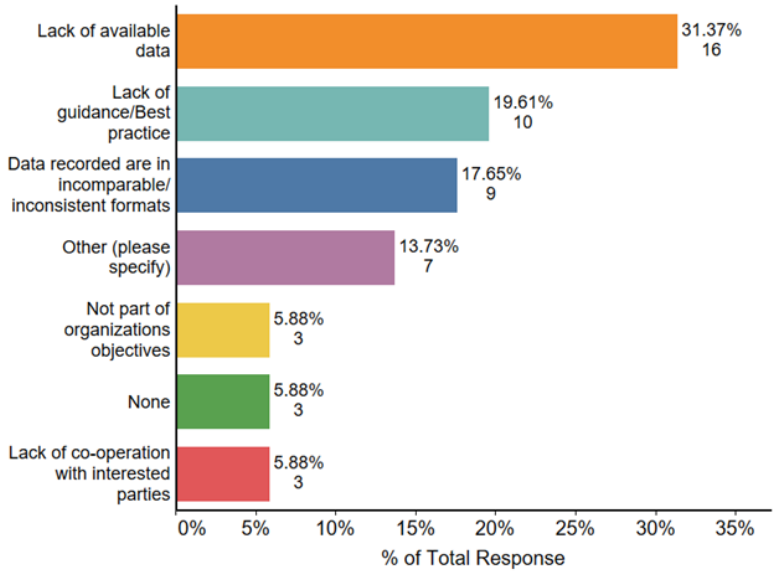
Question 11: Does your organization compare ITS performance, benefits, and deployment/usage with other jurisdictions or USDOT/FHWA benchmark?

Out of 33 respondents, only 36.36% (n=12) of the agencies benchmarked or compared ITS performance, benefits, or deployments with other jurisdictions or agencies, including DOT and FHWA.

Question 12: What are the main barriers that prevent benchmarking or the establishment of consistent performance indicators across your organization's jurisdiction?

Of the 51 tallied responses of 33 respondents, 31.37% (n=16), 19.61% (n=10), and 17.65% (n=9) indicated the lack of available data, lack of guidance or best practices, and incomparable or inconsistent data formats, respectively, as reasons their organizations did not benchmark or compare ITS performance with other agencies or jurisdictions. Also, benchmarking “not part of agency objectives” and “lack of inter-agency cooperation” were indicated as reasons by 5.88% (n=3) and 5.88% (n=3), respectively. "Other" reasons specified by 13.73% (n=7) included resource constraints, lack of knowledge, time constraints, and funding constraints. Also, 5.88% (n=3) indicated nothing (“none”) prevented their organizations from comparing or benchmarking ITS performance. The reasons provided are shown in Figure 7, in descending order.

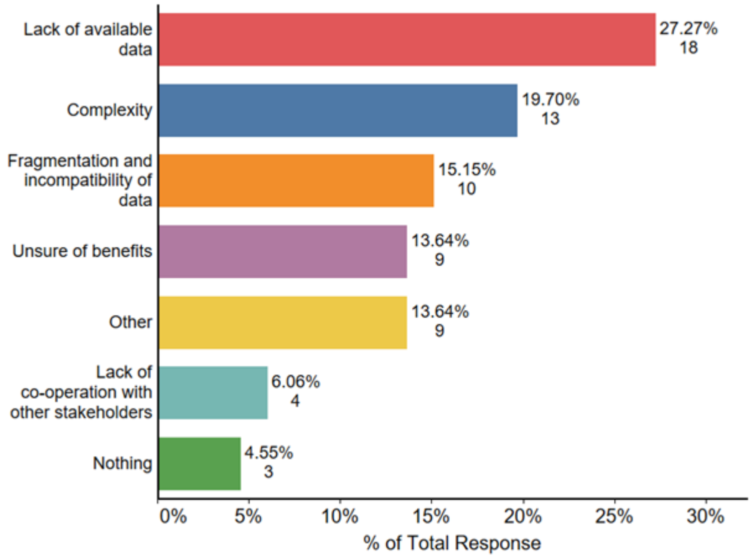
Figure 7. Reasons agencies do not compare or benchmark ITS performance with others



Question 13: Does any of the following prevent your organization from measuring ITS performance, benefits, and deployment/usage more often or to a higher quality?

Of the 66 tallied responses of 33 respondents, the reasons that prevent monitoring of ITS performance, benefits, deployment to greater details, and quality are mostly lack of available data (27.27%, n=18), complexity (19.70%, n=13), and fragmented and incomparable data (15.15%, n=10). Also, unsure benefits and lack of cooperation with stakeholders were indicated as reasons by 13.64% (n=9) and 6.06% (n=4), respectively. The "Other" reasons specified by 13.64% (n=9) of the tallies included: resource, funding, time constraints, lack of data scientists, specific data-focused positions in organizations, and difficulty assigning responsibilities when inter-agency collaboration is required. Additionally, 4.55% (n=3) indicated “nothing” prevented their organizations from measuring performance to greater detail and quality. The reasons provided by respondents in descending order are shown in Figure 8.

Figure 8. Reasons preventing organizations from measuring ITS performance



Conclusions

From the qualitative survey, state DOTs are highly represented, providing reasons most respondents indicated statewide ITS deployment. Also, interstate highways, freeways, and principal arterials are roadways that most respondent organizations operate, with most ITS programs deployed being Traveler Information and Traffic Management. Other high deployment areas include Data Management, Maintenance, and Construction. Program areas not widely implemented by organizations include Vehicle Safety, Sustainable Travel, Parking Management, Support, and Public Transportation. The following emerged from the survey:

- ITS performance measurement has been fairly integrated into ITS programs by agencies, with most organizations monitoring their ITS programs considering it beneficial to operations and taxpayers.
- Most organizations monitored ITS performance on deployment and systems functionality levels with a few others also monitoring the levels of service provision and user benefits. Policy achievement and network benefits are less monitored.
- Considerable data are collected directly from ITS equipment, which is expected to be available at no additional cost. Besides this source, agencies rely on public or private-sector-owned data with a few collecting internally.

- On the relevance of ARC-IT-provided resources, organizations rarely consulted or found ARC-IT recommendations helpful in developing their ITS performance measures. The number of responses was not enough to generalize this feedback across agencies.
- State DOTs generally do not benchmark or compare ITS performance with other agencies and jurisdictions, mainly for the following reasons: lack of available data, lack of guidance or best practices on the subject, and incomparable data gathered across agencies/jurisdictions.
- The following featured highly as the reasons that prevent agencies from measuring performance, benefits, and deployment to greater detail and quality: lack of available data, complexity in the endeavor, and fragmented and incomparable data.
- “Other” reasons included the lack of data scientists, lack of specific data-focused positions in organizations, and difficulty assigning responsibilities when inter-agency collaboration is required.

These findings and conclusions were expected to guide the development of Louisiana’s ITS performance measures.

Developed ITS Performance Measures

The development of the ITS performance measures followed an iterative process using the information gathered from literature, qualitative survey, and inputs from the stakeholders. The initial and final performance measures are shown in Appendix B. The final list indicates the ITS programs' objectives to be evaluated, the performance measures, the data, and data sources.

Due to data availability challenges and the limited time available to evaluate the performance of the programs using all performance measures, performance measures shown in Table 4 were used to evaluate the selected programs to assess the objective of the research. For each ITS program area, sub-study areas were developed, and the performances were evaluated for the periods mainly between 2016 and 2020, as shown in Table 4. To make the comprehension of the sub-study easy, they were structured to follow: an introduction or background, objective(s), data analysis and discussions, findings, and conclusions, where possible.

Table 4. ITS program areas, performance measures and scope of evaluations

Program Area	#	Objectives	Performance Measures	Data	Data Sources	Extent of Study (2016-2020)
Arterial Management	1	Increase the percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras	Percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras per Z distance.	Inventory and locations of installed CCTV cameras	LTRC	Assess coverage of closed-circuit television (CCTV) cameras on significant highways in Louisiana.
	2	Reduce delay associated with incidents on arterials	Delay associated with incidents	Travel time data	Crash database/RITIS	Evaluate change in incident response time on highway segments with CCTV coverage.
Emergency Management and Motorist Assistance Patrol (MAP)	1	Reduce mean incident clearance time per incident	Roadway clearance duration	• Incident notification time, On-scene arrival time for incident, time full traffic operational status returns. • Travel time data	Crash database	An assessment of incident clearance time on Louisiana's roadways with MAP coverage.
Commercial Vehicle Operations	1	Decrease point-to-point travel times on selected freight-significant highways	Point-to-point travel times on selected freight-significant highways	Travel time data	RITIS	An assessment of travel time of commercial vehicles on freight significant highways in Louisiana.
	2	Decrease hours of delay per 1,000 vehicle miles traveled on selected freight significant highway	Hours of delay per vehicle miles on selected freight-significant highways.			
	3	Decrease the annual average travel time index for selected freight-significant highways	Travel time index on selected freight-significant highways.			
	4	Reduce commercial vehicle crash rate.	Number of crashes involving large trucks and buses	Number of crashes involving large trucks and buses	Crash database	
Freeway Management & Traffic Management Centers	1	Increase the level of traffic management center (TMC) field hardware	Total number of TMC equipment	Inventory of TMC field hardware	TMCs to assist	Inventory of statewide TMC (ITS) resources and an evaluation of transportation systems monitored by TMC for real-time performance.
	2	Increase the percent of regional transportation systems monitored by the TMC for real-time performance				
	3	Determine effects of ramp meters on traffic flow and safety at merge sections	Number of crashes	Number of crashes	Crash database/Localized data	Assessment of the safety performance of active ramp meters in Louisiana.
Electronic Payment and Congestion Pricing	1	Improve average travel time during peak periods	Average travel time during peak periods (minutes)	• Travel time data • Person travel along links	RITIS	Evaluation of peak travel time on tolled Causeway Blvd.
	2	Reduce hours of delay per capita	Hours of delay (person-hours)			
Traveler Information	1	Increase the number of traveler information portals	• Number of 511 calls per year • Number of visitors to traveler information website per year • Number of web (e.g., Twitter, Facebook) followers	• Count of users of 511 channels • Count of traveler information website users • Count of web followers (e.g., Twitter, Facebook, etc.)	511 Program	Evaluation of the current state of Louisiana's traveler information program area.
	2	Increase the accuracy of traveler information posted				

Arterial Management

The DOTD's broad ITS objective to reduce travel time variability by delays can be achieved through the state's Arterial Management program. Specific strategies that can be deployed to reduce travel time reliability include the installation of closed-circuit television (CCTV) cameras on arterials and freeways to allow TMCs to monitor the performance of transportation systems in real-time and aid incident detection and response. This section evaluates the objectives to increase the percentage of major and minor arterials and freeways equipped and operating with CCTV cameras, and to reduce delays associated with incidents on Louisiana's road network through an:

- Assessment of CCTV cameras coverage on significant highways in Louisiana;
- Evaluation of the change in incident response time on highway segments equipped with CCTV cameras.

Assessment of CCTV Camera Coverage on Significant Highways in Louisiana

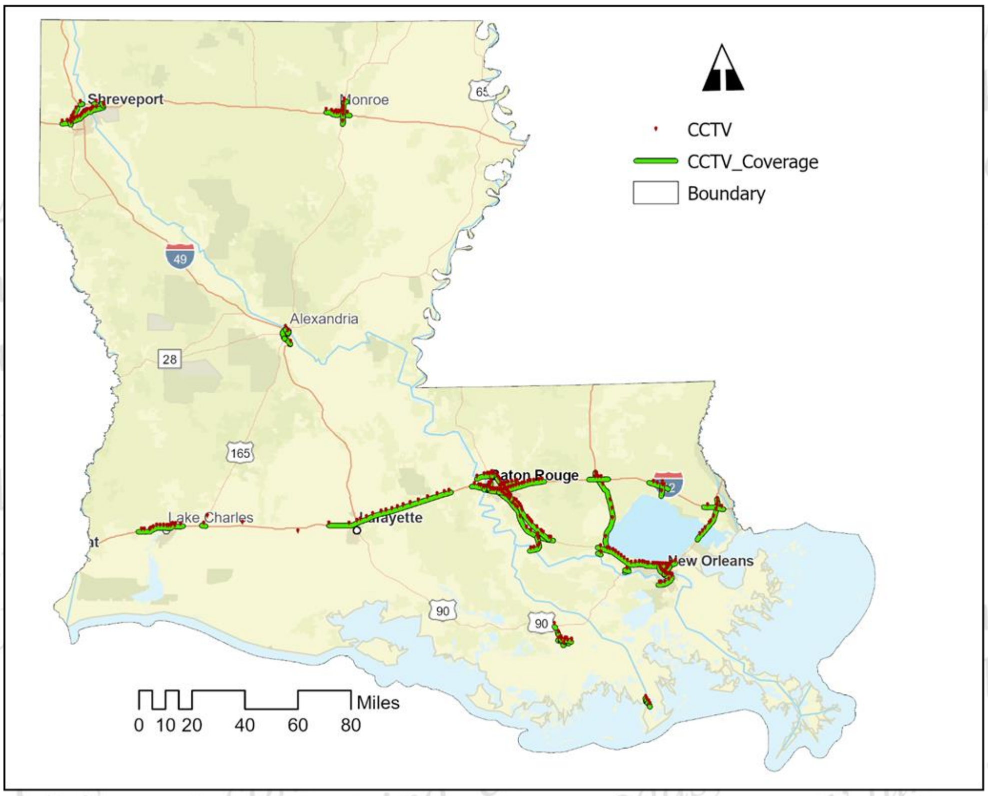
Background. For cost estimation, the roadway category (interstate highway, primary municipal network, primary rural network, and bridge) has been determined to need full or key location coverage. On average, roadways with full coverage in urban areas are assumed to need one CCTV camera every 1.5 miles, while key locations in rural areas are assumed to need one CCTV camera every 5 miles [18].

Objectives. The objective of this section was to assess the performance of DOTD to increase the percentage of major and minor arterials and freeways equipped and operating with CCTV cameras by assessing the extent of major and minor arterials equipped and operating with CCTV cameras.

Methodology. A coverage map was created that showed the geographic locations of all installed CCTV cameras in Louisiana's highway system and was used to assess the current CCTV camera coverage and the need for future installations. The estimated one camera every 1.50 and 5.0 miles on urban and rural roadways, respectively, was used to assess the adequacy of coverage of CCTV cameras on significant highways in Louisiana. The crash frequencies per milepost of the interstate systems over the past years (2016 – 2020) were assessed to determine the immediate and future CCTV camera coverage needs by identifying locations with unusually high crash frequencies or clusters on the interstate system.

Discussions. The geographical locations of all 420 CCTV cameras installed in the Louisiana highway system are shown in the coverage map in Figure 9. The CCTV cameras are deployed mainly on the interstate and state highways in and around New Orleans, North Shore, Shreveport, Lake Charles, Baton Rouge, Monroe, Alexandria, Lafayette, and Houma; and on the LA 1 in Leeville, Louisiana, as shown in the coverage map. The coverage map serves as a visual monitor of the gaps in coverage on the highway system.

Figure 9. Current CCTV camera coverage on Louisiana highway system



Closer detail of the installed CCTV camera locations shown in the coverage map is shown in Figure C1 in Appendix C.

Estimated Adequacy of the Current CCTV Camera Coverage

Barring any blind spots that may necessitate extra CCTV camera needs, the recommended one CCTV camera every 1.5 and 5 miles (each direction) in urban and rural locations, respectively, were used to assess the adequacy of the current CCTV coverage on highways at these locations. The assessment did not include existing or desired cameras for specialty applications, such as security locations, rest areas, or other trouble-spot locations. The estimated adequacy of the deployed CCTV cameras is shown in Table 5.

For instance, from the table, the estimate showed that routes I-210, between LA 3132 and Highway 70 and Highway 80, and I-10 between LA 77 and LA 415 had inadequate coverage; but these are recommended total numbers for estimation only. The actual number required by DOTD should be based on design decisions, actual site conditions, and verification by the local TMCs.

Table 5. Estimated adequacy of current CCTV camera coverage

Location	Route	Corridor / Cross Street	Direction	Urban/ Rural	Parish	District	Length (miles)	Mile/ Device	Recommended # of Devices	Existing # of Devices	Difference	Remarks
Lake Charles, LA	I-10	Ruth Street to LA 397	East/West	Urban	Calcasieu	7	17.4	1.5	12	28	16	
Lake Charles, LA	I-10	LA 397 to US 165	East/West	Rural	Calcasieu	7	12	5	3	3	0	
Fort Fourchon	LA 1	LA 1 North Leeville to LA 1 @ Vessel Graveyard #1	North/South	Urban	Lafourche	2	6	1.5	4	8	4	
Houma	LA 182	LA3197 to LA3040/LA 24	North/South	Urban	Terrebonne	2	1.87	1.5	2	5	3	
Baton Rouge	Airline Highway	I-10 to US-61	East/West	Urban	Baton Rouge/Ascension	61	27.8	1.5	19	25	6	
Shreveport, LA	I-210	LA 3132 (70th St. SE) to Hwy 79/80	North/South	Urban	Caddo/Bossier	4	19.6	1.5	13	10	-3	Inadequate
Shreveport, LA	I-20	Bert Kouns to I-220 Off Ramp	East/West	Urban	Caddo/Bossier	4	19.2	1.5	13	20	7	
Baton Rouge	I-10	I-12 JCT #5 to Bluff	East/West	Urban	East Baton Rouge	61	10.2	1.5	7	8	1	
Baton Rouge	Florida St/US 190	US 60 to Stevendale	East/West	Urban	East Baton Rouge	61	6	1.5	4	8	4	
Baton Rouge	I-10	Bluff to US-61	East/West	Rural	East Baton Rouge/Ascension	61	19.3	5	4	12	8	
Baton Rouge	I-12	I-10 to Middle Colyell	East/West	Urban	East Baton Rouge/Livingston	61	17.54	1.5	12	22	10	
Baton Rouge	US 61/US 190	LA 415 to I-10	East/West	Urban	East/West Baton Rouge	61	11.8	1.5	8	14	6	
Baton Rouge	I-110	LA 415 to I-10	East/West	Urban	East/West Baton Rouge	61	6.71	1.5	5	10	5	
Baton Rouge	I-10	West of LA415 to I-110 JCT	East/West	Urban	East/West Baton Rouge	61	5.63	1.5	4	13	9	
Baton Rouge	I-10	I-110 JCT to I-12 JCT #5	East/West	Urban	East/West Baton Rouge	61	3.98	1.5	3	10	7	
Grosse Tate/Baton Rouge	I-10	LA 77 to West of LA 415	East/West	Rural	Iberville/West Baton Rouge	61	10	5	2	0	-2	Inadequate
Lake Charles, LA	US 210	I-10 to US 90	North/South	Urban	Jefferson Davis	7	1.25	1.5	1	2	1	
Lake Charles, LA	US 165	US 165 #2 to Woodlawn Tower	North/South	Rural	Jefferson Davis	7	8.46	5	2	2	0	
Lafayette	I-10	Duson, LA to I-49 #1	East/West	Rural	Lafayette	3	12.2	5	3	5	2	
New Orleans	US-90/US-90B	Claiborne Ramp #1 to Avenue K	East/West	Urban	Orleans	2	11.2	1.5	8	24	16	
New Orleans	I-10	West End to Franklin Ave #1	East/West	Urban	Orleans	2	7.2	1.5	5	13	8	
New Orleans	I-10/I-610	Laplace Tower #2 to Chef Menteur	East/West	Urban	Orleans/Jefferson/ St. Charles/St. John	62	32.4	1.5	22	27	5	
Monroe, LA	US 165	Finks Hideaway to Richwood	North/South	Urban	Ouachita	5	12.2	1.5	8	13	5	
Monroe, LA	LA-165 Business	Cypress to US-80	East/West	Urban	Ouachita	5	4.02	1.5	3	4	1	
Monroe, LA	I-20	Well Road to Pecanland Mall	East/West	Urban	Ouachita	5	9.78	1.5	8	8	0	
Alexandria	I-49	US 71 to US 165/71	North/South	Urban	Rapides	8	9.87	1.5	7	9	2	
Sunshine Bridge	LA 70	LA 18 #1 to LA 44 #1	East/West	Urban	St. James	61	8.5	1.5	6	10	4	
Hammond	I-55	LA 22 to I-10	North/South	Rural	St. John the Baptist	62	25.8	5	6	8	2	
Lafayette/ Atchafalaya	I-10	I-49 #1 to LA 77 (Grosse Tete)	East/West	Urban	St. Martin/Iberville	3	36.5	1.5	25	25	0	
Slidell	I-59	Concord Blvd to I-10	North/South	Urban	St. Tammany	2	4.15	1.5	3	4	1	
Slidell	I-12/I-10	West of I-12/I-59 to East of I-12/I-59	East/West	Urban	St. Tammany	62	6.52	1.5	5	7	2	
Slidell	I-10	I-10 to I-59	North/South	Urban	St. Tammany/Orleans	62	14.2	1.5	10	12	2	
Hammond	I-55	US 190 Jct to LA 22	East/West	Urban	Tangipahoa	62	5.3	1.5	4	5	1	
Hammond	I-12	West of I-55 to East I-55	East/West	Urban	Tangipahoa	62	4.4	1.5	3	4	1	
Covington	I-12	West of US-190 to East of US 190	East/West	Urban	Tangipahoa	62	7.31	1.5	5	7	2	
Covington	US 190	North of I-12 to LA 22	North/South	Urban	Tangipahoa/St. Tammany	62	3.97	1.5	3	4	1	
Houma	S Hollywood Rd	S Hollywood Rd to LA 24	East/West	Urban	Terrebonne	2	1.51	1.5	1	4	3	
Houma	LA 24	US 90 to LA 3087	East/West	Urban	Terrebonne	2	10.31	1.5	7	8	1	
Port Allen	LA 1	Intracoastal Canal #1 to Intracoastal Canal #2	North/South	Urban	West Baton Rouge	61	3.3	1.5	2	4	2	

Assessment of Immediate Future CCTV Camera Coverage Needs

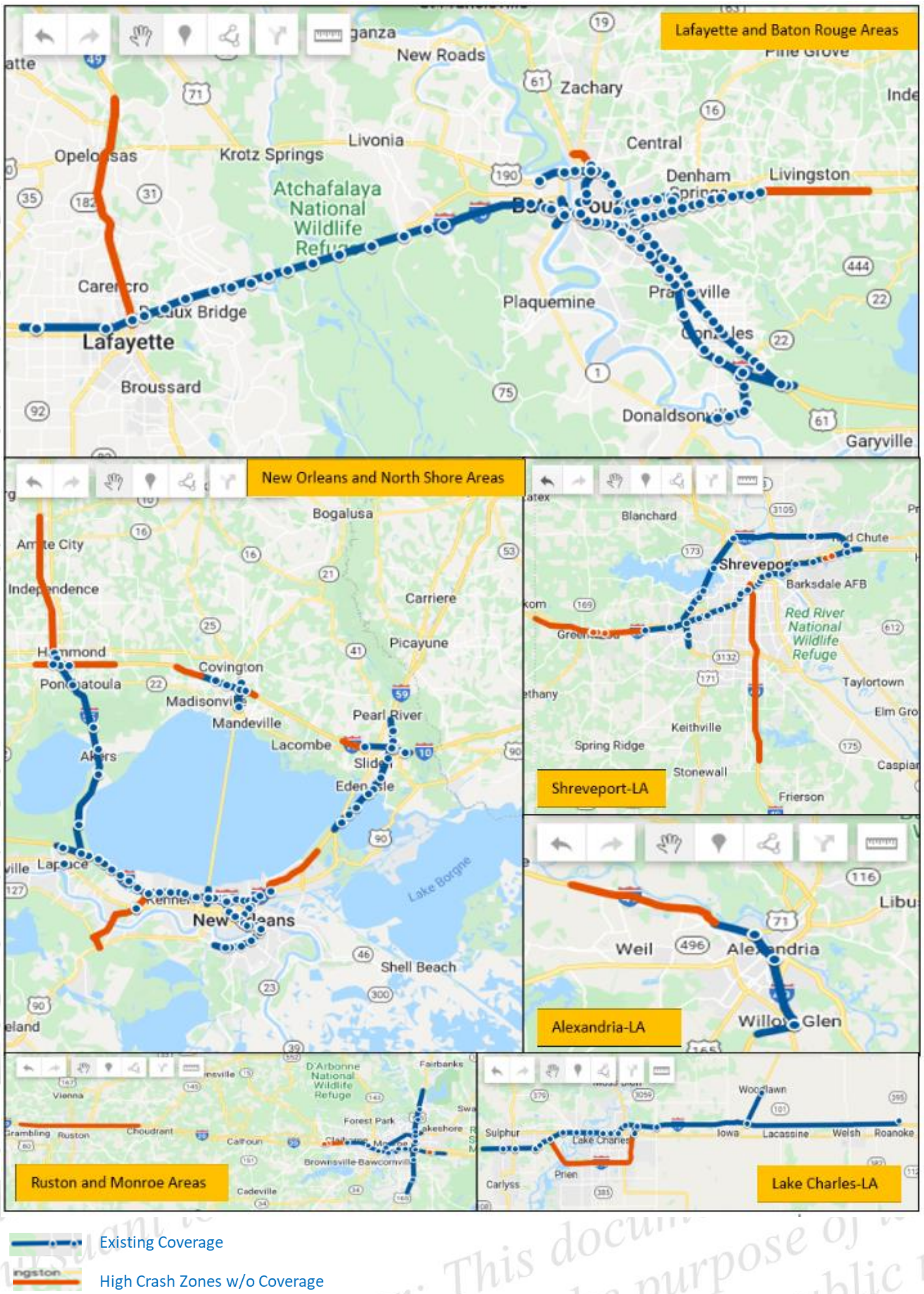
Locations with unusually high crash frequencies (greater than about 85 crashes per year, that is, one crash every 4.3 days) and places with apparent clusters of crashes (aggregated in 5-mile intervals, bi-directionally) were determined to need CCTV coverage. The crashes per 5 mile-segments on each interstate highway system between 2016 and 2020 are shown in Figure C2 through Figure C13 in Appendix C. The apparent crash cluster locations and mileposts with high crash frequencies are shown in Table 6 from the interpretations of the figures in Appendix C.

Table 6. Crash cluster locations and mileposts with high crash frequencies on Louisiana's interstate system

Highway Name	Total Mileage	Mileposts with high crash frequencies and apparent clusters	Locations
I-10	274-miles	20-45, 95-120, 150-185, 210-250, and 260-270	Lake Charles, Lafayette, Baton Rouge, New Orleans, and on interstate I-10 approach to I-12 in Slidell, LA
I-12	85-miles	0-30, 35-50, 55-65, and 80-85	From the I-10 connection with I-12 in Baton Rouge to the LA-441 crossing, Hammond, Covington, and the I-12 approach to I-10 in Slidell, LA
I-20	189-miles	0-25, 80-85, and 110-125	From the Texas-Louisiana border to Shreveport, Ruston, and Monroe, LA
I-49	247-miles	0-25, 80-85, and 195-210	From Lafayette through Opelousas to Washington, LA, Alexandria, and the I-49 approach to Shreveport, LA
I-55	66-miles	20-50	Between Hammond and the LA-1048 crossing with I-55
I-110	9-miles	Entire interstate	Baton Rouge
I-210	12.5-miles	Entire interstate	Lake Charles
I-220	18-miles	5-10	Shreveport
I-310	11.5-miles	Entire interstate	New Orleans
I-610	3-miles	Entire interstate	New Orleans

The segments with apparent crash clusters, unusually high crash frequencies, and the existing CCTV camera coverage on the interstate highway system in Louisiana are shown in Figure C14 in the appendix, with closer details also shown in Figure 10. High crash cluster locations and high crash frequency segments with existing CCTV cameras were determined to have existing coverage, so they were marked accordingly. The segments with apparent crash clusters and unusually high crash frequencies without CCTV cameras were determined to need immediate future coverage. For instance, interstate highway I-210 in Lake Charles, I-49 from Lafayette through Opelousas to Washington, and I-310 in New Orleans need immediate or future CCTV camera deployments.

Figure 10. Current CCTV camera coverage and segment with high crash frequencies in Louisiana (Detailed)



Recommendation. Segments with apparent crash clusters and unusually high crash frequencies without CCTV camera coverage are determined to need immediate future coverage.

Evaluation of the Change in Incident Response Time on Interstate Highway Segments with Camera CCTV Coverage

Introduction. Louisiana's Arterial Management aims to reduce delays associated with incidents on arterials and freeways, which can be realized with incident management. Incident management refers to the development and implementation of ITS to rapidly detect, verify, respond, and clear incidents [1]. The primary benefit of incident management includes reduced incident response and clearance times, improved safety, and improved resource efficiency. As a widely used incident detection and verification ITS equipment, CCTV cameras can be used to identify the exact location of incidents, verify and confirm incidents, relay valuable information about the incident, and help formulate strategies with responders [27].

Objectives. In order to demonstrate the benefits of reduced delays associated with incidents on arterials and freeways with CCTV coverage on Louisiana's roadways, this study evaluated the incident response times on roadways with CCTV camera coverage and compared with incident response times on roadways of similar features without CCTV camera coverage.

Methodology. One-mile segments with CCTV camera coverage on interstate highways in New Orleans, North Shore, Shreveport, Lake Charles, Baton Rouge, Monroe, and Alexandria were selected. Equally, one-mile segments of interstate highways with similar features but without CCTV coverage, in the same direction of traffic and locality, were also selected to compare corresponding incident response times. The impulse of the selection ensured the roadways had similar annual average daily traffic (AADT) and limited any biases in data collected for evaluation. This comparison hypothesized that the mean incident response time on roadways with CCTV coverage would be lower than on roadways without CCTV camera coverage, at a 5% level of significance.

The one-mile segments with and without CCTV camera coverage on the selected interstates are shown in Table 7.

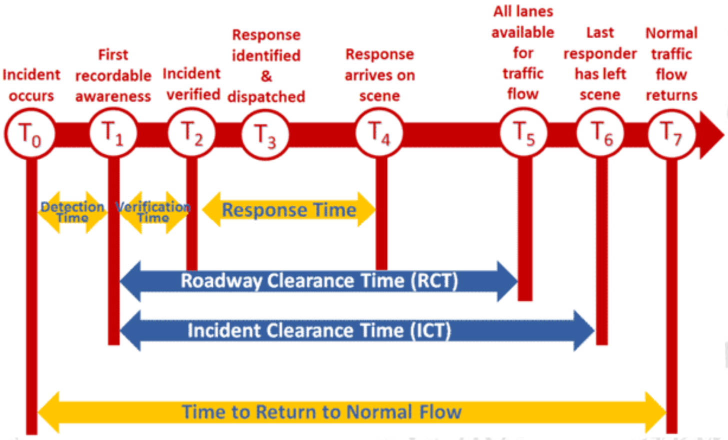
Table 7. One–mile segment of roadways (with/without CCTV camera coverage)

CCTV Location	Roadway /Highway	Direction	Start (longitude/latitude)	End (longitude/latitude)	Coverage Condition
Lafayette	I-10	East	30.276905, -91.963137	30.281813, -91.947319	with
Lafayette (near Rayne)	I-10	East	30.243278, -92.310045	30.248647, -92.29498	without
Lake Charles	I-10	West	30.246144, -93.163594	30.246607, -93.180798	with
Lake Charles (near Vinton)	I-10	West	30.142217, -93.667629	30.135668, -93.682576	without
Alexandria	I-49	North	31.303884, -92.447230	31.316213, -92.456244	with
Alexandria	I-49	North	31.223122, -92.466756	31.235023, -92.457703	without
Shreveport	I-20	East	32.457132, -93.841475	32.462303, -93.825277	with
Shreveport	I-20	East	32.446171, -93.974545	32.444688, -93.957351	without
Monroe	I-20	West	32.500819, -92.099711	32.496518, -92.115280	with
Monroe	I-20	West	32.482082, -91.914130	32.483949, -91.931106	without
Baton Rouge	I-10	West	30.451494, -91.313392	30.448589, -91.329703	with
Baton Rouge	I-10	West	30.441055, -91.217031	30.445734, -91.232669	without
Baton Rouge	I-12	East	30.470504, -90.859412	30.472538, -90.842672	with
Baton Rouge	I-12	East	30.474474, -90.664298	30.474632, -90.647313	without
New Orleans	I-10	West	30.174278, -90.882438	30.181544, -90.896838	with
New Orleans	I-10	West	30.122614, -90.670723	30.123965, -90.687329	without
New Orleans	I-10	East	30.078021, -90.405805	30.069276, -90.392424	with
New Orleans	I-10	East	30.122640, -90.673674	30.120997, -90.657002	without
North Shore	I-12	West	30.33812, -89.893427	30.345824, -89.907643	without
North Shore	I-12	West	30.428901, -90.082901	30.433065, -90.099189	with
Slidell (North Shore)	I-10	East	30.298056, -89.711175	30.297297, -89.694363	with
Slidell (North Shore)	I-10	East	30.318824, -89.587178	30.323596, -89.571386	without

Data Collection

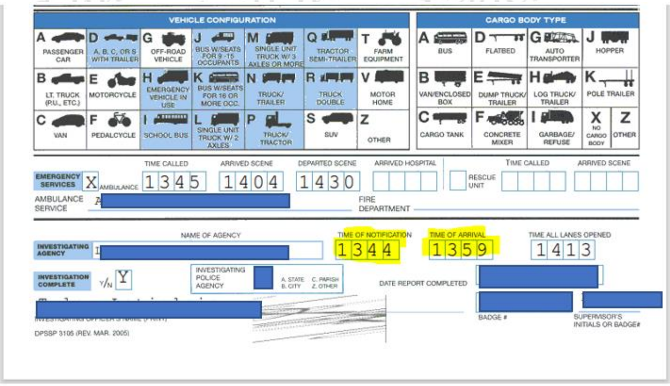
With the incident response time (IRT) defined as the time between the first recordable awareness (notification) of an incident by a responsible agency and the arrival of a first responder to the incidence scene [28], the IRTs of every incident on the selected segments were collected for specified times of the day for the period studied. The definition of the IRT is shown in Figure 11, which shows the timeline of elements of traffic incidents.

Figure 11. Timeline of traffic incident elements [28]



The crash reports were retrieved from the Louisiana crash database [29] for each incident that occurred on the selected segments of the interstate highway system during the AM peak (between 7:00 a.m. – 8:00 a.m.), midday (between 12:00 p.m. – 1:00 p.m.), and PM peak (between 5:00 p.m. – 6:00 p.m.), from January 2016 to December 2020. A snippet of a Louisiana crash report showing the recorded time of notification and the time of arrival on a crash scene is shown in Figure 12.

Figure 12. Snippet of Louisiana crash report [29]



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

	TIME CALLED	ARRIVED SCENE	DEPARTED SCENE	ARRIVED HOSPITAL		TIME CALLED	ARRIVED SCENE
EMERGENCY SERVICES X AMBULANCE	1345	1404	1430		☐ RESCUE UNIT		

AMBULANCE SERVICE A[redacted]
FIRE DEPARTMENT

	NAME OF AGENCY	TIME OF NOTIFICATION	TIME OF ARRIVAL	TIME ALL LANES OPENED
INVESTIGATING AGENCY	I[redacted]	1344	1359	1413

INVESTIGATION COMPLETE Y/N Y
INVESTIGATING POLICE AGENCY [redacted] A. STATE B. CITY C. PARISH Z. OTHER
DATE REPORT COMPLETED [redacted]
[redacted] INVESTIGATING OFFICER'S NAME (PRINT)
[redacted] BADGE #
[redacted] SUPERVISOR'S INITIALS OR BADGE#
DPSSP 3106 (REV. MAR. 2005)

Data Cleaning Efforts

The data collection required a manual sifting of the crash reports for the time of notification and time of arrival for the over 1000 recorded crashes that occurred in the selected segments from 2016 to 2020. Besides the laborious and time-consuming data collection efforts, the following challenges were imminent:

- Missing crash reports from crash database for recorded crashes – There were instances where there were no or missing data to carry out evaluations for a whole mile stretch of the selected segment.

- Recorded incident response time of zero – Many incidents had zero time between the time of notification and time of arrival on site. These recorded data points tended to skew data distribution left and affect statistics.
- Outlier data points – There were many outlier data points above the maximum recorded IRT. These had the tendency to skew the data distribution right and affect statistics.
- An uneven number of data points recorded on comparable segments – Due to the unavailability of crash reports, there were unequal data points for datasets among most comparable highway segments.

The exhibits of these situations are shown in Figure C15 in Appendix C.

The following actions were taken to overcome the identified challenges:

- For the unequal number of data points and missing or unattached crash reports, the daily time frame for the study was extended to 7:00 a.m. – 7:00 p.m. to allow for more crashes to be counted on the segments for which crash reports may be available. However, this action could not eliminate the uneven data points to a large extent.
- The recorded zero data points and outliers were not excluded from the analysis, as they have the potential to depict the true situation in these selected segments. The elimination also could reduce the number of data points further.
- Datasets from segments on I-10 North Shore and I-12 North Shore were combined to ensure enough data points were available for the analysis of the North Shore region.

Discussion. With the unit of assessment defined as an incident on the Louisiana interstate highway system, a sample population of all incidents on a one-mile segment of the interstate highway with and without CCTV camera coverage was collected for analysis. The target population for the assessment was all incidents that occurred on Louisiana's interstate highway system from 2016 to 2020. The response variable of assessment here was the IRT recorded for an incident on the interstate highway system.

The statistic of the assessment was the sample population mean IRT for all incidents that occurred on the sampled one-mile segment of the interstate highway. With sample population mean IRT specified as μ_{with} and μ_{without}, respectively for interstate segments "with" and "without" CCTV camera coverage, the parameter of the assessment μ_{with} was defined as the mean IRT that would be observed if all incidents occurred on an interstate highway with CCTV camera coverage during the studied period. On the other hand, the parameter μ_{without} was defined as the mean IRT that would be observed if all incidents occurred on an interstate highway without CCTV camera coverage during the studied period.

To assess the evidence that IRTs on interstate highways in Louisiana with CCTV camera coverage are lower than the IRTs on interstate highways without CCTV camera coverage, the null hypothesis,

H_0, and the research (alternative) hypothesis, H_1, were defined as follows at a 5% level of significance:

- Null hypothesis H_0: $\mu_{with} \geq \mu_{without}$, and
- Research hypothesis H_1: $\mu_{with} < \mu_{without}$, such that,

The null hypothesis, H_0, is defined such that the mean IRT that would be observed if all incidents had occurred on interstate highways with CCTV camera coverage would be equal to or greater than the mean IRT that would be observed if all incidents occurred on interstate highways without CCTV camera coverage.

The research hypothesis, H_1, is defined such that the mean IRT that would be observed if all the incidents had occurred on interstate systems with CCTV camera coverage would be less than the mean IRT that would be observed if all incidents occurred on an interstate highway without CCTV camera coverage.

The hypotheses above are appropriate because one clearly stated the objective of the assessment in the alternative hypothesis, which was assumed false as opposed to the null hypothesis, until there was strong evidence to reject the null hypothesis in favor of the research hypothesis.

The findings from the assessment of incident response times on interstate systems in New Orleans, Baton Rouge, Lake Charles, Lafayette, Shreveport, Alexandria, Monroe, and North Shore are discussed in the following section.

Incident Response Time (IRT)

The IRT distribution on the selected interstate highway segments “with” and “without” CCTV camera coverage in eight locations are shown in Figure C16 in Appendix C. The corresponding quantiles of the distribution are shown in Table 8. Table 9 summarizes the IRT data analysis for interstate highways “with” and “without” CCTV camera coverage in the eight locations.

The box plot in Figure C2-3 indicates that the IRT distributions for all roadways segments selected in each area are slightly skewed negatively, with outliers seen in data for both “with” and “without” data distributions. The highest observed maximum IRTs were in Lake Charles, Baton Rouge, and New Orleans with IRTs greater than 60 minutes. The least observed maximum IRT was in Alexandria and Shreveport.

The observed slightly negative skew and variability in the IRT data distribution can be seen in Table 8 of the quantiles. Here, the outlier data were not excluded from the analysis of the means.

Table 8. Quantiles – IRT (minutes)

Area	Level	No. of Data	Min	10%	25%	Median	75%	90%	Max
Alexandria	With	16	2.0	2.7	6.3	8.0	13.0	26.8	31.0
	Without	12	3.0	3.6	6.3	10.0	16.8	24.9	27.0
Baton Rouge	With	48	0.0	3.8	5.3	12.0	25.5	33.3	61.0
	Without	113	0.0	5.0	8.5	17.0	29.5	42.6	100.0
Lafayette	With	78	0.0	8.0	12.0	19.5	30.3	40.3	98.0
	Without	25	0.0	1.8	7.5	11.0	19.5	56.4	63.0
Lake Charles	With	54	0.0	3.0	6.0	8.0	12.0	29.0	81.0
	Without	63	3.0	15.0	20.0	26.0	36.0	58.0	153.0
New Orleans	With	105	0.0	3.6	10.0	19.0	28.5	41.0	91.0
	Without	48	0.0	1.9	13.0	23.5	30.5	46.1	89.0
North Shore	With	189	0.0	4.0	7.0	11.0	18.0	27.0	86.0
	Without	37	0.0	0.0	7.5	14.0	17.5	23.0	55.0
Shreveport	With	72	0.0	2.0	4.0	6.0	10.0	13.7	30.0
	Without	34	0.0	1.0	3.0	5.0	9.3	14.0	26.0
Monroe	With	115	0.00	2.00	4.00	7.00	12.00	16.40	48.00
	Without	14	1.00	1.50	4.50	10.00	14.25	23.50	30.00

From the quantiles in Table 8, the median IRT across all the locations with CCTV camera coverage ranged between 6.0 minutes in Shreveport and 19.5 minutes in Lafayette. The median IRT on the roadway segment without CCTV camera coverage across the locations ranged between 5.0 minutes in Shreveport and 26.0 minutes in Lake Charles. The quantiles did not follow any particular trend. Contrary to the research hypothesis, there were instances where the IRTs observed for locations without coverage were less than locations that had coverage.

The summary in Table 9 includes information on the mean of the distributions, standard deviations, and the 95% confidence intervals for the IRT observed on the segments in each location. As observed from the table, the mean IRT recorded did not follow any apparent trend, just as was observed for the medians. A comparison of the upper and lower confidence intervals and ranges also did not show any particular relationship between the segments with and without CCTV camera coverage in these locations. Again, there were instances where the IRTs observed for the segments without CCTV camera coverage were less than the IRT on the roadways with CCTV camera coverage, which was not what this research postulated.

Table 9. Summary of IRT (minutes)

Area	Level	No. of Data	Mean	Std Dev	StdErr Mean	95% CI			*p-value*
						Min	Max	Range	
Alexandria	With	16	10.56	7.79	1.95	6.41	14.71	8.3	0.3278
	Without	12	11.83	7.04	2.03	7.36	16.31	9.0	
Baton Rouge	With	48	16.08	13.87	2.00	12.06	20.11	8.1	0.0196
	Without	113	21.51	17.67	1.66	18.22	24.81	6.6	
Lafayette	With	78	22.37	15.69	1.78	18.83	25.91	7.1	0.8965
	Without	25	17.36	17.38	3.48	10.19	24.53	14.3	
Lake Charles	With	54	12.50	15.04	2.05	8.40	16.60	8.2	0.0001
	Without	63	31.32	22.15	2.79	25.74	36.89	11.2	
New Orleans	With	105	21.60	17.21	1.68	18.27	24.93	6.7	0.2584
	Without	48	23.54	17.08	2.47	18.58	28.50	9.9	
North Shore	With	189	14.41	11.62	0.85	12.74	16.08	3.3	0.6881
	Without	37	13.51	9.75	1.60	10.26	16.77	6.5	
Shreveport	With	72	7.47	5.45	0.64	6.19	8.75	2.6	0.8474
	Without	34	6.32	5.29	0.91	4.48	8.17	3.7	
Monroe	With	115	8.77	7.57	0.71	7.37	10.16	2.8	0.2753
	Without	14	10.07	7.57	2.02	5.70	14.44	8.7	

Hypothesis Testing

The proportion greater than the observed population mean IRT difference, $\delta = \mu_{without} - \mu_{with}$, which is the directional p-value for testing the null hypothesis at a 5% level of significance, is shown in Table 9 for all locations with and without CCTV camera coverage. Since the p-value recorded for Baton Rouge and Lake Charles were very small compared to the 5% significance level, there was very strong evidence to reject the null hypothesis in favor of the research hypothesis at these locations. That is to say, the IRT that would be recorded if all incidents in these locations occurred on interstate highways with CCTV camera coverage would be significantly lower than if all the incidents occurred on interstate highways without CCTV camera coverage. Conversely, there was not enough evidence to support the research hypothesis in Alexandria, Lafayette, New Orleans, North Shore, Shreveport, and Monroe, since the p-values for testing the null hypothesis in these areas were larger than the 5% level of significance. In other words, there would be no significant difference between the IRT recorded on interstate highways with CCTV camera coverage and those without CCTV camera coverage in these areas.

Conclusions. Notwithstanding the need to increase the sample sizes and other factors that can influence IRT on roadways, the following findings and conclusions can be made from the evaluation:

- In Baton Rouge and Lake Charles, the IRTs observed on roadways with CCTV camera coverage were significantly lower than the IRT on roadways without CCTV camera coverage.
- There was not enough evidence from the evaluations done for Alexandria, Lafayette, New Orleans, North Shore, Shreveport, and Monroe to support the research hypothesis that the IRT on roadways with CCTV camera coverage would be lower than the IRT on roadways without a CCTV camera coverage.

Even though road users in Louisiana may be benefiting from installed CCTV cameras on roadways in other ways, the evidence available through this evaluation was not enough to claim that road users in Louisiana benefited from installed CCTV cameras in terms of reduced incident response times.

Emergency Management and Motorist Assist Patrol (MAP)

Evaluation of Change in Incident Clearance Time on Highways with MAP Coverage

Background. Motorist assistance patrol (MAP) by DOTD refers to the service that manages critical roadways when incidents occur to reduce the probability of extensive congestion and secondary incidents. The MAP patrol is usually the first to respond to incidents that include the removal of debris in roadways, provide assistance to disabled vehicles, and coordinate incident response with other emergency responders where it is deployed [1]. In 2017, MAP patrolled over 3 million miles and responded to 60,993 incidents, which included 8,382 accidents and 33,446 disabled vehicles in Louisiana [30].

The metropolitan areas, hours and days of operation, and sections of the highway covered by the DOTD MAP program are shown in Table 10. The segments on highways with coverage shown in Table 10 are also shown in a map in Figure C17 in Appendix C. The metropolitan areas with MAP include Baton Rouge, New Orleans, and Lake Charles.

Table 10. MAP patrol coverage in Louisiana [31]

MAP Patrol Areas	Hours of Operation	Days of Operation	Highway Coverage
Baton Rouge	5:30 a.m. to 7:30 p.m.	7 days/ week	I-10 - From Highland Rd. to La. 77 I-12 - From Walker to the I-10/I-12 Split I-110 - Entire Interstate Stretch La. 1 - From south of Intracoastal Bridge to I-10
New Orleans	5:30 a.m. to 7:30 p.m.	7 days/ week	I-10 - From U.S. 61 in Ascension Parish to Michoud Blvd. I-610 - Entire Interstate Stretch I-55 - From I-10 to Manchac (Exit 15) U.S. 90B - From I-10/U.S. 90B split to Westwood
	7:30 p.m. to 5:30 a.m.	7 days/ week	I-10 from I-10/I-610 west split to Morrison Rd. I-610 - Entire Interstate Stretch
Shreveport	5:30 a.m. to 7:30 p.m.	7 days/ week	I-20 - From La. 526 to I-220 in Bossier City I-49 - From La. 526 to I-20 I-220 - Entire Interstate Stretch La. 3132 - From I-20 to La. 526
Lake Charles	6:30 a.m. to 6:30 p.m.	7 days/ week	I-10 - From La. 1256 to La. 397 I-210 - Entire Interstate Stretch
North Shore	6:30 a.m. to 6:30 p.m.	Weekdays	I-10 - From Michoud Blvd. to I-10/I-12/I-59 I-12 - From La. 1249 to I-10/I-12/I-59 I-55 - From Manchac (Exit 15) to La. 3234 Support provided on I-10 between I-10/I-12/I-59 and the Mississippi State Line as needed.
Alexandria	6:30 a.m. to 6:30 p.m.	Weekdays	I-49 - From U.S. 71 to U.S. 167 U.S. 71 - From U.S. 167 to I-49 U.S. 167 - From I-49 to U.S. 71
Lafayette	24 hours per day	7 days/ week	Project No. H.003003 I-10: E. Jct. I-49 to La. 328 Project No. H.003014 I-10: La. 347 to Atchafalaya Fldwy Br I-10 - From I-49 to La. 3177

Objectives. An objective of the Emergency Management and MAP program in Louisiana is to reduce the mean incident clearance time associated with each incident. This section evaluated the benefits achieved through the implementation of MAP on interstate highway segments in terms of reduced incident clearance time using roadway clearance time (RCT) as the performance measure.

Methodology. The RCT on highway segments with MAP was compared to the RCT on highway segments without MAP. This comparison hypothesized that the mean RCT on interstate highways with MAP would be lower than on highways without MAP, at a 5% significance level.

Site Selection – with and without MAP Patrol

The RCT on a length of interstate highway in metropolitan areas where MAP is deployed was selected and compared to the RCT on an equal length of the same interstate highway segment within the same metropolitan area but without MAP. The segments without MAP were selected on the same interstate highway and, at best, in the same direction of traffic flow to ensure that roadway configurations and exposures such as AADT would be similar to those on the highway segments with MAP. The selected interstate segments in Lafayette, Lake Charles, Baton Rouge, North Shore, New Orleans, Alexandra, and Shreveport are shown in Table 11.

Table 11. MAP patrol areas (highway segments selected for studies)

MAP Patrol Area	Description	Dist. (miles)	Start	End	Direction	Condition
Lafayette	I-10 - from I-49 to LA 3177	18.57	30.342994, -91.720491	30.259746, -92.015575	West	with
Lafayette	I-10 - from LA 182 to I-10 (Rayne)	18.57	30.251355, -92.036382	30.235704, -92.342880	West	without
Lake Charles	I-10 - from LA 1256 to LA 397	14.40	30.244646, -93.129230	30.216013, -93.358958	West	With
Lake Charles	I-10 - from Sulphur to LA/TX	14.40	30.202798, -93.478419	30.127500, -93.701436	West	without
Baton Rouge	I-10 from I-110 to Exit 159	3.70	30.435002, -91.177320	30.419304, -91.120760	East	with
Baton Rouge	I-10 from Pairville to Geismar	3.70	30.315885, -90.999840	30.264809, -90.983462	East	without
North Shore	I-12 from Madisonville to Exit 59	5.00	30.476772, -90.231538	30.450481, -90.153438	East	with
North Shore	I-12 from Livingston (Exit 22) to Holden	5.0	30.474785, -90.758106	30.474737, -90.673736	East	without
New Orleans	I-10 - from Dwyer Rd to I-10	2.5	30.020258, -90.014064	30.000836, -90.040496	West	with
New Orleans	I-10 - from Ascension to Gonzales	2.5	30.181329, -90.896730	30.181329, -90.896730	West	without
Alexandria	I-49 from US 71 to US 167	6.10	31.243158, -92.429832	31.324633, -92.462525	North	with
Alexandria	I-49 from US 71 to US 167	6.10	31.122555, -92.442227	31.205263, -92.472862	South	without
Shreveport	I-20 from Exit 14 to Queensborough	3.00	32.470703, -93.801969	32.495294, -93.762922	East	with
Shreveport	I-20 from Caddo to Exit 3	3.00	32.456040, -94.032855	32.447434, -93.983130	East	without

Crash Data

Crashes that occurred on the selected segments between 11:00 p.m. – 1:00 a.m., 8:00 a.m. – 10:00 a.m., 12:00 p.m. – 2:00 p.m., and 4:00 p.m. – 6:00 p.m., from January 2016 to December 2020, were considered for the study. Of the 6059 crashes recorded, only 3071 crashes had available crash reports and information adequate to establish the RCT of the crashes. These 3071 crashes were used in the study. Crashes that occurred on segments with MAP but outside the hours of operations of the MAP program on the segments were considered crashes that occurred on segments without-MAP incidents.

The roadway clearance time (RCT) is the time between the first recordable awareness of the incident by a responsible agency and the time at which all lanes are cleared and opened to traffic [28]. The definition of RCT is shown in Figure 11, with the timeline of elements of traffic incidents.

Discussion. With the unit of assessment defined as an incident on the Louisiana interstate highway system, sampled populations of all incidents on equal lengths of interstate highway segments with MAP and without MAP in the same metropolitan area were collected for analysis. The target population was all incidents on Louisiana's interstate highway system from 2016 to 2020. The response variable here was the RCT recorded for an incident on the interstate highway system, and the statistics were the sample population mean RCT for all incidents that occurred on the specified length of the interstate highway segments sampled. With the sampled population mean RCT specified as μ_{with} and $\mu_{without}$, respectively for highway segments "with" and "without" MAP, the assessment parameters were defined for the period studied. The parameter μ_{with} was defined as the mean RCT that would be observed if all crashes on interstate highways in the specified metropolitan area occurred on roadway segments with MAP. On the other hand, the parameter $\mu_{without}$ was defined as the mean RCT that would be observed if all crashes in the specified metropolitan areas occurred on roadway segments without MAP.

To assess the evidence that the RCTs on interstate highways in Louisiana with MAP coverage are lower than the RCTs on interstate highways without MAP, the null hypothesis, H_0, and the research hypothesis, H_1, were defined as follows, at a 5% level of significance:

- ○ Null hypothesis H_0: $\mu_{with} \geq \mu_{without}$
- ○ Research hypothesis H_1: $\mu_{with} < \mu_{without}$

The null hypothesis, H_0, is defined such that the mean RCT that would be observed if all incidents had occurred on an interstate highway with MAP would be equal to or greater than the mean RCT that would be observed if all incidents had occurred on interstate highway segments without MAP. The research hypothesis, H_1, is defined such that the mean RCT that would be observed if all the incidents occurred on an interstate highway with MAP would be less than the mean RCT that would be observed if all incidents occurred on an interstate highway without MAP.

The hypothesis was appropriate because it clearly stated the objective of the assessment in the alternative hypothesis, which it assumed false as opposed to the null hypothesis. There was strong evidence to reject the null hypothesis in favor of the research hypothesis. The findings from the assessment are discussed in the following sections.

Roadway Clearance Time (RCT)

The RCT distribution on the selected interstate highway segments “with” and “without” MAP in the seven metropolitan areas is shown in boxplots in Figure C18 in Appendix C. The corresponding quantiles of the distribution are shown in Table 12. Table 13 summarizes the RCT data analysis for interstate highways “with” and “without” MAP in the seven metropolitan areas.

The box plots in Figure C18 (Appendix C) indicate that the RCT distributions for all roadway segments selected in each metropolitan area are skewed negatively with variability outside the upper quartiles and outliers in both data distributions. The highest observed maximum RCT from the boxplots were in Lake Charles and New Orleans, with both greater than 700 minutes. The least observed maximum RCT was in Alexandria, with an RCT of less than 180 minutes.

The negative skewness and variability observed in the distribution of the RCT data from the boxplots are apparent from the quantile in Table 12. For instance, while 90% of the observed RCT on the roadway segment with MAP in Baton Rouge were not more than 62 minutes, 10% of the observed data ranged between 62 minutes to 305 minutes, which is more than thrice the range between the minimum observed RCT and the 90th percentile RCT, skewing the distribution negatively. The outliers were, however, not excluded from the analysis of the means.

From the quantiles shown in Table 12, the median RCT across the metropolitan areas for roadway segments with MAP ranged between 15.0 minutes in New Orleans and North Shore and 21.0 minutes in Lafayette. The median RCTs on the roadway segment without MAP across the metropolitan areas were rather higher and ranged between 23.5 minutes in Baton Rouge and 45.0 minutes in Shreveport. The minimum RCTs observed in all metropolitan areas were less than 5 minutes.

Table 12. Quantiles – RCT (minutes)

Area	Level	No. of Data	Min	10%	25%	Median	75%	90%	Max
Alexandria	With	54	4.0	6.0	8.0	19.5	40.0	51.0	118.0
	Without	46	2.0	4.4	8.5	27.5	51.2	95.9	178.0
Baton Rouge	With	864	1.0	5.0	9.0	18.0	40.0	62.0	305.0
	Without	226	1.0	6.0	10.0	23.5	43.3	74.8	241.0
Lafayette	With	254	1.0	5.0	10.0	21.0	51.3	95.0	363.0
	Without	192	1.0	5.0	13.5	37.0	62.0	94.7	326.0
Lake Charles	With	630	1.0	4.0	6.0	16.0	49.0	94.7	703.0
	Without	73	1.0	2.0	8.0	24.0	59.0	107.6	855.0
New Orleans	With	282	2.0	6.0	10.0	15.0	39.0	80.0	846.0
	Without	118	1.0	7.0	10.0	26.5	78.5	117.3	839.0
North Shore	With	28	1.0	1.0	6.0	15.0	42.3	88.5	300.0
	Without	93	3.0	5.0	12.0	24.0	54.0	104.4	269.0
Shreveport	With	150	2.0	5.0	9.8	20.5	55.3	87.8	182.0
	Without	61	1.0	8.2	15.5	45.0	86.0	116.0	262.0

The summary in Table 13 includes information on the mean of the distributions, standard deviations, and the 95 percent confidence intervals for the RCT observed on the segments in each metropolitan area. As observed from the table, the mean RCTs recorded on roadways with MAP across all metropolitan areas were lower than those recorded on corresponding roadway segments without MAP. Comparing the upper bound confidence intervals showed that, except in North Shore, roadways with MAP have lower upper bound RCTs than those without MAP at a 95 percent confidence. Again, besides North Shore, the confidence interval range (upper – minimum RCT) for the metropolitan areas showed that roadways with MAP have a narrow range of 95 percent confidence intervals than roadways without MAP. The narrow confidence intervals observed suggest less variability in the RCTs on roadways with MAP as opposed to those without a MAP. The observed variability is seen in the standard deviations, and the standard error of the mean recorded suggested the need to increase the sample sizes, especially on the roadways without MAP. The need to increase the data size was not satisfied due to data collection challenges discussed in previous sections.

Table 13. Summary of RCT (minutes)

Area	Level	No. of Data	Mean	Std Dev	StdErr Mean	95% CI			*p-value*
						Min	Max	Range	
Alexandria	With	54	26.7	23.7	3.2	20.2	33.2	13.0	0.0234
	Without	46	40.8	41.8	6.2	28.4	53.2	24.8	
Baton Rouge	With	864	27.4	26.7	0.9	25.6	29.2	3.6	0.0114
	Without	226	32.7	32.1	2.1	28.5	36.9	8.4	
Lafayette	With	254	39.3	47.5	3.0	33.5	45.2	11.7	0.1339
	Without	192	44.1	42.0	3.0	38.1	50.1	12.0	
Lake Charles	With	630	40.5	68.7	2.7	35.1	45.9	10.8	0.1505
	Without	73	55.8	123.0	14.4	27.1	84.5	57.4	
New Orleans	With	282	33.1	60.8	3.6	26.0	40.3	14.3	0.0049
	Without	118	58.5	97.7	9.0	40.7	76.3	35.6	
North Shore	With	28	34.1	58.4	11.0	11.4	56.7	45.3	0.2483
	Without	93	42.4	47.2	4.9	32.6	52.1	19.4	
Shreveport	With	150	36.5	37.1	3.0	30.5	42.4	12.0	0.0039
	Without	61	58.5	58.5	7.5	43.5	73.4	29.9	

Hypothesis Testing

The proportion greater than the observed population mean difference, $\delta = \mu_{without} - \mu_{with}$, which is the directional p-value for testing the null hypothesis at a 5% level of significance, is also shown in Table 13 for all the MAP deployed metropolitan areas. Since the p-value recorded for Alexandria, Baton Rouge, New Orleans, and Shreveport were very small compared to the 5% significance level, there was very strong evidence to reject the null hypothesis in favor of the research hypothesis at these locations. That is to say that the RCT that would be recorded if all incidents in these metropolitan areas occurred on interstate highways with MAP would be significantly lower than if all the incidents had occurred on interstate highways without MAP. Conversely, there was not enough evidence to support the research hypothesis in Lafayette, Lake Charles, and North Shore since the p-values for testing the null hypothesis in these areas were larger than the 5% level of significance. In other words, there would be no significant difference between the RCT recorded on interstate highways with and without MAP in these metropolitan areas.

Conclusions. Notwithstanding the need to increase the sample sizes, especially for the roadway without MAP, available MAP resources, and other factors that can influence RCT on roadways, the following findings and conclusions can be made from the evaluation:

- In Alexandria, Baton Rouge, New Orleans, and Shreveport, the RCT observed on roadways with MAP are lower than the RCT on roadways without MAP.
- Even though in Lafayette, Lake Charles, and North Shore, where the RCTs on roadways with MAP are not significantly lower than RCTs on roadways without MAP, road users still benefit in terms of lower mean RCTs and upper bound of the confidence interval of the RCT observed.

In general, it can be concluded that road users in Louisiana benefit from reduced RCT on roadways that have MAP.

Recommendation. It is recommended that a study is undertaken to identify or predict the factors that influence road clearance times on the Louisiana interstate highway system.

Commercial Vehicle Operations

Background

The freights moved by trucks in 2012 accounted for approximately 58 percent of the tonnage and value of freight moved in, out, and through Louisiana, excluding pipelines. These estimates corresponded to 569 million tons of goods worth about $531 billion. With an estimated annual freight shipment growth of 1.7 percent per year between 2012 and 2040 from or within Louisiana, truck-borne freight is projected to grow by 58 percent by 2040 [32]. Consequently, the large truck freight tonnage, commercial values, and truck flows make CVO and the performance of the highway system critically important to Louisiana's economic growth [33]. For the importance of CVO to Louisiana, the 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 [14, 32, 34].

In order to assess how Louisiana has met the CVO broad goals on freight significant highways, specific objectives and corresponding performance measures in Table 4 were developed. Additionally, in accordance with 23 CFR 490 - National Performance Management Measures, the Federal Highway Administration (FHWA) established the Truck Travel Time Reliability (TTTR) performance measure that states DOTs, including the DOTD, need to assess the performance of freight movement on the interstate highway system [35, 36].

Freight Significant Highways in Louisiana. Freight movement by truck in Louisiana relies heavily on the interstate highway system, with I-10, I-12, and I-20 providing much of the east-west movement for trucks, while I-49, I-55, and I-59 facilitate north-south truck freight movements. The mileages of interstate highways in Louisiana are shown in Table 14 [37]. The official truck-designated routes in Louisiana are shown in Figure D1 in Appendix D.

Table 14. 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 in Louisiana	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

Truck Bottlenecks in Louisiana. The locations of the greatest delay incurred by trucks collected in 2016 on the National Highway System in Louisiana are shown in Figure D2 in Appendix D. This shows roadways in Baton Rouge, New Orleans, and Lake Charles as being among the urban areas in Louisiana within the top first percentiles in terms of hours of truck delays [32].

The strategies to improve the freight delays on the interstate system include adding capacity in terms of new lanes, embarking on truck-related improvements, and operational improvements through ITS. The incorporation of ITS can provide low-cost, quick, but efficient alternatives [38].

Objectives

The study's objective in this section was to assess how Louisiana has met the broad goals of its CVO program area by estimating the following on freight significant highways in Louisiana:

1. Truck Travel Time Reliability (TTTR) Index
2. Commercial vehicles user delay costs
3. Commercial vehicle crash rate

Methodology

The freight movement performance measure of the third performance measure rule (PM3), defined by FHWA: TTTR Index [35, 36], and the commercial vehicle user delay costs were used in place of the three performance measures to evaluate the point-to-point travel times, hours of delay, and the average travel time index on freight-significant highways. Additionally, the commercial vehicle crash rates on the interstate highway system in Louisiana were evaluated. The selection of the interstate highway for the safety evaluation was notwithstanding that the highest number of crashes involving commercial vehicles in Louisiana occurred on rural state roadways [32].

Sourced Data. The TTTR Index data was sourced from the National Performance Management Research Data Set (NPMRDS) and calculated on the Regional Integrated Transportation Information

System (RITIS) platform for selected freight significant highways in Louisiana between 2016 and 2020. The user delay costs on the state highway system were also calculated with the user delay cost analysis widget and with data sourced from the NPMRDS analytics platform for the period between 2016 and 2021 [39].

Crash reports were retrieved from the Louisiana Crash Database for crashes that occurred on principal freight significant highways in Louisiana to assess the number of commercial vehicles involved in crashes during the study period between 2016 and 2020. This statewide repository of crash reports offered a comprehensive record of reported crashes in Louisiana, compiled typically by state law enforcement agencies [29].

Truck Travel Time Reliability (TTTR) Index. TTTR Index is the freight movement reliability performance measure on the interstate highway defined by the PM3 federal rule (23 CFR Part 490 Subpart F Measure) [35, 36]. The TTTR 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 segment and rounded to the nearest hundredth for each applicable period for the entire year.

$$TTTR_i = \frac{95th\ Percentile\ Travel\ Time_i}{50th\ Percentile\ Travel\ Time_i} \qquad (1)$$

Where *i* is the time-period:

Monday – Friday	AM Peak	6:00 a.m. – 10:00 a.m.
	Mid-Day	10:00 a.m. – 4:00 p.m.
	PM Peak	4:00 p.m. – 8:00 p.m.
Weekends		6:00 a.m. – 8:00 p.m.
Overnight (all days)		8:00 p.m. – 6:00 a.m.

The maximum TTTR of all five time periods for each segment to the nearest hundredth 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 segment, divided by the total interstate system miles as expressed in equation 2.

$$TTTR\ Index = \frac{\sum_{i=1}^{T}(SL_i \times maxTTTR_i)}{\sum_{i=1}^{T}(SL_i)} \qquad (2)$$

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

Segments with a TTTR of less than 1.50 are considered reliable; conversely, those with TTTR greater than 1.50 are considered unreliable.

The following interpretations are generally given to the TTTR:

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

In order to calculate TTTR Index for a state interstate highway, the state must be selected along with TTTR Index as the measure to be estimated in the MAP-21 portal on the NPMRDS analytics platform. The TTTR Index target for the state, the year for which the TTRI Index is required, and how the results must be presented (graph or map) must also be selected. The target for the TTTR Index on Louisiana highway systems is set at 1.50.

TTTR Index on Interstates in Louisiana. The AM peak, midday, PM peak, weekend, overnight, and maximum TTTR were calculated for each traffic message channel (TMC) segment that made Louisiana's entire (100%) interstate highway system. The output of the TTTR calculations provided information on the 95th and 50th percentile travel time for the five-time periods for each segment, along with other information that includes AADT, TMC codes, the direction of traffic, county, start and end geographic locations of TMC, and the mile-length of the segment. In all, the TMC segments that make up the entire interstate highway system added up to 1881.65 miles. The length (1881.65 miles) is synonymous with the total interstate mileage in this report. The TTTR Index was calculated and reported per year with monthly details for the entire state.

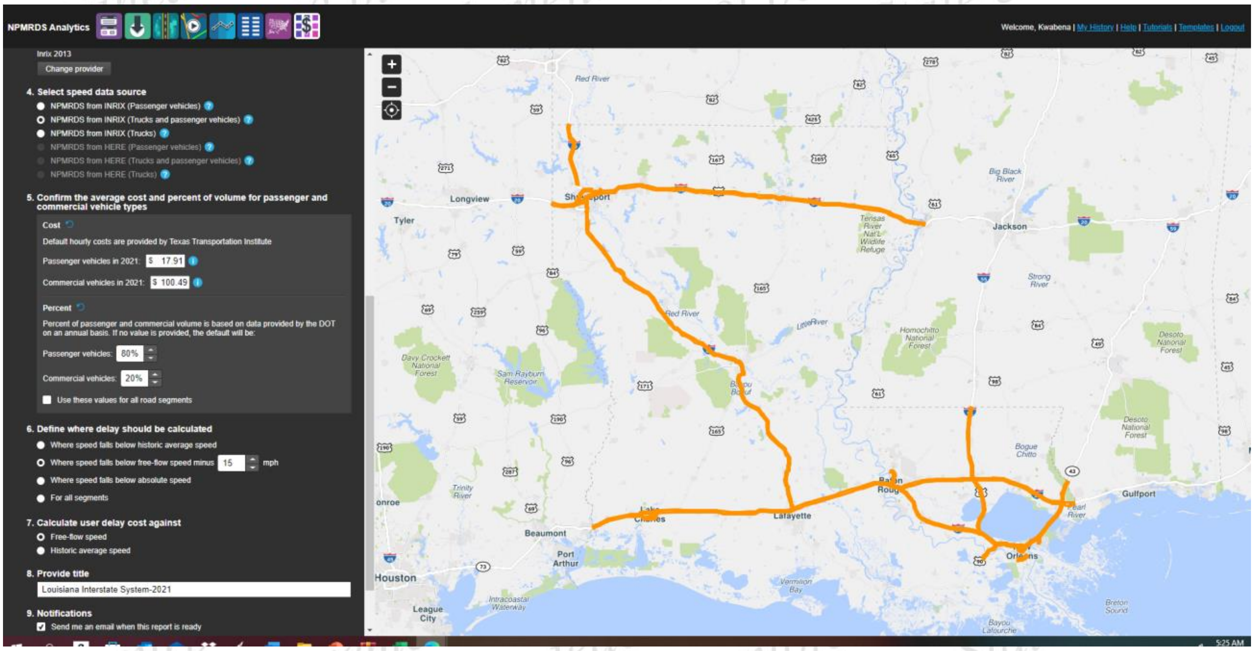
Commercial Vehicles User Delay Cost Analysis. The user delay cost analysis tool in the NPMRDS analytics was used to estimate the delay cost experienced by commercial vehicles on freight-significant highways in Louisiana from 2016 to 2021. To report the impact of the performance of a roadway on users, the road, the required analysis time frame, and the source of the vehicle volume data must be selected. Further, the speed data source, the average vehicle operation cost, proportions of commercial and passenger vehicles on the selected roadway, and delay must also be defined.

The user delay cost analysis tool allows users to generate user delay reports 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. The tool also generates other reports that include Person- and Vehicle-Hours of Delay, Vehicle-Mile-Traveled (VMT), and Delay-Minutes per VMT at different levels of detail [39]. A snippet of the user delay cost analysis portal is shown in Figure 13.

The Texas Transportation Institute 2017 estimates of vehicle operating costs of $100.49 per hour for commercial vehicles and $17.91 per hour for passenger vehicles were used for the cost analysis on Louisiana’s highways [39, 40]. A 20 percent commercial vehicle population estimate based on the 2010 distribution of annual vehicle distance traveled [41] and information provided in the study by DOTD [42] was used. Only single-unit and combination trucks were considered commercial vehicles for the volume mix estimated.

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 segment for all time periods, the delay was calculated for all segments whose raw speeds fell 15 mph or worse than the free-flow speed of a segment. This measure showed delay costs for any time the speeds were 15 mph worse than free-flow speeds on a TMC segment [39].

Figure 13. NPMRDS analytics for the user delay cost analysis



Inrix 2013

Change provider

4. Select speed data source

● 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 2021: $ 17.91

Commercial vehicles in 2021: $ 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 historic average speed
○ Where speed falls below free-flow speed minus 15 mph
● Where speed falls below absolute speed
● For all segments

7. Calculate user delay cost against

○ Free-flow speed
● Historic average speed

8. Provide title

Louisiana Interstate System-2021

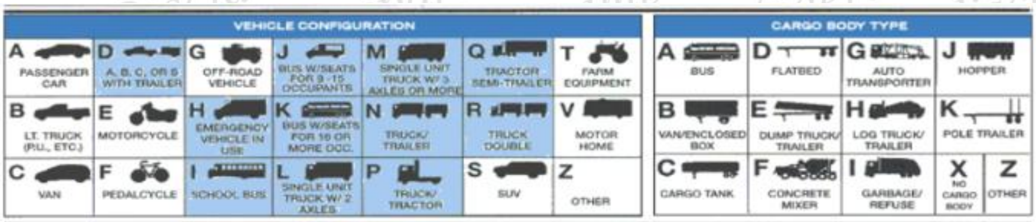
9. Notifications

☑ Send me an email when this report is ready

User Delay Cost Analysis on Louisiana's Interstate System. The user delay costs experienced by commercial vehicles and by all (commercial and passenger vehicles) were calculated for the entire (100%) interstate highway system, which consisted of 1504 TMC segments as of the 2020 evaluation. The TMC segments on the entire interstate highway system added up to 1881.65 miles, the same as in the estimation of the TTTR Index. A comparative analysis was also made between the user delay cost experienced on the entire interstate highway system and the user delay cost experienced on TMC segments that recorded a maximum TTTR greater than 1.50 between 2016 and 2020. Two urban locations with a high cluster of TMC segments that recorded maximum TTTR greater than 1.50 during the period were also selected, and user delay costs experienced were estimated for analysis.

Commercial Vehicle Crash Rate Calculation. The number of commercial vehicles involved in crashes on each interstate system was determined from the crash database and aggregated per year. Only crashes that involved 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 in Figure 14 were considered as commercial vehicles on the Louisiana Uniform Motor Vehicle Traffic Crash Report by this study. The object of this selection was to limit the scope of evaluation to goods-carrying vehicles, though both trucks and buses are considered commercial vehicles in Louisiana [32]. If more than one commercial vehicle was involved in a crash, each was counted towards the number of commercial vehicles involved in crashes.

Figure 14. Snippet of the Louisiana uniform motor vehicle traffic crash report



The number of commercial vehicle crash rates on each segment of the interstate highway system was calculated for every 100 million vehicle-mile of travel (100 MVMT) using the expression in equation 3 [43]:

$$R = \frac{100{,}000{,}000 * \ C}{365 * \ N * \ ADT * L} \tag{3}$$

Where,

R = Commercial vehicle crash rate for the road segment; expressed as crashes per 100 million vehicle-mile of travel (100 MVMT).
C = Total number of commercial vehicles involved in crashes in the study period.
N = Number of years of data.
ADT = Average Daily Traffic Volume (both directions).
L = Length of roadway segment in miles.

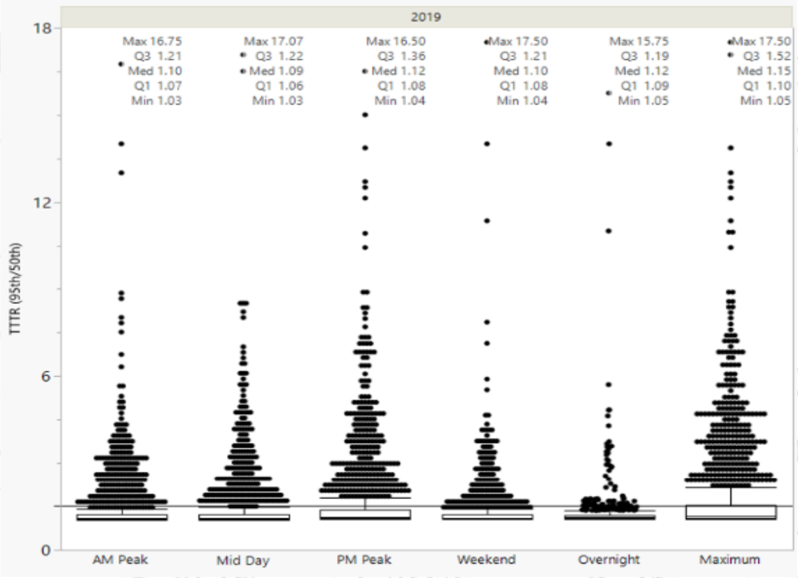
Since there were different ADT counts on different segments of a particular interstate highway system, the ADT reported with each crash on the interstate highway system was averaged for each year and used to estimate the commercial vehicle crash rate per year on the segment of interstate highways.

Discussion

Truck Travel Time Reliability. Overall, the TTTR values calculated on Louisiana interstate highway for all the five periods were skewed towards TTTR = 1.00, with the central tendencies across all the five periods below the 1.50 target, which are considered good. Also, besides 2019 where a maximum third quartile TTTR value of 1.52 was observed, three-quarters of the maximum TTTR values recorded across the years were all on or below the 1.50 target threshold, with outliers observed across the time periods. Further, the PM peak periods contributed to the maximum TTTR outlier across the years except during 2019, where the weekend contributed the maximum TTTR outlier of 17.50, possibly due to a non-recurrent incident. Generally, the weekends and overnight had a more reliable truck travel time. The box plot in Figure 15 shows the TTTR ($95^{th}/50^{th}$) values calculated for the five periods: AM peak, midday, PM peak, weekend, overnight, and maximum

TTTR observed across the five-time periods by all TMC segments in Louisiana for 2019. The boxplots for 2016 to 2018 and 2020 can be found in Figures D3, D4, D5, and D6 in Appendix D.

Figure 15. TTTR – Louisiana interstate highway system, 2019



Truck Travel Time Reliability Index. Though the five summary numbers from the distribution shown on the box plots in Figure 15 (and Appendix D) suggested that about 25% of the observed yearly maximum TTTR values were outliers, the interstate highway system in Louisiana had remained reliable over the study period with a monthly TTTR Index less than 1.50 across the years except for August 2016, where a TTTR Index greater than 1.50 was experienced.

For the TTTR Index, aggregated yearly between 2016 and 2020, the interstate system has remained reliable with the best performance experienced in 2020 with a TTTR Index of 1.26, and the worst performance of 1.35 experienced in 2018 and 2019; all of which are considered good performances for the interstate highway system for freight operations per the target set by Louisiana. The reduced TTTR Index recorded for 2020 from what was experienced in the preceding years, for instance, translates to commercial trucks having achieved more reliable routes of movement with respect to congestion during 2020, possibly due to the reduced passenger and truck VMT in response to COVID-19 regulations.

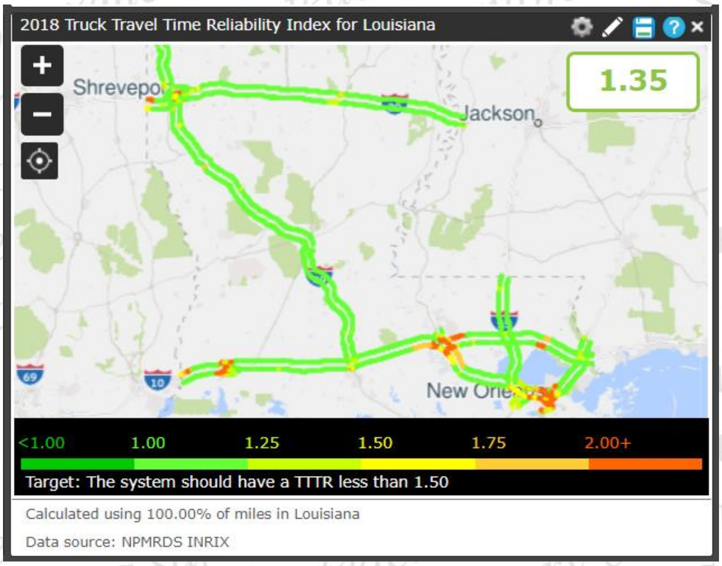
In terms of freight movement travel time from Louisiana’s yearly scores, an operator needed to estimate 15.60 minutes extra for a trip that would take 60 minutes in free-flow conditions to ensure a 95 percent reliability of on-time arrival in 2020 compared to 21 minutes in 2018 and 2019. The historical monthly and yearly TTTR Index in Louisiana for the study period is shown in Table 15.

Table 15. Truck Travel Time Index - interstate highway systems (2016-2020)

Monthly Truck Travel Time Reliability Index for Louisiana (TTTR (%))					
Month\Year	2016	2017	2018	2019	2020
January	1.31	1.31	1.34	1.42	1.31
February	1.37	1.38	1.35	1.41	1.36
March	1.45	1.36	1.42	1.47	1.27
April	1.38	1.35	1.42	1.37	1.11
May	1.37	1.41	1.38	1.4	1.14
June	1.36	1.38	1.42	1.4	1.23
July	1.42	1.34	1.37	1.42	1.22
August	1.53	1.36	1.37	1.4	1.26
September	1.39	1.39	1.42	1.33	1.4
October	1.38	1.34	1.42	1.39	1.4
November	1.44	1.4	1.42	1.4	1.33
December	1.36	1.33	1.38	1.39	1.3
Yearly Truck Travel Time Reliability Index for Louisiana					
Year	2016	2017	2018	2019	2020
TTTR Index	1.33	1.31	1.35	1.35	1.26

The maps shown in Figure 16 depict the reliable and unreliable TMC segments, defined by the 1.5 TTTR score threshold on the interstate highway system in Louisiana for 2018. As shown on the heatmap in the figure, some TMC segments on the interstate highway system experienced TTTR scores higher than the state threshold of 1.50 but were not enough to result in a bad TTTR Index score for Louisiana for that year.

Figure 16. 2018 Louisiana truck travel time index scorecard (map)



2018 Truck Travel Time Reliability Index for Louisiana

1.35

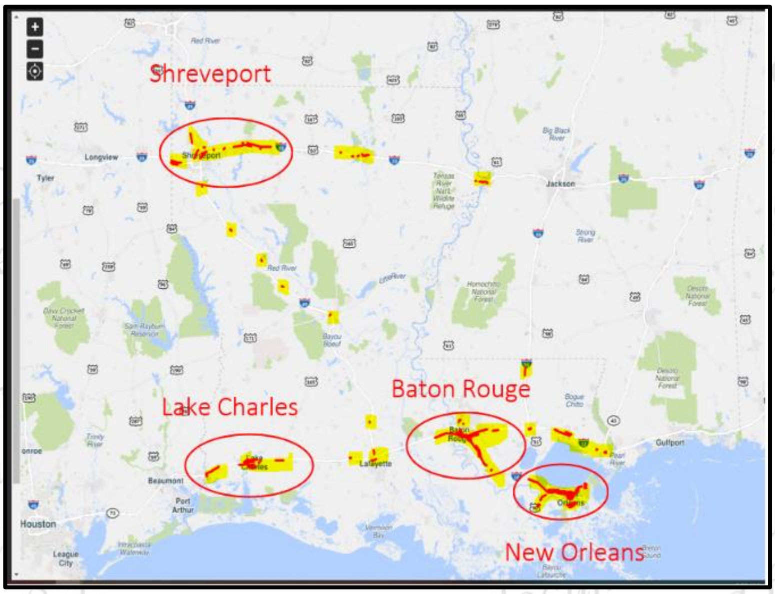
Target: The system should have a TTTR less than 1.50

Calculated using 100.00% of miles in Louisiana

Data source: NPMRDS INRIX

Bad Performing TMC Segments (TTTR>1.50) on Interstate Highway System. The TMC segments with maximum recorded TTTR scores greater than 1.50 were considered bad-performing TMC segments, which are shown in Figure 17 for all TMC segments that recorded a maximum TTTR score greater than 1.50 between 2016 and 2020 in Louisiana.

Figure 17. Bad performing TMC segments in Louisiana (TTTR>1.50) from 2016-2020



From this plot, locations with a high cluster of bad-performing TMC segments on the interstate highway system were mainly within New Orleans, Baton Rouge, Shreveport, and Lake Charles, with a few dotted along I-12, I-20, and I-49. In all, 412 TMC segments recorded a bad TTTR score during the study period out of the 1504 TMC segments that made up the entire (100%) interstate highway system in 2020.

These 412 TMC segments summed up to 291.04 miles (15.47%) of the total 1881.65 TMC mileage on Louisiana's interstate highway system. Further, of the 412 TMC segments, 92 were in and around Baton Rouge. These 92 TMC segments made up 53.03 miles (2.81%) of the total TMC mileage. Also, 146 of the 412 TMC segments were in and around New Orleans. These 146 TMC segments made up 73.39 miles (3.90%) of the total TMC mileage. The map of the bad-performing TMC segments in Baton Rouge and New Orleans is shown in Figures D7 and D8 in Appendix D.

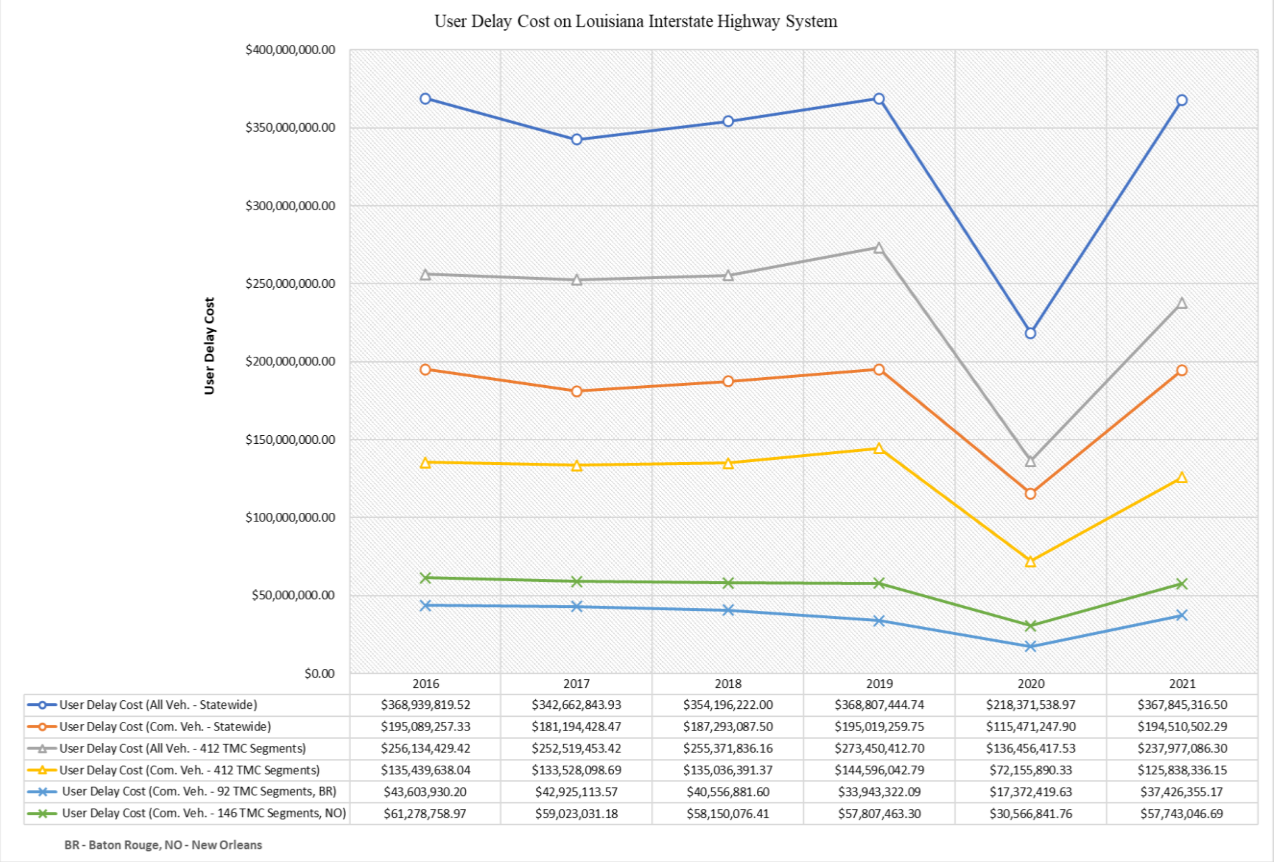
Together, the TMC segments with bad TTTR scores located in and around Baton Rouge and New Orleans made up 126.42 miles (6.72%) of the total TMC mileage on Louisiana's interstate highway system. With respect to the total mileage of the 412 TMC segments, the TMC segments in and around Baton Rouge and New Orleans with bad TTTR scores made up 18.22% and 25.22%, respectively, and together, 43.44% of the total mileage of the 412 TMC segments.

An analysis of the user delay costs experienced on Louisiana's interstate highway system between 2016 and 2021 is presented in subsequent sections. Specifically, the user delay costs experienced by all (passenger and commercial) vehicles and by only commercial vehicles across the entire interstate highway system and on the 412 TMC segments with bad TTTR scores across Louisiana are presented in addition to the user delay costs on the bad performing TMC segments in and around Baton Rouge and New Orleans.

Truck User Delay Cost. The trend and relationship between annual user delay costs on Louisiana's interstate highway system between 2016 and 2021 are presented in Figure 18. Specifically, the trends of the user delay costs experienced by commercial vehicles and by all vehicles on the entire (100%) interstate highway system and the 412 bad-performing TMC segments are shown, in addition to the user delay cost experienced by commercial vehicles (only) on the bad performing TMC segments in New Orleans and Baton Rouge. From observation, the annual user delay costs by commercial vehicles and the user delay cost by all vehicles remained relatively stable between 2016 and 2019 but dipped in 2020, possibly in response to COVID-19 guidelines that resulted in reduced VMT in 2020. However, the trend of the user delay cost bounced back in 2021. The observation was true for the user delay cost statewide and of the 412 bad-performing TMC segments and the bad-performing TMC segments in Baton Rouge and New Orleans. Compared with Baton Rouge, the annual commercial vehicle user delay costs experienced on the bad performing 146 TMC segments (73.39 miles) in New Orleans were higher than the annual commercial vehicle user delay costs experienced on the 92 bad-performing TMC segments (53.03 miles) in Baton Rouge.

Comparative ratios of the vehicle user delay costs in Figure 18 on Louisiana's interstate highway system between 2016 and 2021 are presented in Table 16.

Figure 18. User delay cost on Louisiana interstate highway system (2016-2021)



	2016	2017	2018	2019	2020	2021
User Delay Cost (All Veh. - Statewide)	$368,939,819.52	$342,662,843.93	$354,196,222.00	$368,807,444.74	$218,371,538.97	$367,845,316.50
User Delay Cost (Com. Veh. - Statewide)	$195,089,257.33	$181,194,428.47	$187,293,087.50	$195,019,259.75	$115,471,247.90	$194,510,502.29
User Delay Cost (All Veh. - 412 TMC Segments)	$256,134,429.42	$252,519,453.42	$255,371,836.16	$273,450,412.70	$136,456,417.53	$237,977,086.30
User Delay Cost (Com. Veh. - 412 TMC Segments)	$135,439,638.04	$133,528,098.69	$135,036,391.37	$144,596,042.79	$72,155,890.33	$125,838,336.15
User Delay Cost (Com. Veh. - 92 TMC Segments, BR)	$43,603,930.20	$42,925,113.57	$40,556,881.60	$33,943,322.09	$17,372,419.63	$37,426,355.17
User Delay Cost (Com. Veh. - 146 TMC Segments, NO)	$61,278,758.97	$59,023,031.18	$58,150,076.41	$57,807,463.30	$30,566,841.76	$57,743,046.69

BR - Baton Rouge, NO - New Orleans

The following can be deduced from the comparative ratios of the user delay costs:

- In general, the annual commercial vehicle user delay costs on the statewide interstate system were, on average, 52.88 percent of the user delay cost experienced by all vehicles statewide. The same estimates were observed between the annual commercial vehicle user delay costs and the user delay costs by all vehicles on the 412 TMC segments considered bad performers (15.47% of the total TMC mileage on Louisiana’s interstate highway system). These observations can be seen in Table 16 (A and B).

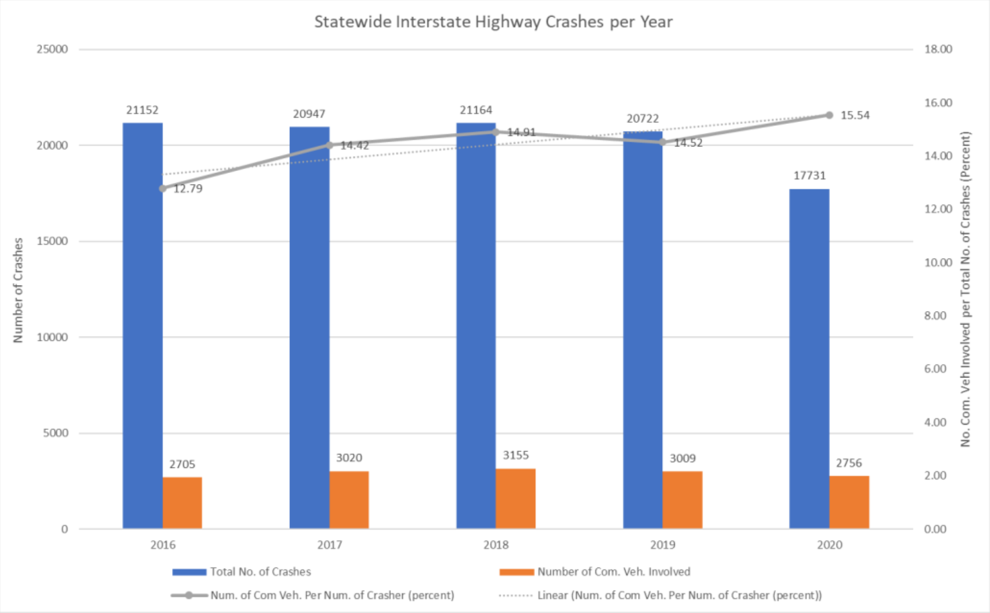
- The annual user delay costs between 2016 and 2019 experienced by all vehicles on the 412 TMC segments that were considered bad performers (15.47% of the total TMC mileage) were, on average, 72.34 percent of the user delay costs experienced by all vehicles on the statewide interstate system. The proportion dropped to 62.49 percent in 2020 and only increased to 64.69 percent in 2021, short of the pre-COVID-19 averages. The same observations were made between 2016 and 2021 for the cost ratios of the annual commercial vehicle user delay costs on the 412 TMC segments that were considered bad performers (15.47% of the total TMC mileage) to the annual commercial vehicle user delay costs on the statewide interstate highway system. These observations can be seen in Table 16 (C and D).
- The total annual commercial vehicle user delay costs between 2016 and 2021 on the TMC segments in Baton Rouge and New Orleans that were considered bad performers (126.42 of the total TMC mileage) were, on average, 38.11 percent of the corresponding annual user delay costs by all vehicles on the 412 TMC segments that were considered bad performers (291.04 of the total TMC mileage). This observation can be seen in Table 16 (E).
- The total annual commercial vehicle user delay costs between 2016 and 2021 on the TMC segments in Baton Rouge and New Orleans that were considered bad performers (126.42 of the total TMC mileage) were, on average, 72.07 percent of the corresponding annual commercial vehicle user delay cost on the 412 TMC segments that were considered bad performers (291.04 of the total TMC mileage). This observation can be seen in Table 16 (F).
- The total annual commercial vehicle user delay cost between 2016 and 2021 on the TMC segments in Baton Rouge and New Orleans that were considered bad performers (6.72% of the total TMC mileage) were, on average, 50.04 percent of the corresponding annual commercial vehicle user delay cost on the statewide interstate highway system. This observation can be seen in Table 16 (G).
- The total annual commercial vehicle user delay costs between 2016 and 2021 on the TMC segments in Baton Rouge and New Orleans that were considered bad performers (6.72% of the total TMC mileage) were, on average, 26.46 percent of the corresponding total annual user delay cost on the statewide interstate highway system. This observation can be seen in Table 16 (H).

Table 16. Comparative ratios of user delay costs (2016-2021)

				A			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (All Veh. - Statewide)	A	$368,939,819.52	$342,662,843.93	$354,196,222.00	$368,807,444.74	$218,371,538.97	$367,845,316.50
User Delay Cost (Com. Veh. - Statewide)	B	$195,089,257.33	$181,194,428.47	$187,293,087.50	$195,019,259.75	$115,471,247.90	$194,510,502.29
Ratio (%)	B:A	52.88	52.88	52.88	52.88	52.88	52.88
				B			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (All Veh. - 412 TMC Segments)	A	$256,134,429.42	$252,519,453.42	$255,371,836.16	$273,450,412.70	$136,456,417.53	$237,977,086.30
User Delay Cost (Com. Veh. - 412 TMC Segments)	B	$135,439,638.04	$133,528,098.69	$135,036,391.37	$144,596,042.79	$72,155,890.33	$125,838,336.15
Ratio (%)	B:A	52.88	52.88	52.88	52.88	52.88	52.88
				C			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (All Veh. - 412 TMC Segments)	A	$256,134,429.42	$252,519,453.42	$255,371,836.16	$273,450,412.70	$136,456,417.53	$237,977,086.30
User Delay Cost (All Veh. - Statewide)	B	$368,939,819.52	$342,662,843.93	$354,196,222.00	$368,807,444.74	$218,371,538.97	$367,845,316.50
Ratio (%)	A:B	69.42	73.69	72.10	74.14	62.49	64.69
				D			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (Com. Veh. - 412 TMC Segments)	A	$135,439,638.04	$133,528,098.69	$135,036,391.37	$144,596,042.79	$72,155,890.33	$125,838,336.15
User Delay Cost (Com. Veh. - Statewide)	B	$195,089,257.33	$181,194,428.47	$187,293,087.50	$195,019,259.75	$115,471,247.90	$194,510,502.29
Ratio (%)	A:B	69.42	73.69	72.10	74.14	62.49	64.69
				E			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (Com. Veh. - 92 TMC Segments, BR)	A	$43,603,930.20	$42,925,113.57	$40,556,881.60	$33,943,322.09	$17,372,419.63	$37,426,355.17
User Delay Cost (Com. Veh. - 146 TMC Segments, NO)	B	$61,278,758.97	$59,023,031.18	$58,150,076.41	$57,807,463.30	$30,566,841.76	$57,743,046.69
User Delay Cost (All Veh. - 412 TMC Segments)	C	$256,134,429.42	$252,519,453.42	$255,371,836.16	$273,450,412.70	$136,456,417.53	$237,977,086.30
Ratio (%)	(A+B):C	40.95	40.37	38.65	33.55	35.13	39.99
				F			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (Com. Veh. - 92 TMC Segments, BR)	A	$43,603,930.20	$42,925,113.57	$40,556,881.60	$33,943,322.09	$17,372,419.63	$37,426,355.17
User Delay Cost (Com. Veh. - 146 TMC Segments, NO)	B	$61,278,758.97	$59,023,031.18	$58,150,076.41	$57,807,463.30	$30,566,841.76	$57,743,046.69
User Delay Cost (Com. Veh. - 412 TMC Segments)	C	$135,439,638.04	$133,528,098.69	$135,036,391.37	$144,596,042.79	$72,155,890.33	$125,838,336.15
Ratio (%)	(A+B):C	77.44	76.35	73.10	63.45	66.44	75.63
				G			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (Com. Veh. - 92 TMC Segments, BR)	A	$43,603,930.20	$42,925,113.57	$40,556,881.60	$33,943,322.09	$17,372,419.63	$37,426,355.17
User Delay Cost (Com. Veh. - 146 TMC Segments, NO)	B	$61,278,758.97	$59,023,031.18	$58,150,076.41	$57,807,463.30	$30,566,841.76	$57,743,046.69
User Delay Cost (Com. Veh. - Statewide)	C	$195,089,257.33	$181,194,428.47	$187,293,087.50	$195,019,259.75	$115,471,247.90	$194,510,502.29
Ratio (%)	(A+B):C	53.76	56.26	52.70	47.05	41.52	48.93
				H			
User Delay Cost	**Ratio**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
User Delay Cost (Com. Veh. - 92 TMC Segments, BR)	A	$43,603,930.20	$42,925,113.57	$40,556,881.60	$33,943,322.09	$17,372,419.63	$37,426,355.17
User Delay Cost (Com. Veh. - 146 TMC Segments, NO)	B	$61,278,758.97	$59,023,031.18	$58,150,076.41	$57,807,463.30	$30,566,841.76	$57,743,046.69
User Delay Cost (All Veh. - Statewide)	C	$368,939,819.52	$342,662,843.93	$354,196,222.00	$368,807,444.74	$218,371,538.97	$367,845,316.50
Ratio (%)	(A+B):C	28.43	29.75	27.87	24.88	21.95	25.87

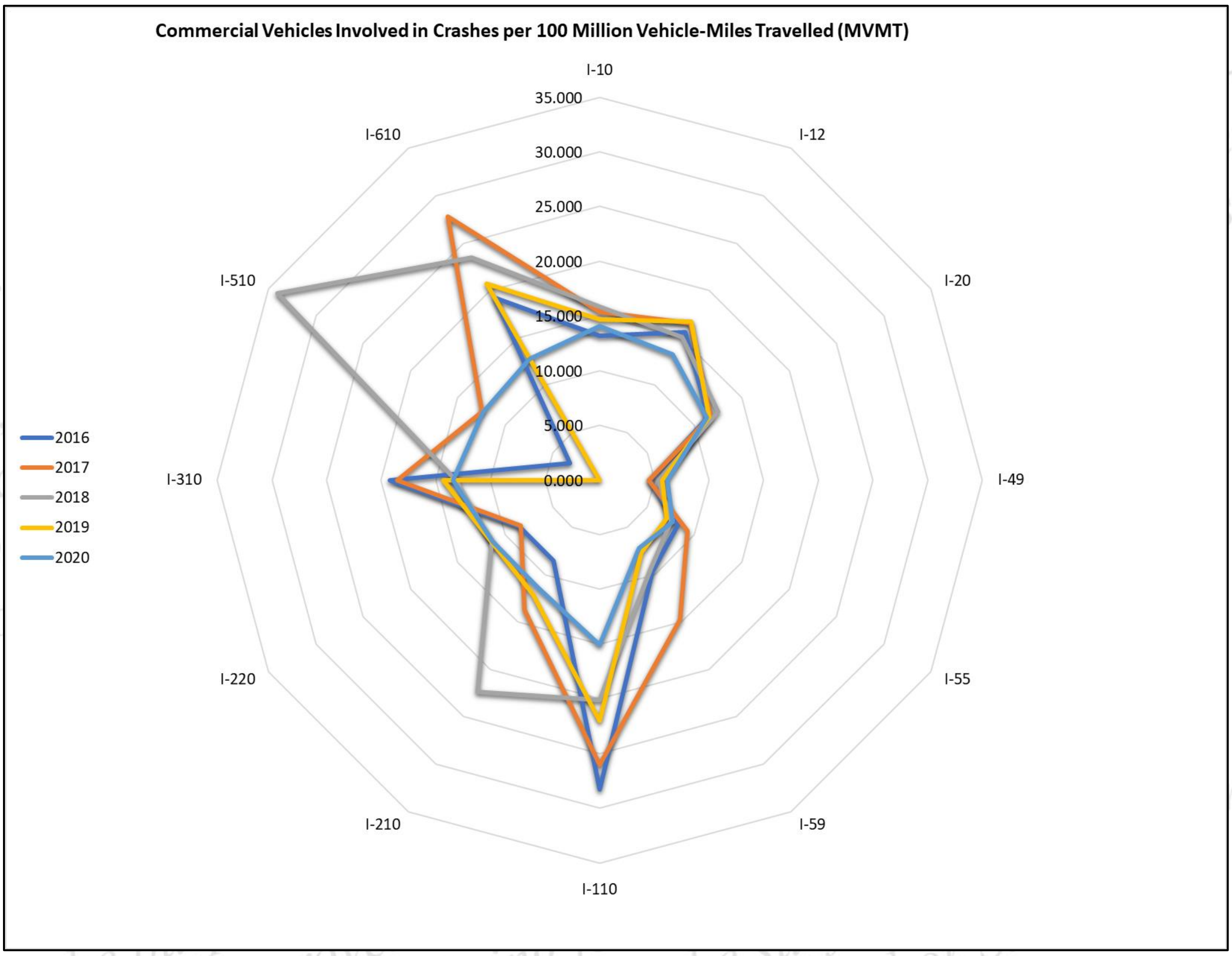
Commercial Vehicle Crashes in Louisiana (2016–2020). The annual total crash frequencies on Louisiana's interstate highway system remained relatively constant between 2016 and 2019 but declined in 2020, possibly in response to COVID-19. Even though the annual total number of commercial vehicles involved in crashes remained relatively constant, the ratio of the annual number of commercial vehicles involved in the crashes saw an increasing trend between 2016 and 2020. Again, despite the declined total number of crashes in 2020, the proportion of commercial vehicles involved in the crashes for that year was highest at 15.54%. The crash frequencies, the annual number of commercial vehicles involved, and the ratio of the number of commercial vehicles involved to the annual crash frequencies on the interstate highway system between 2016 and 2020 are shown in Figure 19.

Figure 19. Annual crashes on Louisiana's interstate highway system (2016-2020)



In terms of commercial vehicle crash rate, expressed in 100 million vehicle miles traveled (100 MVMT), interstate I-110 had the worst performance in three of the five years studied. Other worst performers were interstate I-610, which had two out of five worst crash rates of the five years studied, and interstate I-310, with moderately high commercial vehicle crash rates. It is worth noting that interstate highways I-110, I-610, and I-310 all have mileages of less than 12 miles. Other interstate highways with moderate- to moderately-high crash rates over the study period were I-220, I-210, I-10, and I-12, with 18.0, 12.5, 274.0, and 85.0 total miles in the east- and west-bound directions, as shown in Figure 20.

Figure 20. Commercial vehicle crash rates in 100 MVMT (2016-2020)



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
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

Interstate 49 was relatively safer, with the lowest crash rates in three out of the five years studied. Besides, I-55 and I-59, with 66.0 and 11.0 miles respectively, had moderately lower crash rates over the studied period. Interstate 49, I-55, and I-59 are in north- and south-bound directions. Interstate 510 had spiky commercial vehicle crash rates over the period, as shown in Figure 20.

Details of the trend of the annual crash frequencies and the proportion of commercial vehicles involved in crashes annually on each interstate highway in Louisiana between 2016 and 2020 are briefly presented in Appendix E.

Conclusions

The DOTD established specific objectives and performance measures to assess the state's goals to increase freight mobility, facilitate freight and economic growth, and reduce commercial vehicle crash rates. The project aimed to assess how Louisiana has achieved the state's commercial vehicle operations goals on significant freight highways in Louisiana using the following performance measures: Truck Travel Time Reliability (TTTR) Index, commercial vehicles user delay cost, and commercial vehicle crash rate.

Overall, Louisiana's interstate highway remained reliable over the study period from 2016 to 2020, with TTTR Index scores of less than the 1.50 threshold set by Louisiana to measure reliability. There exist, however, TMC segments in Louisiana that experienced maximum TTTR scores of greater than 1.50 on the interstate highway system. These TMC segments, which contribute to unreliable truck travel times, were altogether 15.47% of the total TMC mileage of the statewide interstate system and were mainly clustered in New Orleans, Baton Rouge, Shreveport, and Lake Charles. The TMC segments in New Orleans and Baton Rouge represented 6.72% of the total TMC mileage of the statewide interstate system.

In general, the annual user delay costs by commercial vehicles and the user delay cost by all vehicles remained relatively stable between 2016 and 2019 but dipped in 2020, possibly in response to COVID-19 guidelines that resulted in reduced VMT in 2020. The trend of the user delay cost bounced back in 2021. The following were deduced from the comparative ratios of the user delays between 2016 and 2021:

- Commercial vehicle user delay costs are, on average, 52.88 percent of the user delay cost experienced by all vehicles on the same interstate highway system, ceteris paribus.
- The 15.47% of the total TMC mileage of the interstate highway (with a maximum TTTR>1.50) contributed, on average, 72.34 % of the annual user delay cost between 2016 and 2019. The proportion dropped to 62.49 percent in 2020 and only increased to 64.69 percent in 2021, short of the pre-COVID-19 averages. These proportions are extremely high, considering the full length of the interstate highway.
- Commercial vehicle user delays on 6.72% of the total TMC mileage of the interstate highway (in New Orleans and Baton Rouge with a maximum TTTR > 1.50) annually contributed to, on average:
    - 38.11% of the user delay costs on the 412 TMC segments (with a maximum TTTR > 1.50).
    - 72.07% of the annual commercial vehicle user delay cost on the 412 TMC segments (with a maximum TTTR > 1.50).
    - 50.04% of the corresponding annual commercial vehicle user delay cost on the statewide interstate highway system.
    - 26.46% of the total annual user delay cost on the statewide interstate highway system.

Further, the annual total crash frequencies on the interstate highway system remained relatively constant between 2016 and 2019 but declined in 2020, possibly in response to COVID-19. Even though the annual frequency of crashes remained relatively constant, the ratio of the commercial vehicle saw an increasing trend between 2016 and 2020, with the highest proportion of commercial vehicles involved in crashes in 2020 at 15.54%. The proportions of annual commercial vehicles involved were, however, higher than the state annual averages on I-110, I-610, and I-12, though some of these interstates were seeing decreasing trends

In terms of commercial vehicle crash rate, expressed in 100 million vehicle miles traveled, I-110 had the worst performance in three of the five years studied. Other worst performers were I-610 and I-310, with moderately high commercial vehicle crash rates. Other interstate highways with moderate-to moderately high crash rates over the study period were I-220, I-210, I-10, and I-12.

Interstate 49 was relatively safer, with the lowest crash rates in three out of the five years studied. Besides, I-55 and I-59 had moderately lower crash rates over the studied period. Interstate 510 on the other hand, had spiky commercial vehicle crash rates over the period.

The study was meant to help identify freight-related transportation improvement needs, monitor the effectiveness of improvement projects, and serve as indicators of Louisiana's freight operations.

Freeway Management

This section evaluated the performance of Louisiana’s freeway management and traffic management center programs by estimating the inventory of the statewide ITS resources and assessing the safety performance of installed ramp meters in Louisiana.

Inventory of ITS Equipment

Introduction. The objectives of the DOTD for freeway management and TMCs are to increase the level of TMC field hardware, increase the hours of TMC operation and level of staffing, and increase the percentage of regional transportation systems monitored by the TMC for real-time performance.

Objectives. This section of the research provided an inventory of regional ITS devices deployed across Louisiana, which are shown in Table 17. These inventories last updated in 2021 were gathered from DOTD-issued documents [1] and were updated by responsible DOTD key resources for this report.

Table 17. Regional ITS devices deployed [22]

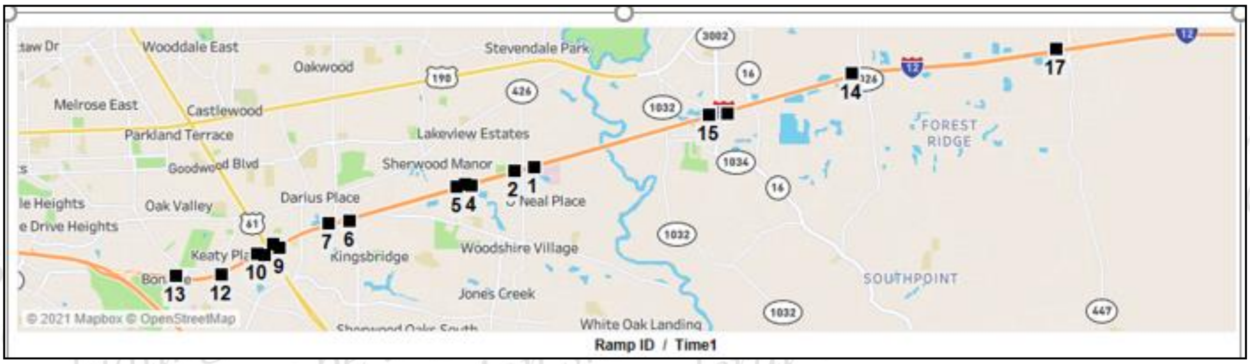
Region	CCTV	DMS	VD	Ramp Meters
Baton Rouge	165	25	115	I-12
Alexandria	20	4	0	0
Shreveport	31	18	74	0
Lake Charles	35	7	0	0
Lafayette	31	7	18	0
Houma	13	1	0	0
New Orleans/Hammond/North Shore	141	40	12	I-10
Monroe	24	4	0	0
Total	460	106	219	-

Conclusion. The inventory of installed equipment needs to be periodic and updated in required documents for easy reference. Additionally, a comprehensive study to assess the coverage of the devices needs to be carried out in a separate study.

Assessment of the Safety Performance of Active Ramp Meters in Louisiana

Introduction. Louisiana has 22 non-restrictive ramp meters installed in Baton Rouge and New Orleans to manage the traffic merging onto the interstate highways. Of these, 17 are installed on I-12 in Baton Rouge, with the location of installation shown in Figure 21. The hours of operation are 6:00 a.m. to 10:00 a.m. and 2:00 p.m. to 7:00 p.m. Some documented benefits of implemented ramp meters include reduced crashes by 26 – 50%, reduced total system travel time by 6 – 16%, increased average mainline speeds by 13 – 26%, and increased fuel savings by 2– 55% [1, 44].

Figure 21. Installed ramp meters on I-12 in Baton Rouge



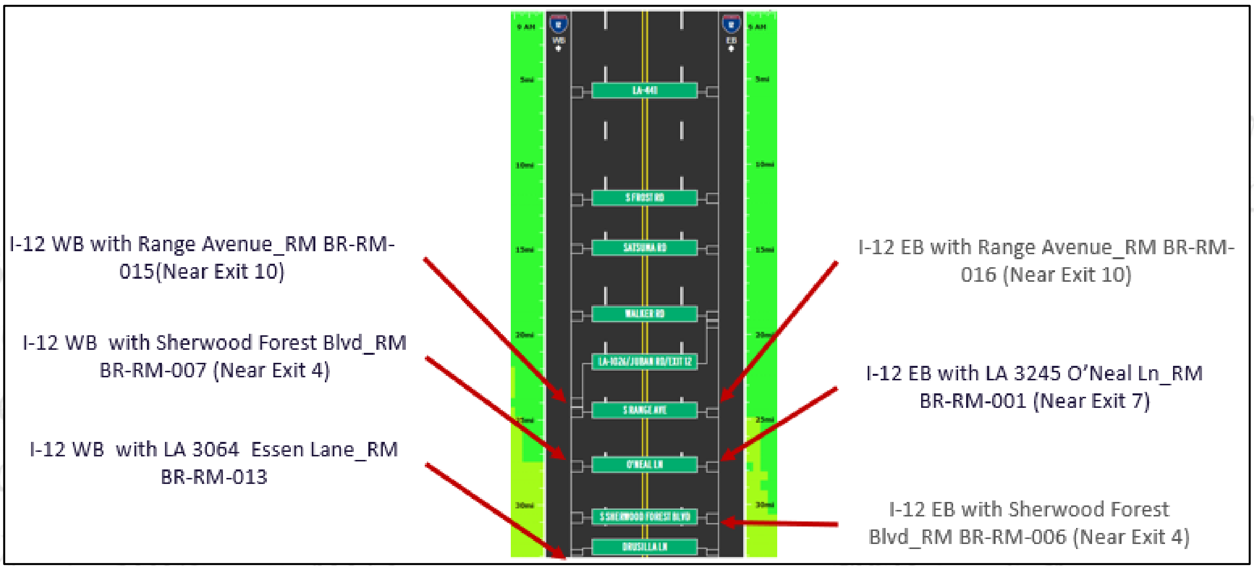
name	description	latitude	longitude	mile_marker	cross_road	direction	district
BR-RM-001	I-12 EB @ LA 3245 ONEAL LANE RM	30.44273377	-91.00482941	7.32	O'Neal Lane	E	61 - Baton Rouge
BR-RM-002	I-12 WB @ LA 3245 ONEAL LANE RM	30.44208527	-91.01009369	7.01	O'Neal Lane	W	61 - Baton Rouge
BR-RM-003	I-12 WB @ MILLERVILLE ROAD NB RM	30.43886757	-91.02296448	6.21	Millerville Rd	W	61 - Baton Rouge
BR-RM-004	I-12 EB @ MILLERVILLE ROAD RM	30.43862343	-91.02131653	6.3	Millerville Rd	E	61 - Baton Rouge
BR-RM-005	I-12 WB @ MILLERVILLE ROAD SB RM	30.4383049	-91.02523041	6.07	Millerville Rd	W	61 - Baton Rouge
BR-RM-006	I-12 EB @ SHERWOOD FOREST BLVD RM	30.4305954	-91.05358887	4.29	Sherwood Forest	E	61 - Baton Rouge
BR-RM-007	I-12 WB @ SHERWOOD FOREST BLVD RM	30.42994881	-91.05929565	3.99	Sherwood Forest	W	61 - Baton Rouge
BR-RM-008	I-12 WB @ U.S. 61 NB RM	30.42506981	-91.07402039	3.02	US 61 NB	W	61 - Baton Rouge
BR-RM-009	I-12 EB @ U.S. 61 NB RM	30.42436028	-91.07219696	3.09	US 61 NB	E	61 - Baton Rouge
BR-RM-010	I-12 WB @ U.S. 61 SB RM	30.42285347	-91.07817078	2.73	US 61 SB	W	61 - Baton Rouge
BR-RM-011	I-12 EB @ U.S. 61 SB RM	30.42265701	-91.07615662	2.83	US 61 SB	E	61 - Baton Rouge
BR-RM-012	I-12 EB @ LA 73 JEFFERSON HWY RM	30.41803551	-91.08777618	2.07	LA 73 Jefferson Hwy	E	61 - Baton Rouge
BR-RM-013	I-12 WB @ LA 3064 ESSEN LANE RM	30.41770363	-91.09983826	1.33	LA 3064 Essen Lane	W	61 - Baton Rouge
BR-RM-014	I-12 WB @ JUBAN RD RM	30.46447372	-90.92054749	12.57	Juban Rd	W	62 - Hammond
BR-RM-015	I-12 WB @ RANGE AVE RM	30.4548645	-90.95832062	10.22	Range Rd	W	62 - Hammond
BR-RM-016	I-12 EB @ RANGE AVE RM	30.45530891	-90.95366669	10.49	Range Ave	E	62 - Hammond
BR-RM-017	I-12 WB @ WALKER S RD RM	30.47019577	-90.86637116	15.83	Walker S Rd	W	62 - Hammond

The exact activation dates of the ramp meters in Louisiana were unavailable for this evaluation. However, information indicates that the activation of the first ramp meter in Baton Rouge was on June 8, 2010, with 13 others in Baton Rouge activated subsequently, with their installations noted to have occurred between 2008 and 2010 [44].

Objectives. A recommendation by the 2018 ITS Business Plan [1] was to obtain historical data for analysis to determine the effectiveness of installed ramp meters. Consequently, the objective of this study was to determine the effectiveness as required by the business plan by assessing the safety benefits of installed ramp meters in Louisiana.

Methodology. Six ramp meters in Baton Rouge were selected to assess the benefits with respect to safety improvements in a before-after study. Three were located eastbound, and the other three were in the westbound direction. The selected ramp meters used in the evaluation are shown in Figure 22.

Figure 22. Selected active ramp meters along I-12



name	description	latitude	longitude	mile_marker	cross_road	direction	district
BR-RM-001	I-12 EB @ LA 3245 ONEAL LANE RM	30.44273377	-91.00482941	7.32	O'Neal Lane	E	61 - Baton Rouge
BR-RM-006	I-12 EB @ SHERWOOD FOREST BLVD RM	30.4305954	-91.05358887	4.29	Sherwood Forest	E	61 - Baton Rouge
BR-RM-007	I-12 WB @ SHERWOOD FOREST BLVD RM	30.42994881	-91.05929565	3.99	Sherwood Forest	W	61 - Baton Rouge
BR-RM-013	I-12 WB @ LA 3064 ESSEN LANE RM	30.41770363	-91.09983826	1.33	LA 3064 Essen Lane	W	61 - Baton Rouge
BR-RM-015	I-12 WB @ RANGE AVE RM	30.4548645	-90.95832062	10.22	Range Rd	W	62 - Hammond
BR-RM-016	I-12 EB @ RANGE AVE RM	30.45530891	-90.95366669	10.49	Range Ave	E	62 - Hammond

Data Collection

In order to achieve the objective of the study, crash data from the DOTD crash database were retrieved and analyzed to observe changes caused by implemented ramp meters in a before-after study. Reports of crashes that occurred between 2001 and 2020 on the mainline of the interstate highway, within 500 ft. before the entrance of a ramp meter and 1500 ft. after the entrance, were collected for evaluation along with the records of all the crashes that occurred on-ramps, as shown in Figure 23.

Figure 23. Data collection zones on a ramp meter

Ramp Meter	Approx. Length of Ramp (ft.)
BR-RM-001	1322
BR-RM-006	1368
BR-RM-016	1270
BR-RM-015	1410
BR-RM-013	1175
BR-RM-007	1230

Of the 5652 crashes available to this study between 2001 and 2020 within the zones of the ramp meters along I-12 in Baton Rouge, only the records of crashes that occurred within the operational hours of the ramps (06:00 a.m. – 10:00 a.m. and 2:00 p.m. – 7:00 p.m.) of the selected ramp meters were considered in the before-after analysis.

Since the activation dates of the ramp meters were not readily available, the crash rates per year were graphed, and the trends were observed to determine the possible years of installation, activation, and testing. The installation and activation years were taken when the crash rate trend showed a sudden decline. The period before the sudden decline in the crash rate trend was selected as "before" and the period after the decline as "after." A margin of a few years was used for the installation, activation, and testing to account for possible “regressions to the means” due to the ramp meter installations. A student's t-test was used to determine if there were any significant impact on crash rates after a ramp meter was installed. Where it was not possible to determine the installation and activation period, inferences were made from the graphs.

The mainline and on-ramp crashes per 100 million VMT were computed separately using the expression in equation 4.

$$R = \frac{100{,}000{,}000 * C}{365 * N * ADT * L} \qquad \ldots (4)$$

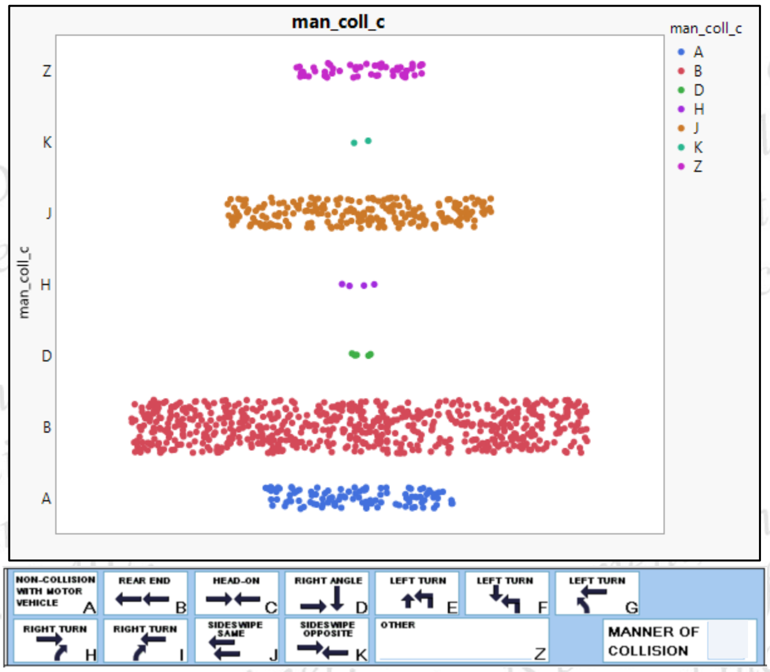
Where,

R = Crashes within zone per 100 million vehicle miles traveled
C = Total number of crashes within a zone
N = Number of years of data
ADT = Average Daily Traffic Volume
L = Segment length in miles.

Since the ADT on-ramps were unavailable, the on-ramp crash rates were evaluated using the ADTs of the mainline, which were from the crash reports. It is possible that using the mainline ADT under- or over-estimated the safety of on-ramps, but since the safety on-ramps were not compared to each other, the evaluation sufficed for this study.

Discussions. As expected of crashes that occur on-ramp meter, the predominant manner of collision of the 5652 crashes within ramp meter zones on I-12, between 2001 and 2020, were rear-end followed by sideswipes, as shown in Figure 24. In many cases, ramp meters can decrease rear-end and sideswipe crashes at the entrance ramps, freeway merge areas, and at the back of mainline queues [45].

Figure 24. Manner of collision – ramp meter zones on I-12 (2001-2020)



Using a student's t-test to test the hypothesis, a before-and-after comparison of the crash records of sampled ramp meters was conducted to determine any significant reductions in the crash rates in the mainline after the ramp meters had been installed. Plots of frequencies in the manner of collisions per year were observed for identifiable reductions in the number of the rear-end and sideswipe crashes.

The before-and-after crash rate evaluations were not conducted for the on-ramp crashes because the crash data available for the evaluation did not have on-ramp crashes prior to 2008. Additionally, records of the mainline crashes between 2001 and 2007 were unavailable for the westbound ramp meters sampled. Discussions from the before-and-after analysis are presented in the following section.

Before-and-After Evaluations

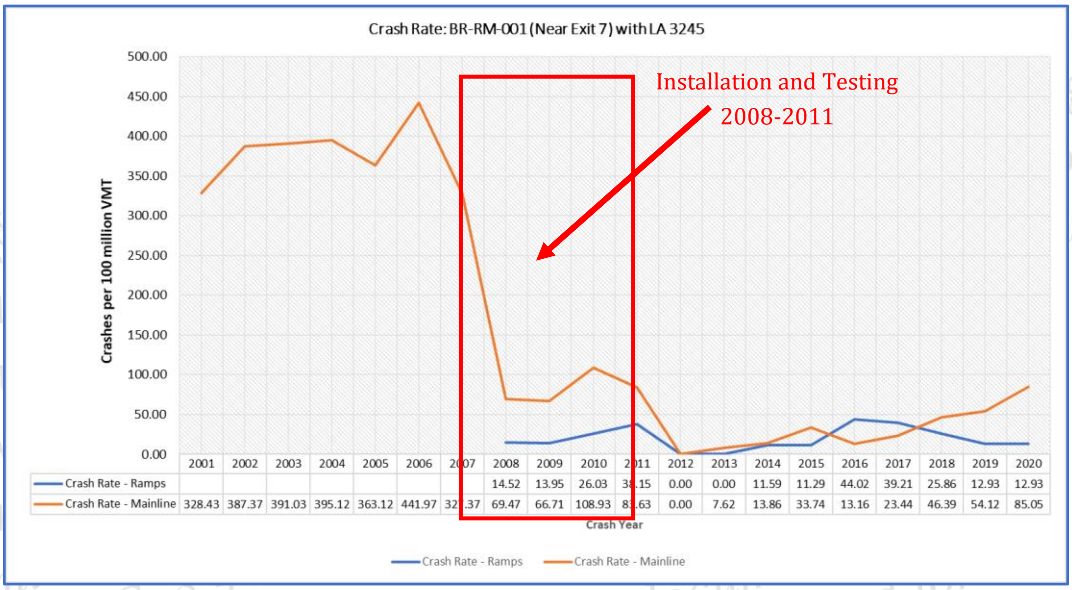
The trends in crash rates per year and manner of the collision on the selected ramp meters in the eastbound direction are shown in Figure 25 through Figure 30. The trends of the crash rate and the manner of the collision in the westbound direction are shown in Figure 31 through Figure 36.

Ramp Meters in the Eastbound Direction

BR-RM-001. The observed trends in the crash rates indicated a reduction in crashes in the mainline after the ramp meter had been deployed, as shown in Figure 25. An observation of the manner of collisions per year, shown in Figure 26, also indicates recognizable reductions in the rear-end and sideswipe crashes after the deployment of the ramp meter.

The mainline saw a reduction in crashes from a mean crash rate of 376 per MVMT to 31 crashes per MVMT after deployment, which is considered very significant with a p-value of less than 0.0001, as shown in Table 18.

Figure 25. Crashes per MVMT at BR-RM-001



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crash Rate - Ramps								14.52	13.95	26.03	38.15	0.00	0.00	11.59	11.29	44.02	39.21	25.86	12.93	12.93
Crash Rate - Mainline	328.43	387.37	391.03	395.12	363.12	441.97	327.37	69.47	66.71	108.93	83.63	0.00	7.62	13.86	33.74	13.16	23.44	46.39	54.12	85.05

Figure 26. Manner of collision at BR-RM-001

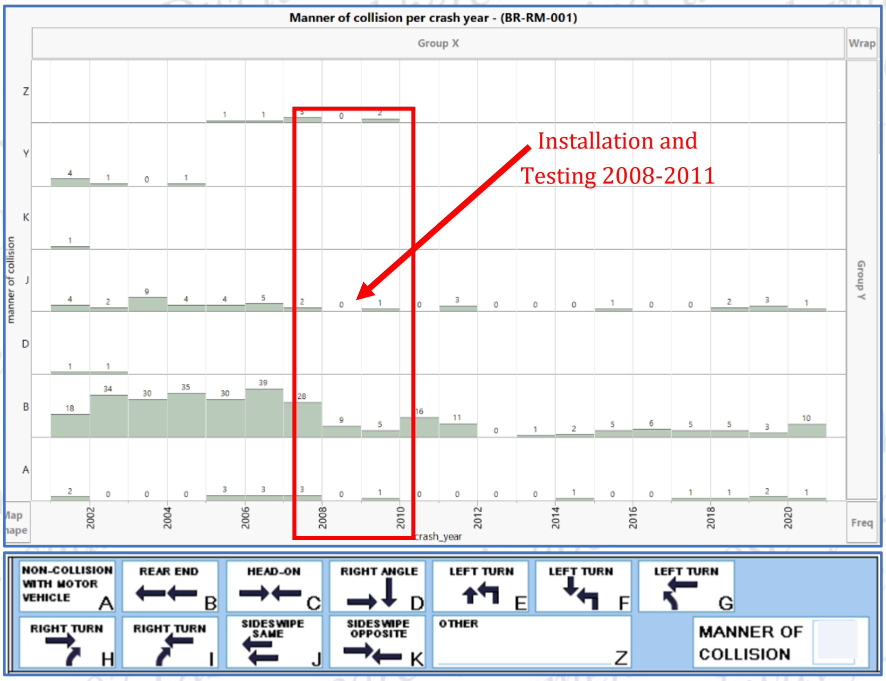


Table 18. t-test at BR-RM-001

	Before	*After*
Mean	376.3441496	30.81926607
Variance	1644.400993	734.5722022
Observations	7	9
Hypothesized Mean Difference	0	
df	10	
P(T<=t) one-tail	1.42982E-09	
P(T<=t) two-tail	2.85964E-09	
t-Test: Two-Sample Assuming Unequal Variances		

BR-RM-006. The observed trends in the crash rates here also indicated a reduction in crashes in the mainline after the ramp meter had been deployed, as shown in Figure 27. An observation of the manner of collisions per year also indicates recognizable reductions in the rear-end crashes after the deployment, as shown in Figure 28.

The mainline saw a reduction in crashes from a mean of 179 crashes per MVMT to 30 crashes per MVMT after deployment, as shown in Table 19. This reduction is considered very significant, with a p-value of less than 0.002.

Figure 27. Mainline crashes per MVMT at BR-RM-006

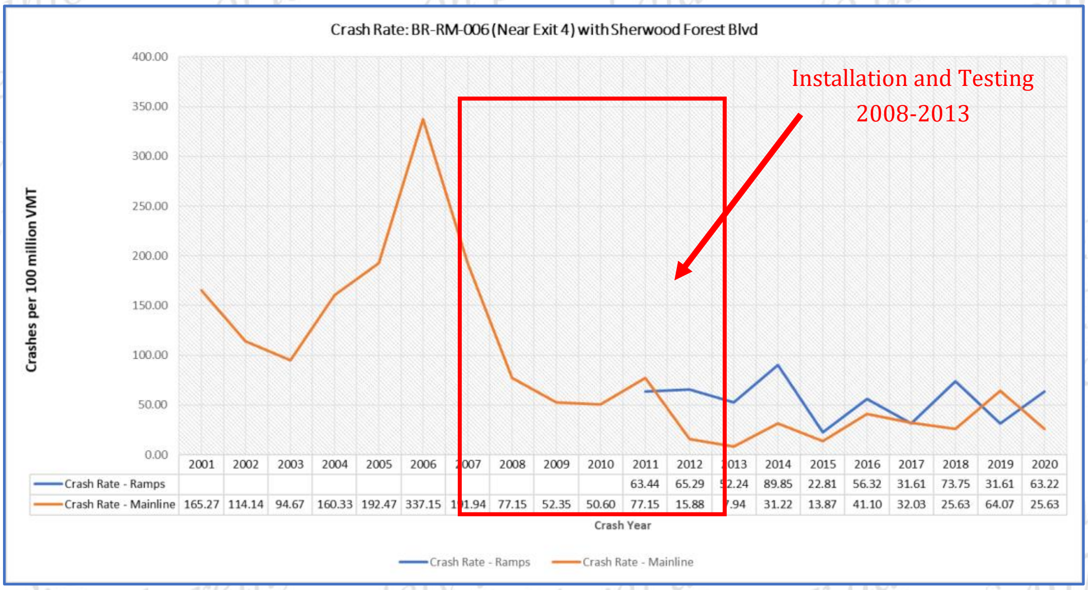


Figure 28. Manner of collision at BR-RM-006

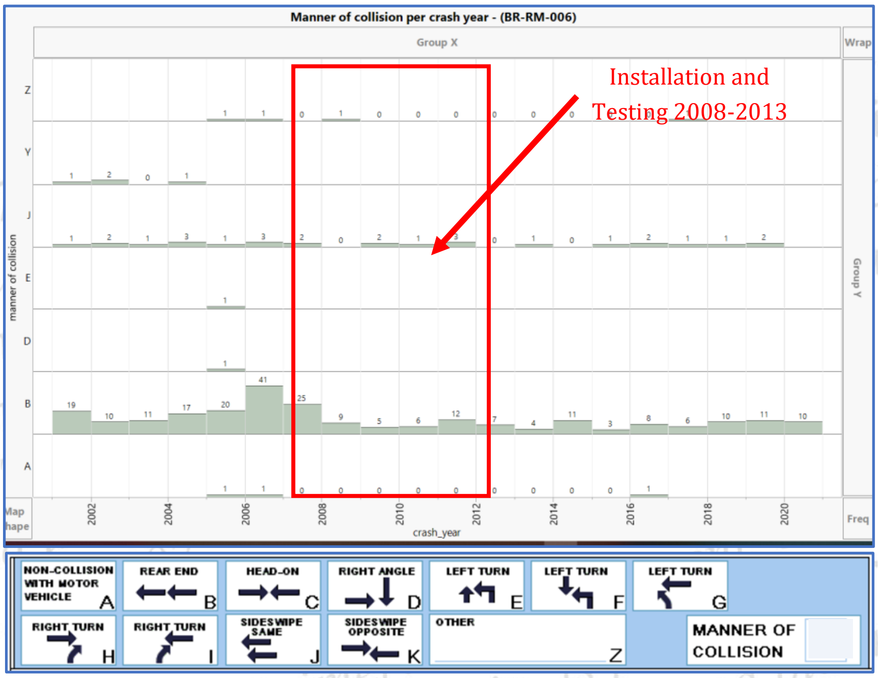


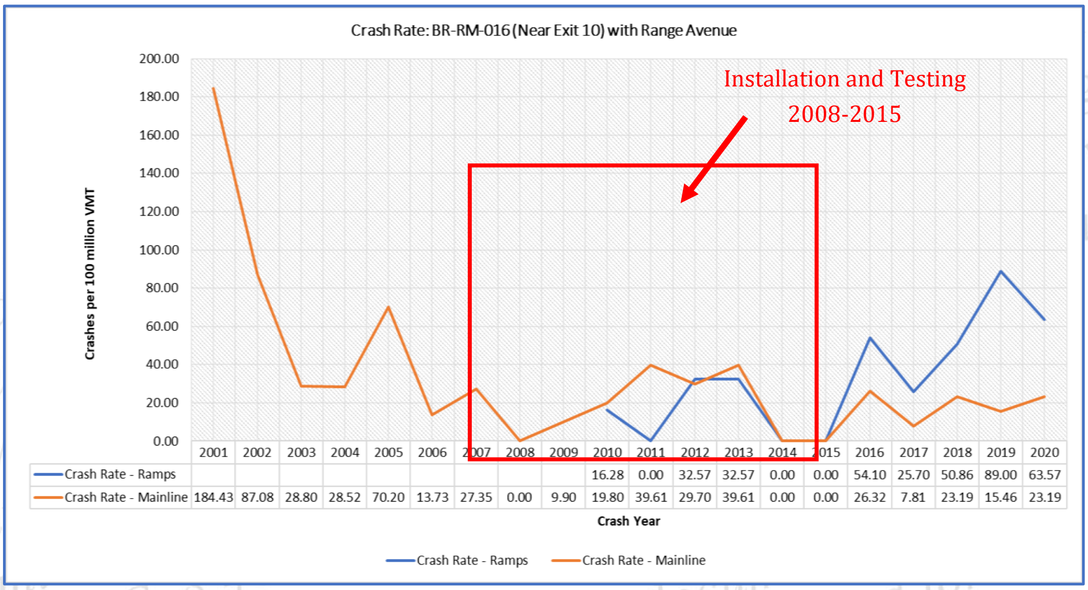
Table 19. t-test at BR-RM-006

	Before	*After*
Mean	179.4263703	30.18590435
Variance	6202.418812	296.3238408
Observations	7	8
Hypothesized Mean Difference	0	
df	7	
P(T<=t) one-tail	0.000864615	
P(T<=t) two-tail	0.001729231	
t-Test: Two-Sample Assuming Unequal Variances		

BR-RM-016. The observed trends in the crash rates indicated a seeming reduction in the mainline crashes after the ramp meter had been deployed, as shown in Figure 29. An observation of the manner of collisions per year did not, however, show recognizable reductions in the rear-end crashes after the deployment, as shown in Figure 30.

The t-test showed a reduction in the mainline of the mean crashes from 63 crashes per MVMT to 17 crashes per MVMT after deployment, as shown in Table 20. This reduction is considered significant, with a p-value of less than 0.05.

Figure 29. Mainline crashes per MVMT at BR-RM-016



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crash Rate - Ramps										16.28	0.00	32.57	32.57	0.00	0.00	54.10	25.70	50.86	89.00	63.57
Crash Rate - Mainline	184.43	87.08	28.80	28.52	70.20	13.73	27.35	0.00	9.90	19.80	39.61	29.70	39.61	0.00	0.00	26.32	7.81	23.19	15.46	23.19

Figure 30. Manner of collision at BR-RM-016

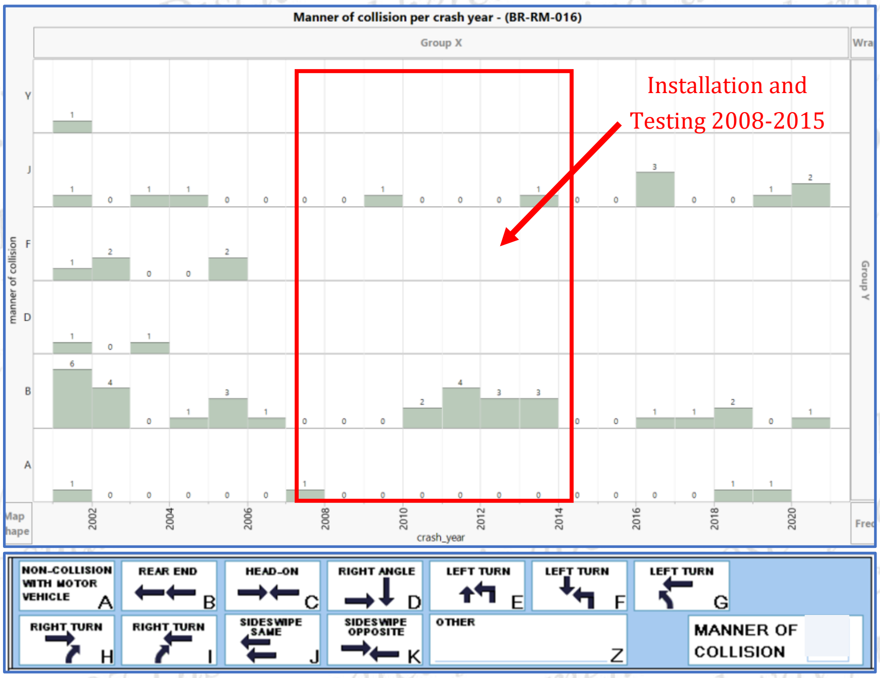


Table 20. t-test at BR-RM-016

	Before	*After*
Mean	62.87320623	16.94864644
Variance	3572.582152	191.3335427
Observations	7	8
Hypothesized Mean Difference	0	
df	7	
P(T<=t) one-tail	0.043649883	
P(T<=t) two-tail	0.087299765	
t-Test: Two-Sample Assuming Unequal Variances		

Ramp Meters in the Westbound Direction

The observation of the mainline crash rates on the westbound ramp meters over the years did not indicate obvious reductions in the mainline crashes, as shown in Figure 31, Figure 33, and Figure 35 for the respective ramp meters. There were also no noticeable reductions in collisions, especially rear-end and sideswipe crashes. Instead, these crashes seem to increase, especially on the ramp meters BR-RM-013 and BR-RM-007. The manners of collision near the westbound ramp meters over the years are shown in Figure 32, Figure 34, and Figure 36 for the respective ramp meters.

Since the crash data between 2001 and 2008 were unavailable and there were no noticeable reductions in crashes on the westbound ramp meters, the test of the significance of any reduction in crashes was not done.

BR-RM-015.

Figure 31. Mainline crashes per MVMT at BR-RM-015

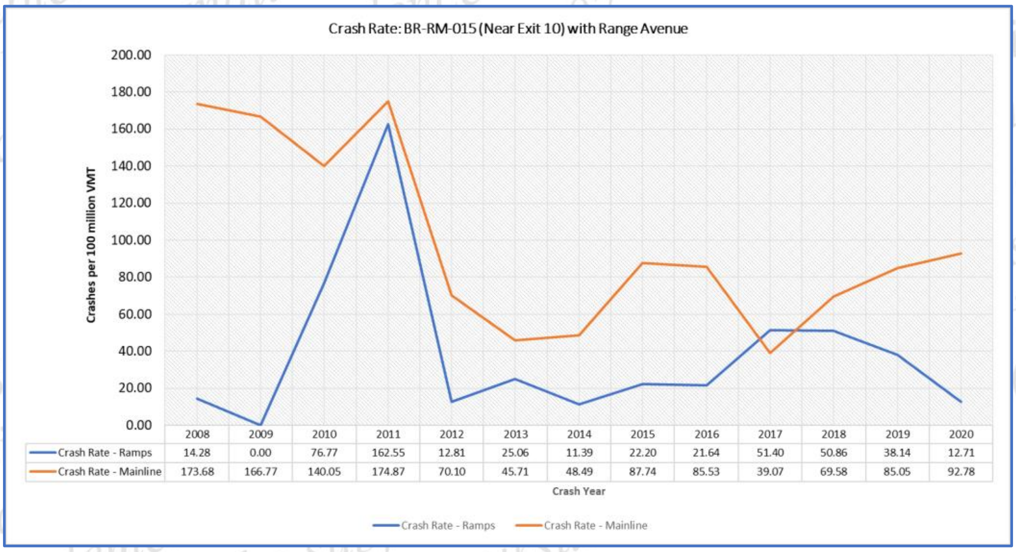
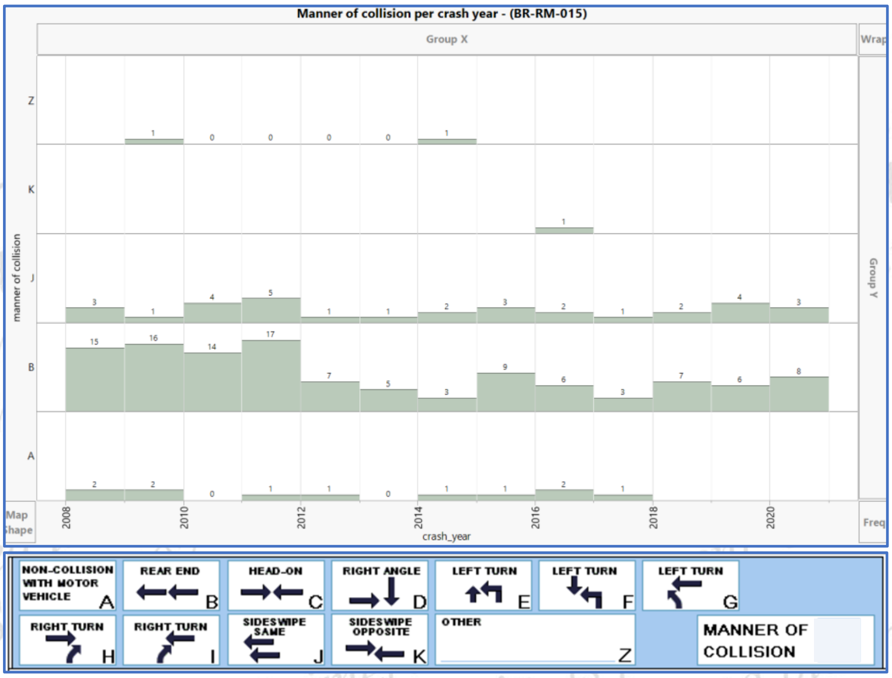
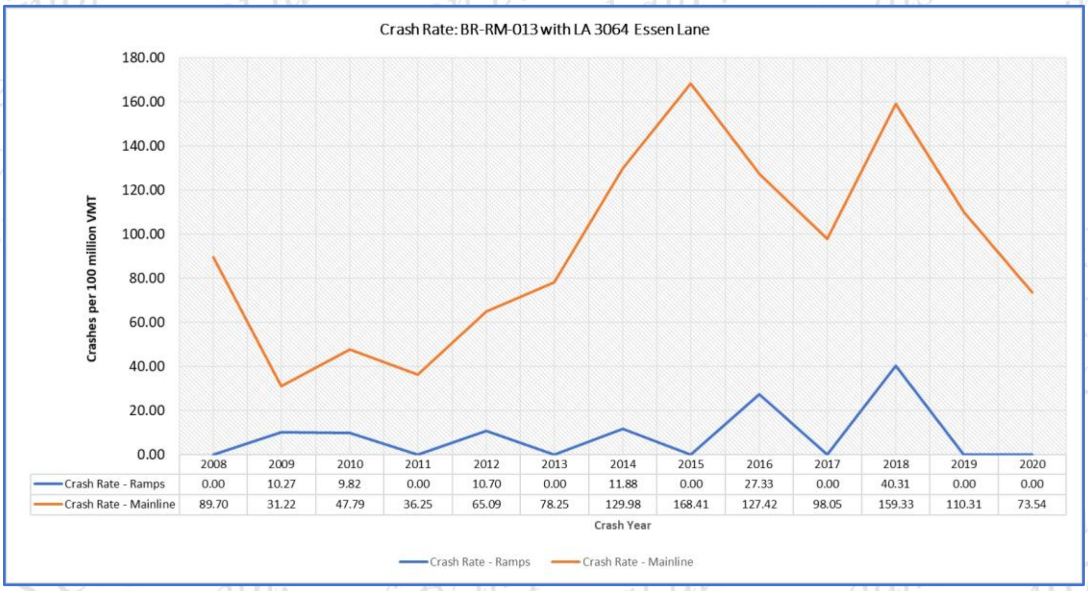


Figure 32. Manner of collision at BR-RM-015



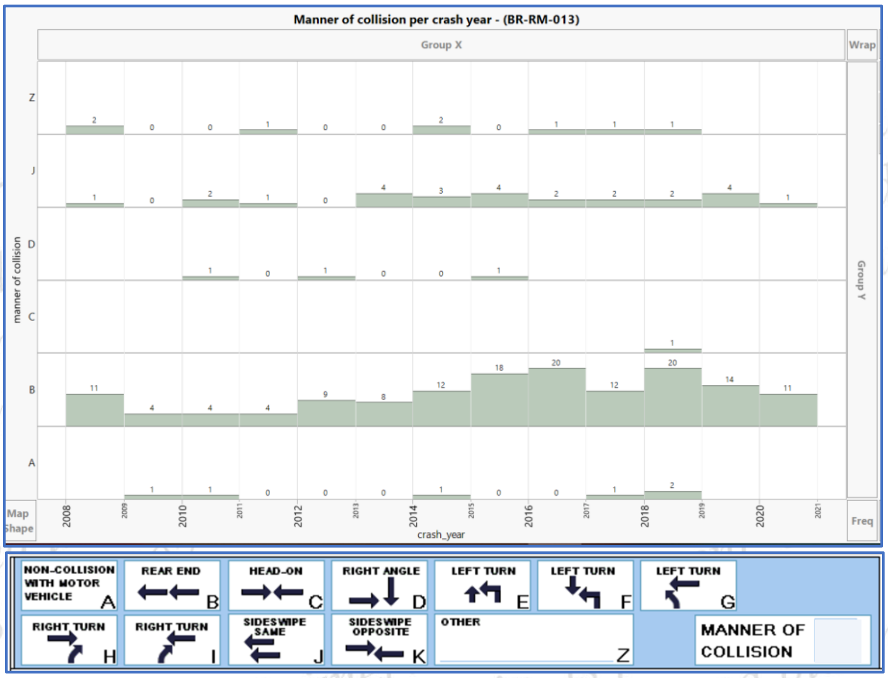
BR-RM-013.

Figure 33. Mainline crashes per MVMT at BR-RM-013



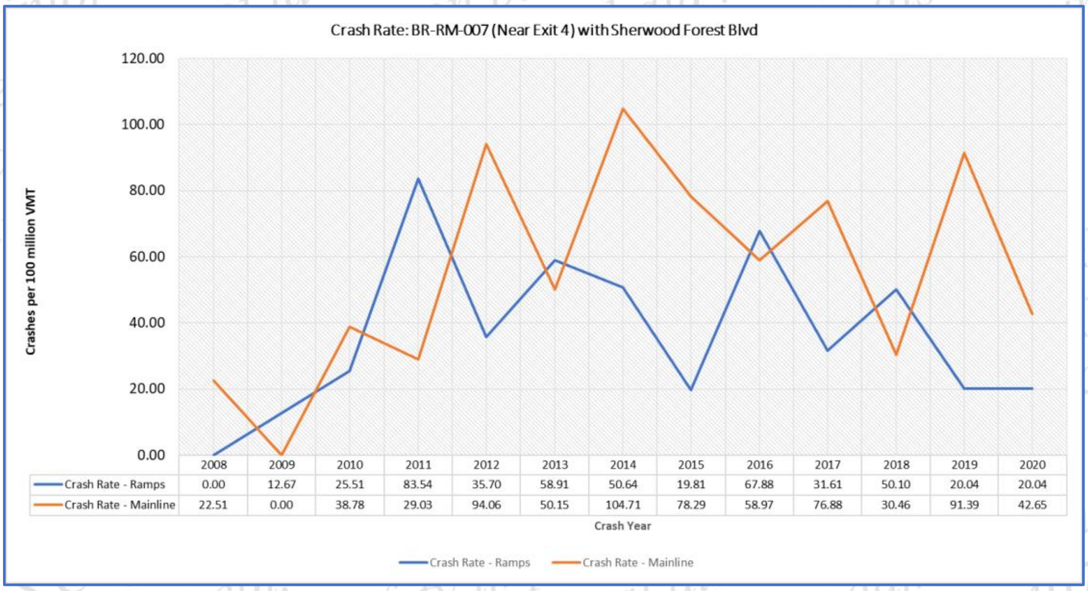
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crash Rate - Ramps	0.00	10.27	9.82	0.00	10.70	0.00	11.88	0.00	27.33	0.00	40.31	0.00	0.00
Crash Rate - Mainline	89.70	31.22	47.79	36.25	65.09	78.25	129.98	168.41	127.42	98.05	159.33	110.31	73.54

Figure 34. Manner of collision at BR-RM-013



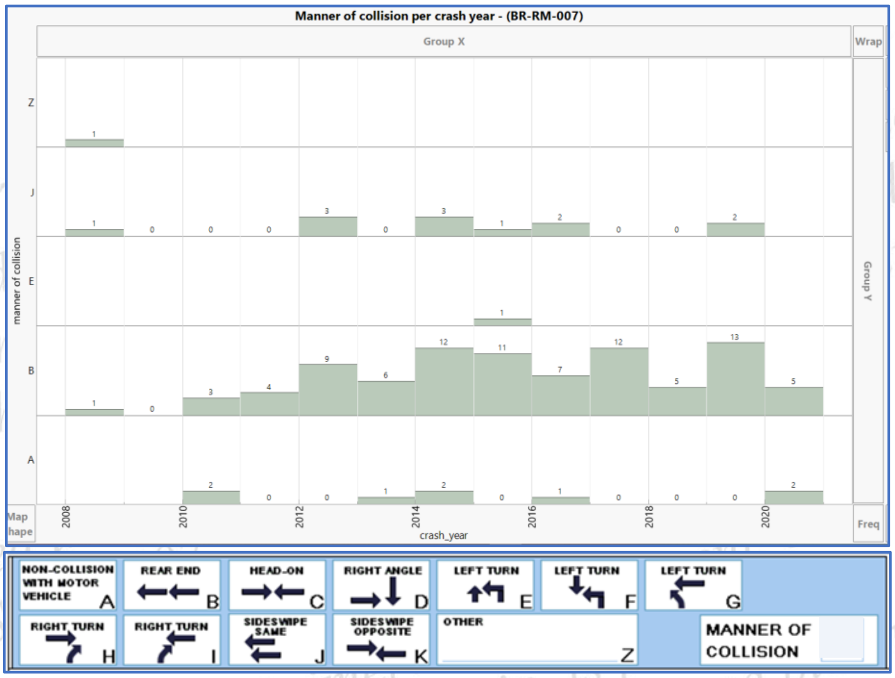
BR-RM-007.

Figure 35. Mainline crashes per MVMT at BR-RM-007



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crash Rate - Ramps	0.00	12.67	25.51	83.54	35.70	58.91	50.64	19.81	67.88	31.61	50.10	20.04	20.04
Crash Rate - Mainline	22.51	0.00	38.78	29.03	94.06	50.15	104.71	78.29	58.97	76.88	30.46	91.39	42.65

Figure 36. Manner of collision at BR-RM-007



Findings and Conclusions. The following are findings from this evaluation:

- As expected, the predominant manners of collisions on the ramp meter zones were rear-end and sideswipe collisions.
- The data available indicate significant reductions in the number of crashes at the installed ramp meters in the eastbound direction.
- The ramp meters in the westbound direction are not providing benefits in terms of reduced crashes in the mainline.

The scope of the evaluation was not enough to generalize the findings of the study across Baton Rouge or Louisiana. It is recommended that a comprehensive study is conducted to reevaluate the operations of ramp meters in Louisiana on a ramp meter-by-ramp meter basis.

Electronic Payment and Congestion Pricing

Evaluation of Travel Time on Tolled Causeway Blvd.

Introduction. The electronic toll collection service package allows toll operators to collect tolls electronically and detect and process violations [8]. The fees collected may be adjusted to implement demand and congestion management strategies. The vehicle equipment and roadside readers may also collect road use statistics [1].

The benefits of an implemented electronic payment and congestion pricing include reduced harmful emissions, increased average speed, improved travel time reliability, reduced traffic volumes, and improved enforcement and low levels of violations. Some documented benefit-cost ratios of implemented electronic payment and congestion strategies include 7:1 to 25:1 for an integrated corridor management, a 6:1 network-wide variable tolling system, and a 6:1 high-occupancy toll lanes and a priced dynamic shoulder lane [46, 47, 48, 49, 50, 51, 52].

Toll Roads in Louisiana

Louisiana has two major toll bridges: the Louisiana Highway 1 Bridge from Golden Meadow to Port Fourchon and the Lake Pontchartrain Causeway, which is composed of two parallel bridges crossing Lake Pontchartrain [53].

Study Area and Tolling System - The Causeway Blvd (Lake Ponchatrain)

The 24-mile span Causeway bridge links St. Tammany and Jefferson parishes and is designated a National Historic Civil Engineering Landmark by the American Society of Civil Engineers. The southern end of the bridge is in Metairie, while the northern end is at Mandeville. The southbound toll plaza located at Mandeville is equipped with an electronic toll collection system and pay booth for customers not equipped with electronic payment tags. The purpose of tolling this bridge is mainly to pay off the remaining debt of the construction of the bridge [54].

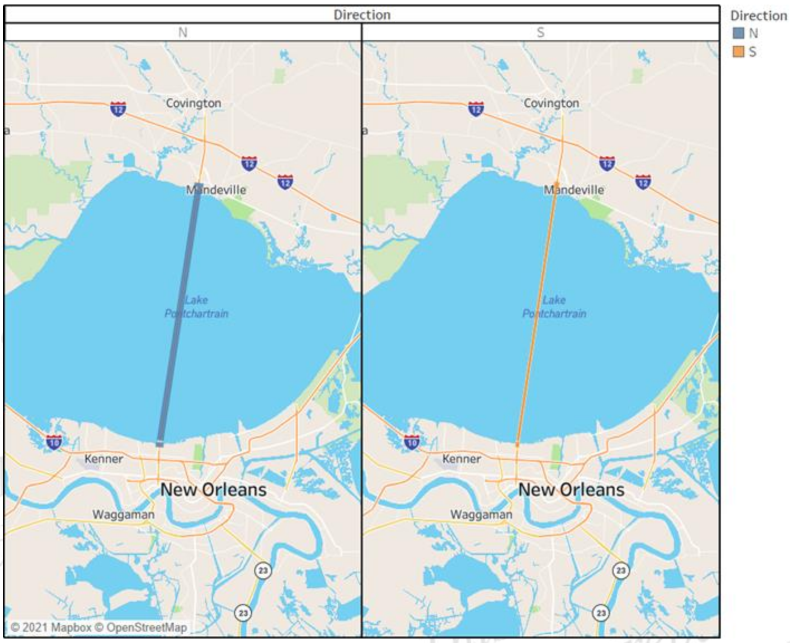
The start and end coordinates, the direction of travel, and the distance of the selected segments on the southbound and northbound lanes for the with-without analysis are shown in Table 21. These selected segments are shown in Figure 37.

Table 21. Segments studied

Highway Code	Approx. Distance (Miles)	Starts	Ends	Starting Coordinates	Ending Coordinates	Direction
Lake Pontchartrain Causeway	24.4	North Shore (Mandeville)	South Shore (New Orleans)	30.366825, -90.093609	30.018079, -90.154789	South (with)
Lake Pontchartrain Causeway	24.4	South Shore (New Orleans)	North Shore (Mandeville)	30.018051, -90.154505	30.366851, -90.093334	North (without)

Objectives. Louisiana's electronic payment and congestion pricing ITS program area is aimed to improve average travel time during peak periods and reduce hours of delay per capita [1]. The performance measures for evaluating these objectives are the average travel time during peak periods and the hours of delay. The objective of the study was to evaluate whether the southbound Causeway Boulevard experienced improved peak travel time due to the tolling operations. The data used for evaluation were collected between January 2016 and December 2020.

Figure 37. Northbound and southbound causeway blvd

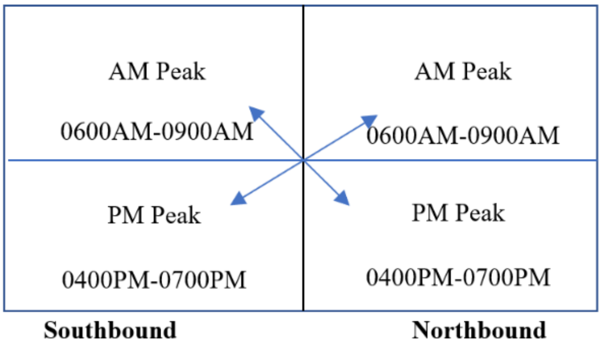


Methodology. A with-without analysis was conducted to assess whether the tolling operations on the southbound lane of the Causeway boulevard resulted in improved peak travel times. In this study, the performance of the 24-mile southbound lane with toll operation was compared with the 24-mile un-tolled northbound lanes, which have similar roadway characteristics as the southbound lane and across the Lake Ponchartrain. A summary of the performance measures of interest is listed below:

- Speeds
- Travel time index (TTI)
- Buffer time index (BTI)

The framework for comparison in the with-without analysis is shown in Figure 38. This framework was to ensure that the traffic flow was comparable. Since most offices and commercial areas are located in New Orleans, it is expected that the commuter traffic that traveled southbound in the AM peak hours would be about the same traffic volume that traveled northbound in the PM peak hours at the end of the workday. It was also expected that the commuter traffic that traveled northbound in the AM peak would be about the same traffic that traveled southbound in the PM peak.

Figure 38. Framework of the evaluation



Research Hypothesis

The research hypothesis of this comparison, which was that the performance in the southbound direction would be better than in the northbound direction, was tested using the student t-test at a 5% level of significance.

Data Sources

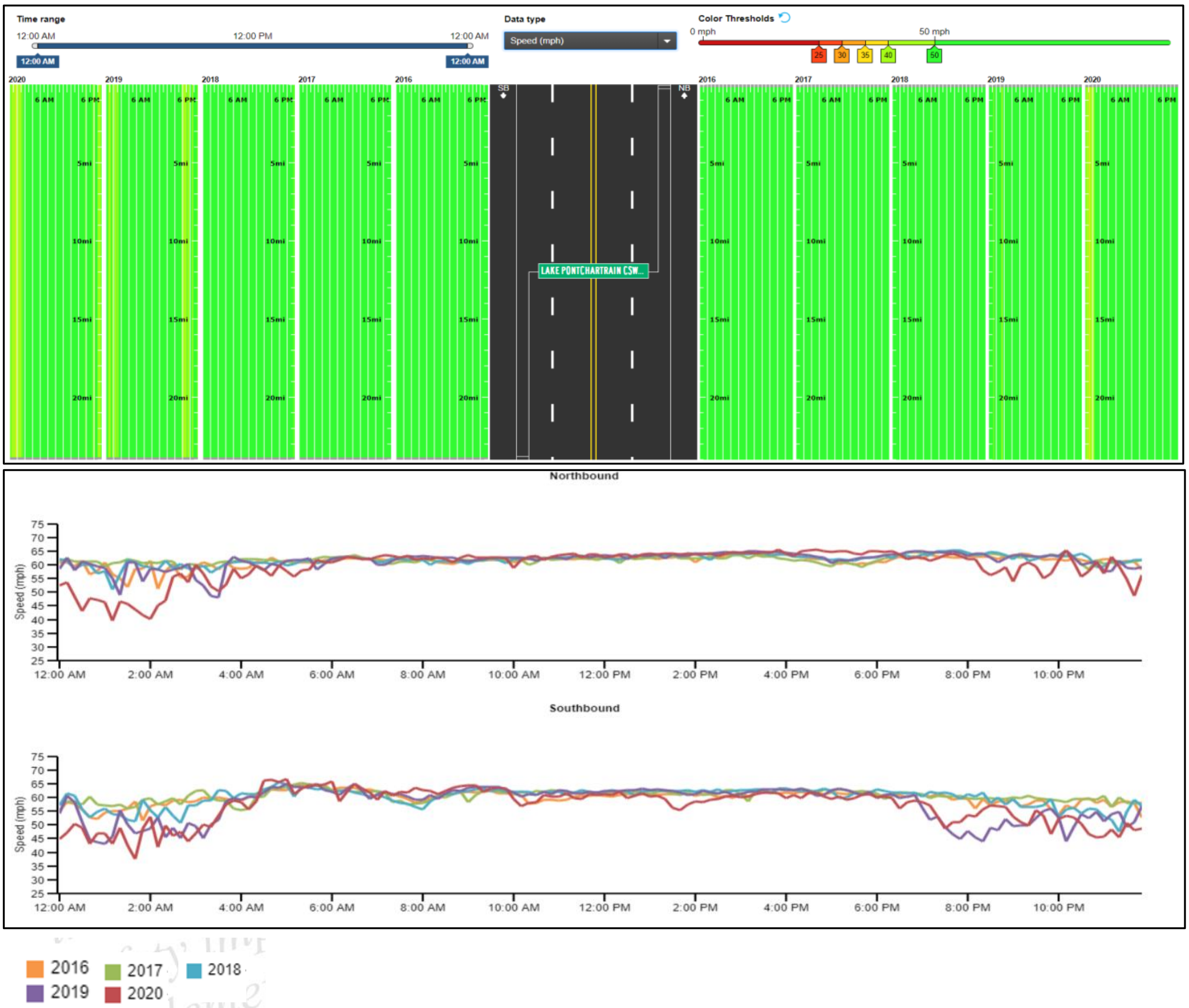
The primary data for the evaluation was the vehicle probe-based data from the NPMRDS, which was accessed through the RITIS [39]. The probe data analytic suite was used to explore five-year data from January 2016 to December 2020. The data did not need cleaning.

Discussion. The speeds, travel time index and buffer time index analyzed for the selected toll road is discussed below.

Speeds

The speed profiles from 2016 to 2020 pointed to increased variability in speeds between 06:00 p.m. through midnight and from midnight to about 06:00 a.m. in both directions, as shown in Figure 39. The observed variability in the speeds in the southbound direction was, however, more than in the northbound direction. For the speeds observed during the day (06:00 a.m. to 06:00 p.m.), there were more variabilities in the speeds in the southbound direction than in the northbound direction. The variability in the speeds observed for 2020 was prominent in both directions.

Figure 39. Speeds using NPMRDS (2016-2020)



From the output of the student's t-test shown in Table 22, the mean speeds on the southbound were 61.22 mph and 61.29 mph, respectively, in the AM and PM peak hours compared to 62.03 mph and 62.78 mph, respectively, in the AM and PM peak hours in the northbound. Testing the hypothesis at the 5% level of significance showed the speeds in the northbound direction without the toll operation to be significantly higher than the observed speeds in the southbound direction, which was not what was hypothesized.

Table 22. Output of student t-test on the mean speeds

	SB AM Peak	*NB PM Peak*
Mean	61.21914894	62.78319149
Variance	3.942571311	2.306927339
Observations	94	94
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	3.59154E-09	
P(T<=t) two-tail	7.18307E-09	
t-Test: Two-Sample Assuming Equal Variances		

	SB PM Peak	*NB AM Peak*
Mean	61.2937234	62.02829787
Variance	1.905842976	0.698218577
Observations	94	94
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	8.60734E-06	
P(T<=t) two-tail	1.72147E-05	
t-Test: Two-Sample Assuming Equal Variances		

Travel Time Index

The TTI profile shown in Figure 40 for 2016 to 2020 indicates variability and higher TTI scores in both directions between 06:00 p.m. through midnight to about 06:00 a.m. The observed variability and increased TTI scores seem more prominent in the southbound than northbound, especially from 2018 to 2020. Compared to the northbound, the southbound direction has variability in the TTI during the day (06:00 a.m. to 06:00 p.m.), as seen in the heatmap and the time-series graph in Figure 40.

From the student's t-test shown in Table 23, the mean TTIs were 1.19 in the AM peak hours and 1.19 in the PM peak hours in the southbound direction, compared to 1.18 in the AM peak hours and 1.16 in the PM peak hours for the northbound direction. Testing the hypothesis at the 5% level of significance showed the TTI scores in the southbound direction with the toll operation to have significantly higher observed TTI scores than in the northbound direction, which again was not hypothesized.

Figure 40. Travel time reliability (2016-2020) from INRIX

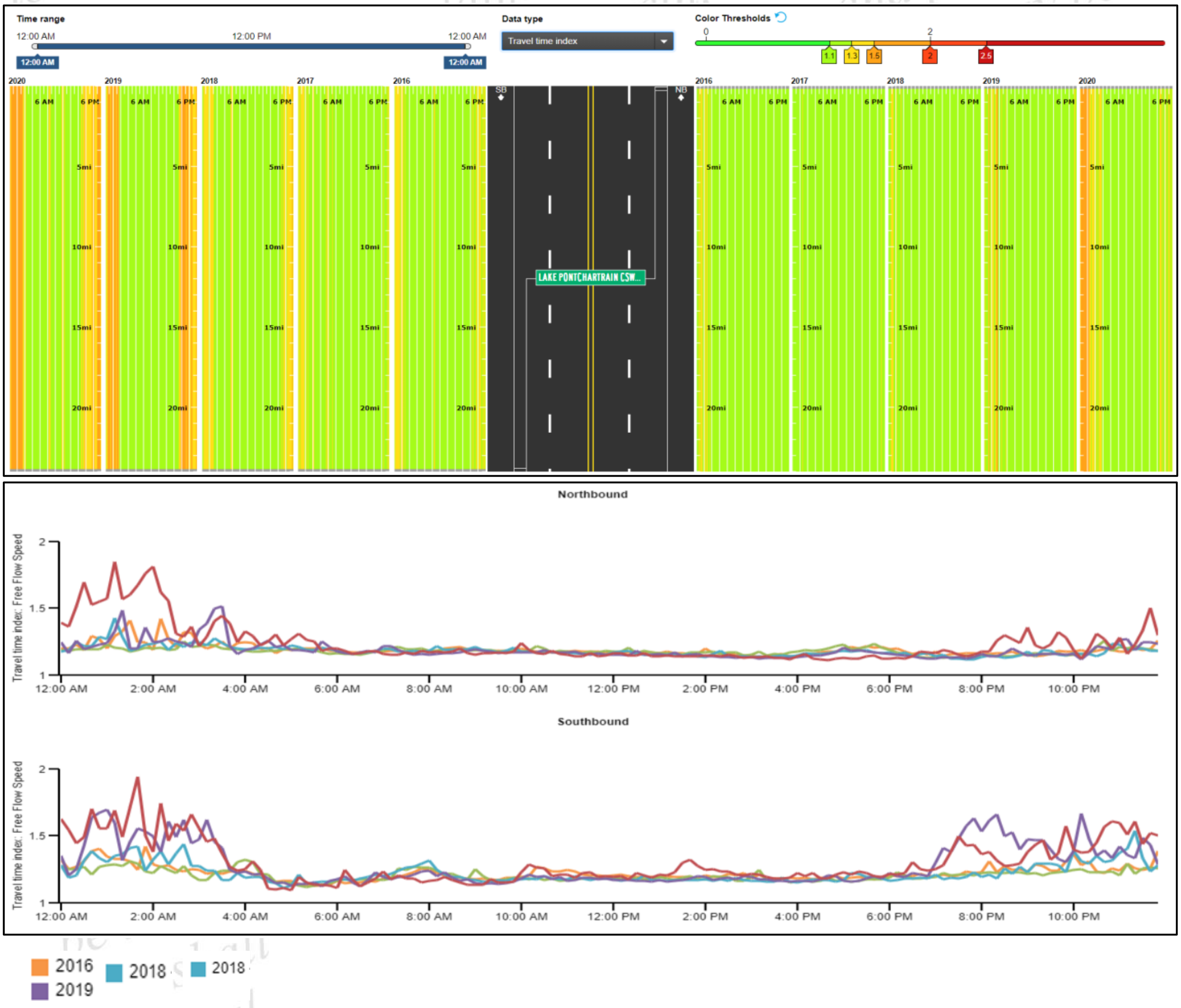


Table 23. Output of student t-test on the mean TTI

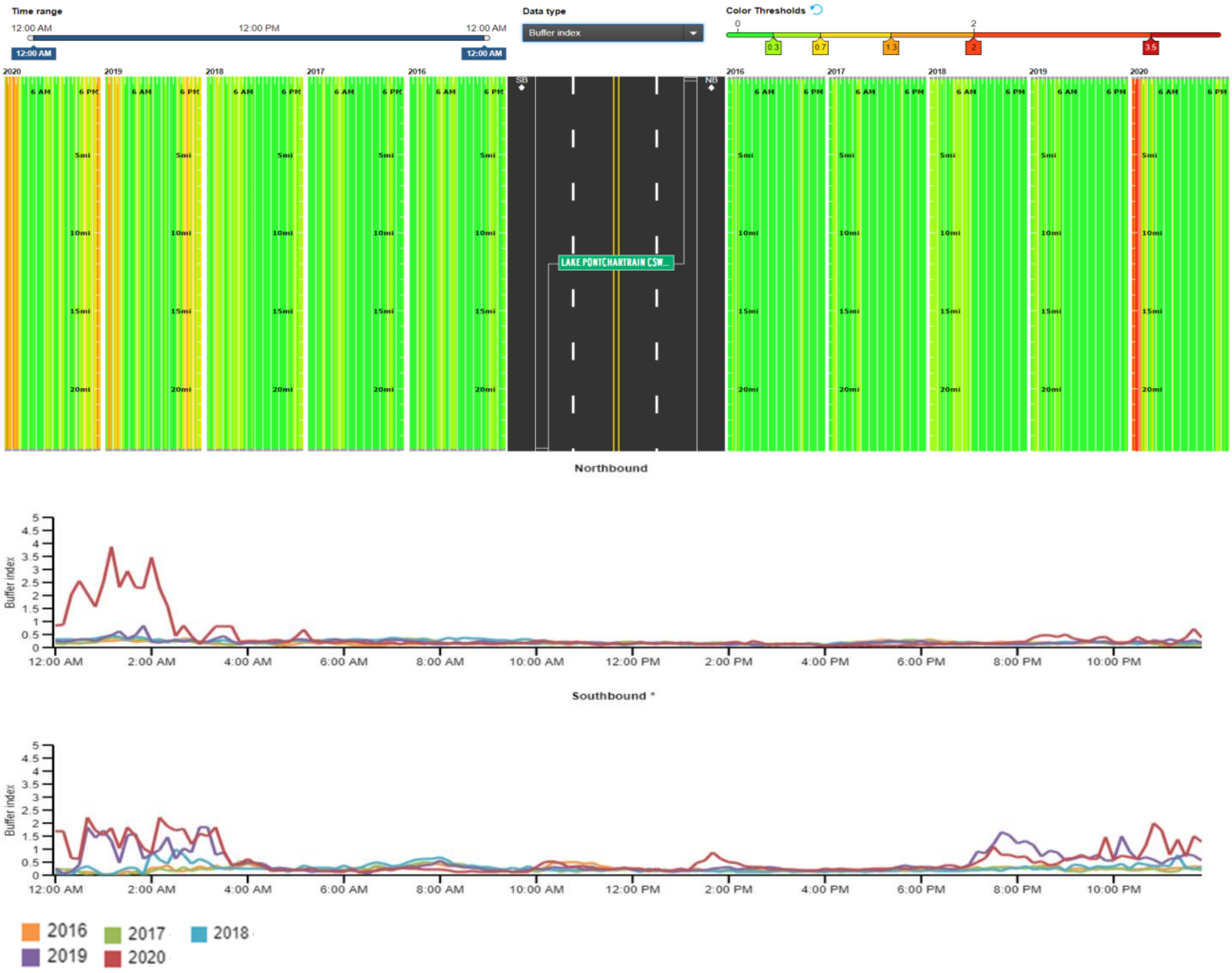
	SB AM Peak	*NB PM Peak*
Mean	1.193617021	1.163297872
Variance	0.001565271	0.000843846
Pooled Variance	0.001204558	
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	5.34511E-09	
P(T<=t) two-tail	1.06902E-08	
t-Test: Two-Sample Assuming Equal Variances		

	SB PM Peak	*NB AM Peak*
Mean	1.191489362	1.177021277
Variance	0.000761199	0.000268451
Observations	94	94
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	1.02498E-05	
P(T<=t) two-tail	2.04996E-05	
t-Test: Two-Sample Assuming Equal Variances		

Buffer Time Index

The BTI profile shown in Figure 41 for 2016 to 2020 again indicates variability and higher BTI scores between 06:00 p.m. and 06:00 a.m., in both directions, with the observed variability and high BTI scores prominent in the southbound than in the northbound. The highest BTI score was observed between midnight and 06:00 a.m. in the northbound direction in 2020. Again, compared to the northbound, the southbound direction has variability in the BTI during the day (06:00 a.m. to 06:00 p.m.), as shown in Figure 41.

Figure 41. Buffer Time Index (2016-2020) from INRIX



From the student's t-test shown in Table 24, the mean BTI scores in the southbound were 0.30 in the AM peak hours and 0.20 in the PM peak hours. This was compared to 0.21 in the AM peak hours and 0.16 in the PM peak hours northbound. While the BTI in the northbound during the PM peak hours was significantly lower than the southbound AM peak BTI, there was no significant difference between the BTIs in the southbound direction during the PM peak hours and the BTI in the northbound direction during the AM peak hours.

Table 24. Output of student t-test on the mean BTI

	SB AM Peak	*NB PM Peak*
Mean	0.302659574	0.16351
Variance	0.017185324	0.00379
Observations	94	94
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	1.7483E-17	
P(T<=t) two-tail	3.49659E-17	
t-Test: Two-Sample Assuming Equal Variances		

	SB PM Peak	*NB AM Peak*
Mean	0.204893617	0.206808511
Variance	0.003861817	0.006077877
Observations	94	94
Hypothesized Mean Difference	0	
df	186	
P(T<=t) one-tail	0.426238302	
P(T<=t) two-tail	0.852476604	
t-Test: Two-Sample Assuming Equal Variances		

Findings. The following are findings from this evaluation:

- The results from the student's t-test did not support the hypothesis that tolling operation on the southbound lane would contribute to an improved travel time reliability in terms of the performance measure used. The finding, however, supports the notion that the tolls on Lake Ponchatrain were for commercial reasons and not for operational improvements.
- The variability in the performance during the night, especially in speeds, poses a safety concern that needs investigation. Though this may result from variable speeds at night on the bridge, it may be from unclear road delineations, lack of lighting, or the absence of shoulders on the stretch of the boulevard.

Traveler Information

Introduction

To expand Louisiana's traveler information and enhance efforts to provide real-time traffic information for commuters, DOTD-ITS integrated the state's 511 with other agencies like the University of Maryland's RITIS, Esri's geographic information system (GIS) mapping software, Integrated Modeling for Road Condition Prediction (IMRCP) system, and other 511 application program interface users. Louisiana has, since August 2020, also integrated fully with Waze, which makes it one of the first DOTs to do so.

Objectives

The objectives of Louisiana's Traveler Information ITS program are to increase the number of traveler information portals and the accuracy of traveler information posted. This section evaluated the current state of Louisiana's traveler information program area by assessing the following:

1. Number of 511 interactive voice response (IVR) call sessions per year (2019-2021)
2. Number of 511 webpage visits per year (2019-2021)
3. Number of 511 app visits per year (2019-2021)
4. Number of Twitter followers (2015-2020)

which are represented in the figures below:

Figure 42. Number of 511 calls per year

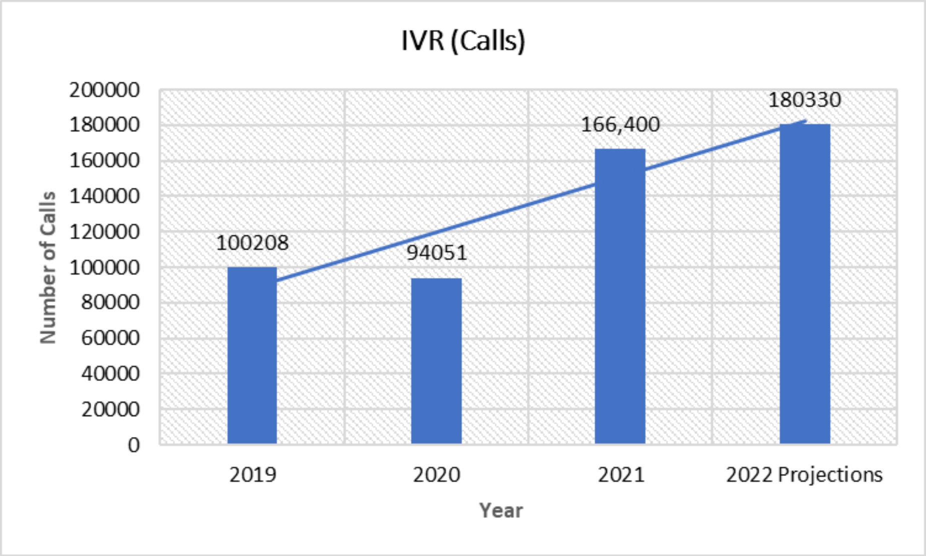


Figure 43. Number of sessions to 511-webpage per year

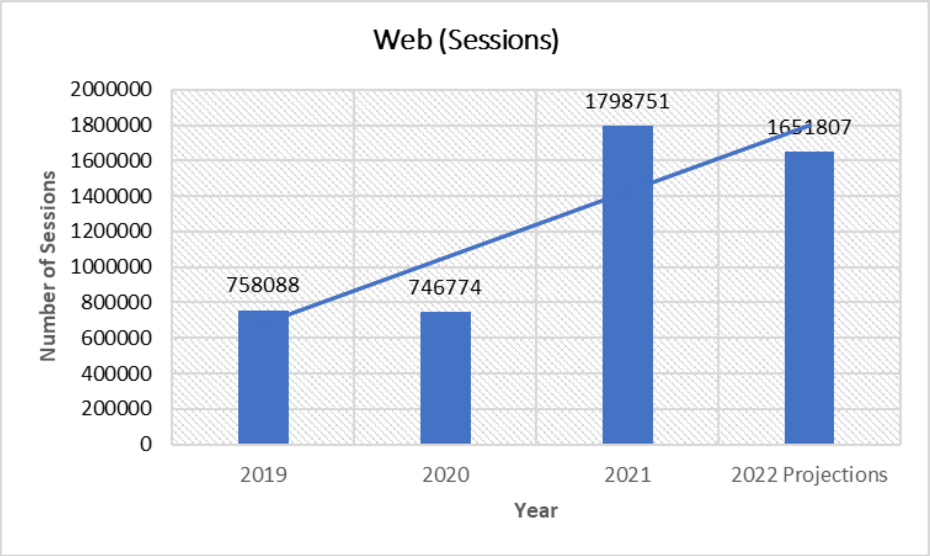


Figure 44. Number of sessions to 511-application per year

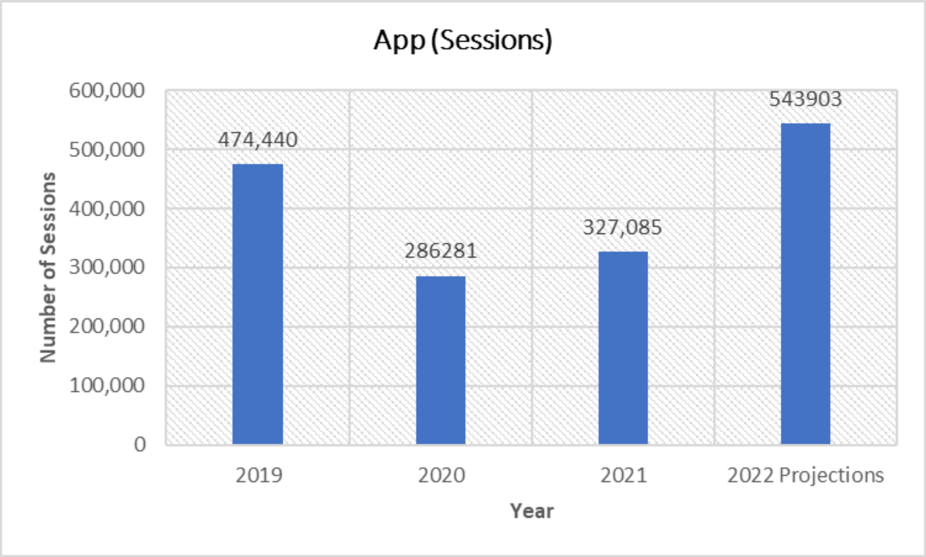


Figure 45. Number of Twitter followers (2015-2020)

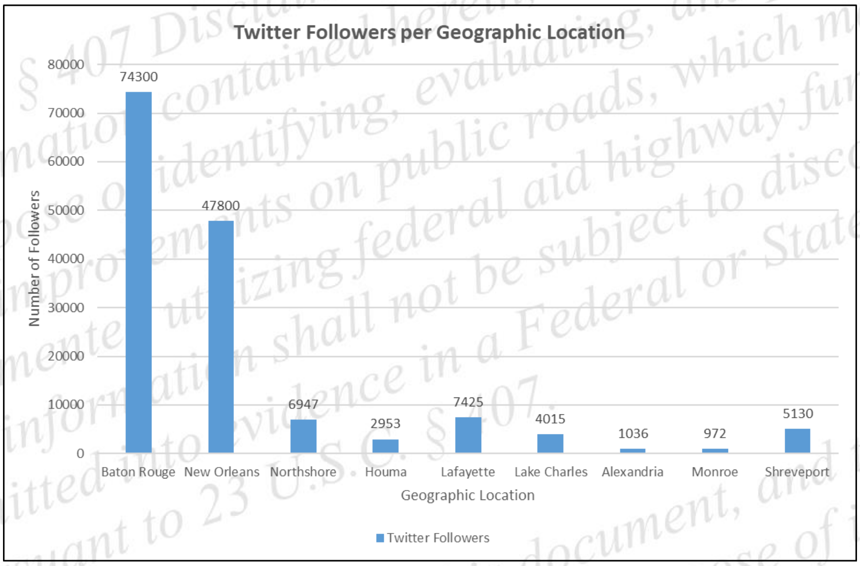
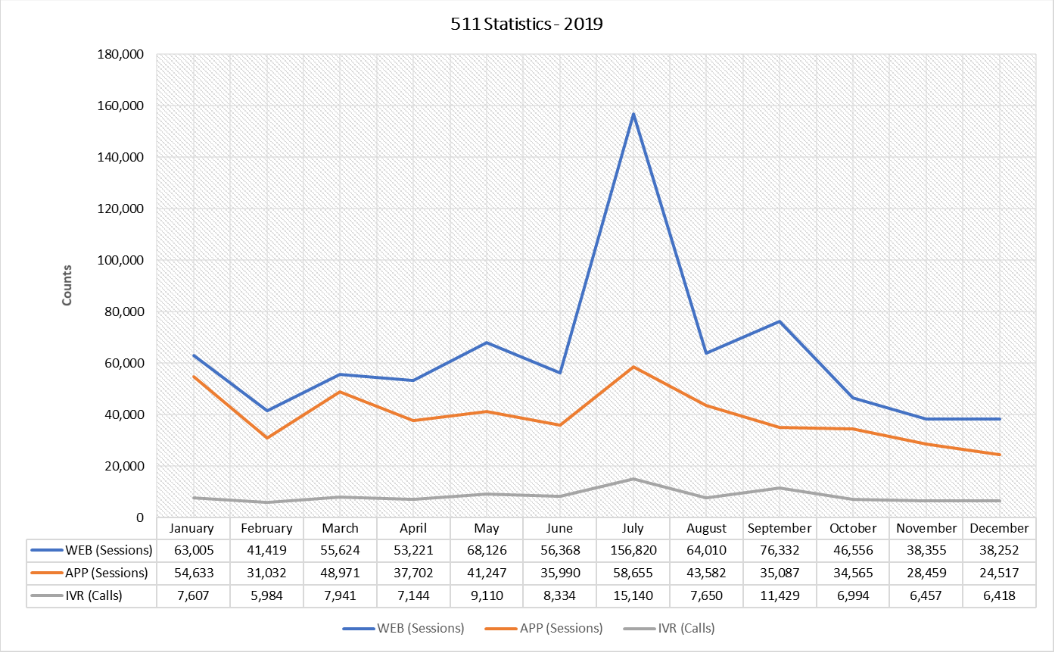
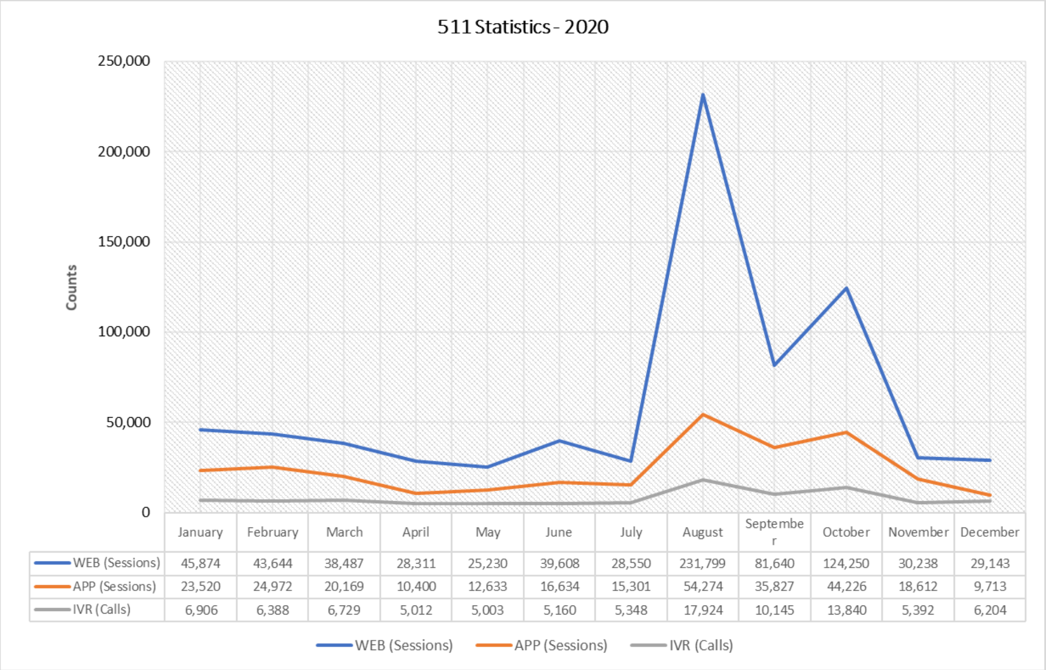


Figure 46. Monthly 511 statistics - 2019



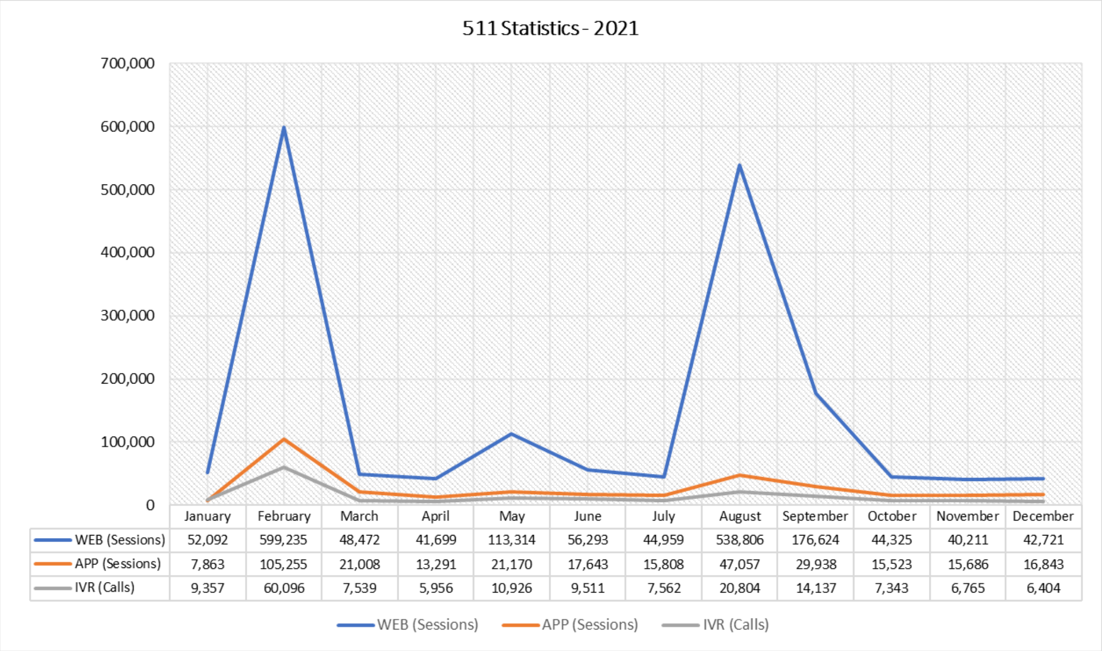
	January	February	March	April	May	June	July	August	September	October	November	December
WEB (Sessions)	63,005	41,419	55,624	53,221	68,126	56,368	156,820	64,010	76,332	46,556	38,355	38,252
APP (Sessions)	54,633	31,032	48,971	37,702	41,247	35,990	58,655	43,582	35,087	34,565	28,459	24,517
IVR (Calls)	7,607	5,984	7,941	7,144	9,110	8,334	15,140	7,650	11,429	6,994	6,457	6,418

Figure 47. Monthly 511 statistics - 2020



	January	February	March	April	May	June	July	August	September	October	November	December
WEB (Sessions)	45,874	43,644	38,487	28,311	25,230	39,608	28,550	231,799	81,640	124,250	30,238	29,143
APP (Sessions)	23,520	24,972	20,169	10,400	12,633	16,634	15,301	54,274	35,827	44,226	18,612	9,713
IVR (Calls)	6,906	6,388	6,729	5,012	5,003	5,160	5,348	17,924	10,145	13,840	5,392	6,204

Figure 48. Monthly 511 statistics - 2021



	January	February	March	April	May	June	July	August	September	October	November	December
WEB (Sessions)	52,092	599,235	48,472	41,699	113,314	56,293	44,959	538,806	176,624	44,325	40,211	42,721
APP (Sessions)	7,863	105,255	21,008	13,291	21,170	17,643	15,808	47,057	29,938	15,523	15,686	16,843
IVR (Calls)	9,357	60,096	7,539	5,956	10,926	9,511	7,562	20,804	14,137	7,343	6,765	6,404

Conclusions

The spikes in monthly 511 statistics, shown in Figure 46, Figure 47, and Figure 48 for 2019, 2020, and 2021 respectively, seem to correlate with the months of major weather events in Louisiana in those years; for instance, hurricanes Berry in July 2019 [55]; Laura [56] in August 2020; Delta [57]; and Zeta [58] in October 2020. In 2021, there was the winter and record cold weather in February [59] and hurricanes Ida [60] and Nicholas [61] in August and September, respectively. This correlation suggests the benefits of the Louisiana traveler information program in the form of increased 511 services during bad weather events to users in and around Louisiana.

Conclusions

Performance measures were developed for DOTD's current ITS programs in this study and were used to evaluate the ITS applications to assess the impact of the programs on the transportation system performance and reveal the return on investment. The following conclusions were made from the research under each of the key areas:

Literature Review

- Responsible organizations like the FHWA and DOT through ARC-IT have provided sufficient guidance and information to develop or incorporate performance measurement strategies into respective ITS programs.
- Louisiana's ITS goals, objectives, and performance measures did not have a clear relationship with the state's existing and desired ITS programs.

Qualitative Survey

- ITS performance measurement has been fairly integrated into ITS programs by agencies, with most organizations monitoring their ITS programs, considering it beneficial to operations and taxpayers.
- Most organizations monitored ITS performance on deployment and systems functionality levels, with a few others also monitoring the levels of service provision and user benefits.
- Considerable data are collected directly from ITS equipment. Besides this source, agencies rely on public or private-sector-owned data, with a few collecting internally.
- Organizations rarely consulted or found ARC-IT recommendations helpful in developing their ITS performance measures, but the number of responses was insufficient to generalize this feedback across agencies.
- State DOTs generally do not benchmark or compare ITS performance with other agencies and jurisdictions, mainly for the following reasons: lack of available data, lack of guidance or best practices on the subject, and incomparable data gathered across agencies/jurisdictions.
- The following featured highly as the reasons that prevent agencies from measuring performance, benefits, and deployment to greater detail and quality: lack of available data, complexity in the endeavor, and fragmented and incomparable data.
- "Other" reasons that prevent agencies from measuring performance included the lack of data scientists and specific data-focused positions in organizations; and difficulty assigning responsibilities when inter-agency collaboration is required.

Arterial Management

- Segments with apparent crash clusters and unusually high crash frequencies without CCTV camera coverage are determined to need immediate future coverage. For instance, I-210 in Lake Charles, I-49 from Lafayette through Opelousas to Washington, and I-310 in New Orleans need immediate or future CCTV camera deployments.

Notwithstanding the need to increase the sample sizes and other factors that could influence IRT on roadways, the following findings and conclusions were made:

- In Baton Rouge and Lake Charles, the IRTs observed on roadways with CCTV camera coverage were significantly lower than the IRT on roadways without CCTV camera coverage.
- There was insufficient evidence from the evaluations done for Alexandria, Lafayette, New Orleans, North Shore, Shreveport, and Monroe to support the research hypothesis that the IRT on roadways with CCTV camera coverage would be lower than the IRT on roadways without CCTV camera coverage.

Even though road users in Louisiana may be benefiting from installed CCTV cameras on roadways in other ways, the evidence available through this evaluation was not enough to claim that road users in Louisiana benefited from installed CCTV cameras in terms of reduced incident response times.

Motorist Assist Patrol

Notwithstanding the need to increase the sample sizes, especially for the roadway without MAP, available MAP resources, and other factors that can influence RCT on roadways, the following findings and conclusions can be made from the evaluation:

- In Alexandria, Baton Rouge, New Orleans, and Shreveport, the RCT observed on roadways with MAP are lower than the RCT on roadways without MAP.
- Even though in Lafayette, Lake Charles, and North Shore where the RCTs on roadways with MAP are not significantly lower than RCTs on roadways without MAP, road users still benefit in terms of lower mean RCTs and upper bound of the confidence interval of the RCT observed.

In general, it can be concluded that road users in Louisiana benefit from reduced RCT on roadways that have MAP.

Commercial Vehicle Operations

- Louisiana's interstate highway system remained reliable over the study period, with TTTR Index scores of less than 1.50; but there exist TMC segments in Louisiana that experienced maximum TTTR scores of greater than 1.50, which are together 15.47% of the interstate highway system.

- The 15.47% of the interstate highway system (with a maximum TTTR>1.50) contributed, on average, 72.34 % of the annual user delay cost between 2016 and 2019. The proportion dropped to 62.49% in 2020, which is extremely high, considering the full length of the interstate highway.
- The annual total crash frequencies on the interstate highway system remained relatively constant between 2016 and 2019 but declined in 2020, possibly in response to COVID-19. Even though the annual frequency of crashes remained relatively constant, the ratio of commercial vehicles saw an increasing trend between 2016 and 2020.

Freeway Management

- The inventory of installed equipment needs to be periodic and updated in required documents and portals for easy reference. A comprehensive study to assess the coverage of the devices needs to be carried out in a separate study.
- As expected, the predominant manners of collisions on the ramp meter zones were rear-end collisions and sideswipe collisions.
- The available data indicate significant reductions in crashes at the installed ramp meters in the eastbound direction of the studied area. On the other hand, the ramp meters in the westbound direction were not seen to provide any benefit in terms of reduced crashes in the mainline. The results of the study are not enough to claim the benefits of ramp meters to road users across Louisiana.

Electronic Payment and Congestion Pricing

- The study results did not support the hypothesis that tolling operation on the southbound lane would contribute to an improved travel time reliability in terms of the performance measure used. The finding, however, supports the notion that the tolls on Lake Ponchatrain were for commercial reasons and not for operational improvements.
- There was observed variability in the performance during the night, especially in speeds that may be from unclear road delineations, lack of lighting, or the absence of shoulders on the stretch of Causeway boulevard.

Traveler Information

- The spikes in monthly 511 statistics seem to have a correlation with the months of major weather events in Louisiana. This suggests the benefits of the Louisiana traveler information program in the form of increased 511 services during bad weather events to users in and around Louisiana.

Recommendations

The study recommended the following for future research.

- It is recommended that a study in the future can identify or predict the factors that influence road clearance times on the Louisiana interstate highway system.
- A comprehensive study to reevaluate the operation of ramp meters may reveal additional information on its effectiveness.
- Future studies can assess the coverage of installed ITS devices separately.
- There exists variability in the performance during the night on Causeway boulevard, especially in speeds, which poses a safety concern that needs investigation.
- Regarding traveler information, the performance measures can be evaluated within a short time, preferably quarterly.

Acronyms, Abbreviations, and Symbols

Term	**Description**
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
ARC-IT	National ITS Reference Architecture
BTI	Buffer Time Index
CCTV	Closed-circuit television
CVO	Commercial Vehicle Operations
DOT	U.S. Department of Transportation
DOTD	Louisiana Department of Transportation and Development
DOTs	State Departments of Transportation
FAST	Fixing American’s Surface Transportation
FHWA	Federal Highway Authority
GIS	Geographic Information System
IMRCP	Integrated Modeling for Road Condition Prediction
IRT	Incident Response Time
ITS	Intelligent Transport Systems
IVR	Interactive Voice Response
JPO	Joint Program Office
LTRC	Louisiana Transportation Research Center
MAP	Motorist Assistance Patrol
MAP-21	Moving Ahead for Progress in the 21st Century Act
MPOs	Metropolitan Planning Organizations
MVMT	Million Vehicle Mile of Travel
NPMRDS	National Performance Management Research Data Set
PBPP	Performance-Based Planning and Programming
PM3	The third performance measure rule – “Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program’’.
RCT	Roadway Clearance Time
RITIS	Regional Integration Transportation Information System
TMC	Traffic Management Centers (a.k.a. Transportation Management Centers)
TMC	Traffic Message Channels
TSMO	Transportation System Management and Operations
TTI	Travel time index
TTTR	Truck Travel Time Reliability
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles of Travel

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Appendix A

Table A1. Interchangeably used terminologies

Term	Definition	Reference	Remarks
Market packages	Potential products or subsystems that address specific services [as used in an ITS architecture]	MnDOT [62]	Referred to as service package in ARC-IT 9.0
Application	A software program with an interface that provides functionality, enabling people to realize safety, mobility, environmental, or other benefits.	ITS JPO [63]	
Goal	A broad statement that describes the desired end state.	[2]	
Objective	A specific, measurable statement that supports the achievement of a goal.	[2]	
Performance measure	A metric used to assess progress toward meeting an objective.	[2]	
Target	A specific level of performance that is desired to be achieved within a specific timeframe.	[2]	
Architecture	Fundamental concepts or properties of a system in its environment; embodied in its elements, relationships, and principles of its design and evolution. It defines "what must be done," not "how it will be done."	ARC-IT [64]	
ITS Architecture	Defines an architecture of interrelated systems that work together to deliver transportation services. It defines how systems functionally operate and the interconnection of information exchanges that must take place between these systems to accomplish transportation services.	ARC-IT [64]	
Service Packages	Represent slices of the Physical View that address specific services like traffic signal control. A service package collects several different physical objects (systems and devices) and their functional objects and information flow that provides the desired service.	ARC-IT [64]	
User Service	User services document what ITS should do from the user's perspective. It allows system or project definition to begin by establishing the high-level services that will be provided to address identified problems and needs.	ARC-IT [64]	Often used interchangeably with Service Area
User Services Bundle	A logical grouping of user services to provide a convenient way to discuss the range of requirements in a broad stakeholder area. In the National Program Plan, the user services were grouped into eight bundles, including Travel and Traffic Management, Public Transportation Management, and Electronic Payment.	ARC-IT [64]	Often used interchangeably with Service Area
User Need	A capability that is identified to accomplish a specific goal or solve a problem supported by a system.	ARC-IT [64]	

User	A user is an entity or individual who uses computers, programs, networks, and related hardware and software systems services. In ARC-IT, users refer to those who use the combination of Mobile, Field, and Center-based devices and applications.	ARC-IT [64]	
ITS Services	Transportation services are performed using ITS elements deployed to meet operational goals and objectives.	ARC-IT [64]	Often used interchangeably with service packages.
Application Area	Application area refers to components of ITS systems from the deployer's perspective. An example is the Dynamic Message Signs application area.	ITS JPO [65]	Often used interchangeably with service packages and service areas.
Deployment	Describes the process of implementing a standard in a real-world project.	ITS JPO [65]	
Deployer	Refers to the organization or staff member that manages an implementation.	ITS JPO [65]	
Functional Requirement	A statement that specifies “what” a system must do. It uses formal "shall" language and specifies functions in terms that the stakeholders will understand.	ITS JPO [65]	
Service Package	Service packages provide an accessible, service-oriented perspective to ARC-IT. Service packages collect one or more physical objects, and their functional objects that must work together to deliver a given transportation service and the information flows that connect them and other important external systems.	ITS JPO [65]	
Equipment Package	They are the building blocks of the physical architecture subsystems. Equipment Packages group similar processes of a particular subsystem into an "implementable" package.	Kansas [66]	

Appendix B

Qualitative Survey Questionnaire

Dear Transportation System Operators,

In conjunction with the Louisiana Department of Transportation and Development (DOTD), Louisiana Transportation Research Center (LTRC) is conducting this survey to help develop a set of performance measures for Louisiana's Intelligent Transportation Systems (ITS) applications.

The survey is designed to solicit information regarding the current performance measures you use to quantify the benefits of ITS applications in your jurisdiction and any suggestions you may have for us.

This survey will not take more than 10 (ten) minutes.

For more information on this survey, please contact Dr. Raju Thapa at Raju.Thapa@la.gov.

We appreciate your assistance with this survey.

ABOUT YOU/YOUR ORGANIZATION

1. **Which of the following best describes the type of organization you represent? (Tick one only)**

☐Federal Highway Authority (FHWA)
☐United States Department of Transportation (DOT)
☐State Department of Transportation (DOTs)
☐Metropolitan Planning Organization (MPO)
☐Regional Transportation Planning Office (RTPO)
☐Non-Governmental Organization
☐ITS Service Provider
☐Vehicle / Component Manufacturer
☐Research / Academic Institution
☐Independent Expert /Consultant
☐Other (Please Specify)

2.a **How would you classify the extent of the ITS deployment that is under your organization’s control? (Tick all that apply)**

☐Nationwide
☐Statewide
☐Regional
☐Municipal
☐City
☐Other (please specify)

2.b **What roadway network do you operate on? (Tick all that apply)**

☐Interstate Highways
☐Other Freeways & Expressways
☐Other Principal Arterials
☐Minor Arterials
☐Major and Minor Collectors
☐Local Roads
☐Other (please specify)

PERFORMANCE MEASURES

3a. **Which of the following best describes the Intelligent Transportation Systems (ITS) service areas currently deployed by your organization? (Tick all that apply).** *Service Areas are as described in ARC-IT 8.3.*

☐Commercial Vehicle Operations
☐Data Management
☐Maintenance and Construction
☐Parking Management
☐Public Safety
☐Public Transportation
☐Support
☐Sustainable Travel
☐Traffic Management
☐Traveler Information
☐Vehicle Safety
☐Weather

3b. **Do you currently monitor the performance of your organization's ITS programs? (Tick one only).**

☐Yes

☐No

4a. **Which of the following best describes the levels at which your organization's ITS performance is monitored? (Tick all that apply).**

☐Technology Deployment (e.g., number of speed cameras installed)
☐System Functionality (e.g., time out of service)
☐Service provision (including quality/level of service)
☐User benefits (e.g., reduction in journey times)
☐Network benefits (e.g., reduction in traffic congestion)
☐Broader economic impacts (e.g., jobs created, Gross Value Added)
☐Policy achievement (e.g., achievement of policy goals/targets)
☐Return on investment (including indicators of financial sustainability/contribution)
☐Others (please specify)

4.b **Do you consider the ITS performance monitoring by your organization beneficial to operations and taxpayers? (Tick all that apply)**

☐Yes

☐No

☐Not Sure

4.c **Who collects the data your organization uses in monitoring performance? (Tick all that apply).**

☐Public sector (e.g., data collected by local authority)

☐Private contractor (e.g., data collected by a road concessionaire/operator)

☐Privately collected (e.g., floating car data, vehicle generated data)

☐Internally collected (e.g., internal bespoke data collection exercises)

☐ITS systems (e.g., data collected and reported automatically)

☐Other (please specify)

5a **Do you publish the findings of the performance monitoring you describe? (Tick one only)**.

☐Yes - internally

☐Yes - publicly

☐Both - internal and externally

☐No

5.b **If possible, please provide us with a URL link to your published reports**

6. **Do you consult or find the suggested Performance Measures listed for individual service packages described in the ARC-IT helpful in developing your organization's ITS performance measures? (Tick one only).** See https://www.arc-it.net/html/archuse/performancemeasures.html

☐Yes

☐No

7 **Does your organization compare ITS performance, benefits, and deployment/usage with other jurisdictions or DOT/FHWA benchmark? (Tick one only)**

☐Yes

☐No

8 **What are the main barriers that prevent benchmarking or the establishment of consistent performance indicators across your organization's jurisdiction? (Tick all that apply)**

☐Lack of available data

☐Data recorded are in incomparable/inconsistent formats

☐Not part of organization's objectives

☐Lack of guidance/Best practice

☐Lack of co-operation with interested parties

☐Other (please specify)

☐None

9 **Does any of the following prevent your organization from measuring ITS performance, benefits, and deployment/usage more often or to a higher quality? (Tick all relevant)**

☐Lack of available data

☐Fragmentation and incompatibility of data

☐Unsure of benefits

☐Complexity

☐Lack of co-operation with other stakeholders

☐Other (please specify)

☐Nothing

Please provide the following details:

Name:

Organization:

Email:

Telephone Number:

Thank you for completing this questionnaire. Someone from DOTD/LTRC may contact you to follow up on some of your responses. We appreciate your input.

Table B1. Initial list of performance measures

Area	Status	DOTD Broad ITS Objectives	Potential Match to DOTD Specific Objectives [9]	Proposed Initial Performance Measures [9]
Advanced Vehicle Systems	Planned Addition	• To continually improve the safety of transportation systems for users and reduce the number of crashes and other incidents [14].	Reduce crashes at intersections	• Number of crashes and fatalities at signalized intersections • Number of crashes and fatalities at unsignalized intersections • Number of crashes and fatalities related to red-light running
			Reduce crashes due to red-light running	• Number of crashes and fatalities related to red-light running
			Reduce crashes due to road weather conditions	• Number of crashes and fatalities related to weather conditions
			Reduce crashes due to unexpected congestion	• Number of crashes and fatalities related to unexpected congestion
			Reduce crashes due to unsafe drivers, vehicles, and cargo on the transportation system	• Number of crashes and fatalities due to commercial vehicle safety violations
			Reduce crashes due to unsafe drivers, vehicles, and cargo on the transportation system	• Number of crashes and fatalities due to commercial vehicle safety violations
			Reduce time to alert travelers of travel weather impacts by X (time-period or percent) in Y years.	• Time from beginning of weather event to posting of traveler information on (variable message signs, 511, Road Weather Information Systems, public information broadcasts etc.). • Time from beginning of weather event to posting of traveler information on agency website.
Arterial Management	Existing	• To reduce recurring and non-recurring delays with a general goal to reduce travel time variability [14].	Reduce buffer index on arterials during peak and off-peak periods by X percent in Y years	• Buffer index or buffer time
			Reduce delay associated with incidents on arterials by X percent by year Y.	• Hours of delay associated with incidents.
			Attain X percent of intersections in the region equipped and operating with traffic signals that enable real-time monitoring and traffic flow management by year Y.	• Percent of intersections in the region equipped and operating with traffic signals enable real-time monitoring and traffic flow management.

Area	Status	DOTD Broad ITS Objectives	Potential Match to DOTD Specific Objectives [9]	Proposed Initial Performance Measures [9]
			Attain X percent of major and minor arterials equipped and operating with arterial link traffic data detection stations (or appropriate technology) per Z distance by year Y.	• Percent of major and minor arterials equipped and operating with arterial link traffic data detection stations (or appropriate technology) per Z distance.
			Attain X percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras per Z distance by year Y.	• Percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras per Z distance.
			Maintain a program of evaluating X percent of signals for retiming every Y years	• Number of traffic signals evaluated for retiming
			Increase the number of intersections running in a coordinated, closed-loop, or adaptive system by X percent in Y years	• Number of intersections running in a coordinated, closed-loop, or adaptive system
			Special timing plans are available for use during freeway incidents, roadway construction activities, or other special events for X miles of arterials in the region by year Y	• Number of miles of arterials that have at least one special timing plan for incidents, construction, or events
			Crash data for all arterials in the region is reviewed every X year to determine if signal adjustments can be made to address a safety issue	• Number of years between reviews of crash data on all arterials for possible signal timing impacts
			To identify the commonly congested roads in the region	• Bottleneck ranking
			Decrease the seconds of control delay per vehicle on arterial roads by X percent in Y years	• Travel times on arterials near traffic signals
			Reduce the total number of crashes in the region by X percent by year Y.	• Total crashes per X VMT
			Reduce crashes due to unexpected congestion	• Number of crashes and fatalities related to unexpected congestion
			Reduce crashes at intersections	• Number of crashes and fatalities at signalized intersections
Commercial Vehicle Operations	Existing	• To decrease resources expended on routine administrative tasks, and increase revenues resulting from: ○ Improved compliance.	Decrease point-to-point travel times on selected freight-significant highways by Y minutes within Y years	• Point-to-point travel times on selected freight-significant highways
			Increase ratings for customer satisfaction with freight mobility in the region among shippers, receivers, and carriers by X percent in Y years	• Percentage of customers satisfied with region's freight management practices
			Reduce the frequency of delays per month at intermodal facilities	• Frequency of delays per month at intermodal facilities

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
		○ Reduced motor carrier regulatory compliance cost [14] . • Reduce commercial vehicle crash rate [14]. • Improve cost-effectiveness of inspections through better targeting of unsafe and illegal carriers [14] .		• Average duration of delays per month at intermodal facilities
			Increase the use of electronic clearance at weigh stations	• Percent of weigh stations in the region using electronic credentialing.
			Decrease hours of delay per 1,000 vehicle miles traveled on selected freight significant highway	• Hours of delay per 1,000 vehicle miles on selected freight-significant highways
			Decrease the annual average travel time index for selected freight-significant highways	• Travel time index on selected freight-significant highways
			Decrease the number of size and weight violations	• Number of size and weight violations
			Decrease point-to-point travel times on selected freight-significant highways	• Point-to-point travel times on selected freight-significant highways
			Reduce number of crashes involving large trucks and buses	• Number of crashes involving large trucks and buses
			Reduce number of crashes due to commercial vehicle safety violations	• Number of crashes due to commercial vehicle safety violations
			Reduce number of fatalities involving large trucks and buses	• Number of fatalities involving large trucks and buses
			Number of fatalities involving large trucks and buses	• Number of fatalities involving large trucks and buses
			Reduce number of crashes due to commercial vehicle safety violations	• Number of crashes due to commercial vehicle safety violations
			Reduce number of fatalities involving large trucks and buses	• Number of fatalities involving large trucks and buses
			Reduce number of fatalities due to commercial vehicle safety violations	• Number of fatalities due to commercial vehicle safety violations
			Reduce number of injuries involving large trucks and buses	• Number of injuries involving large trucks and buses
Electronic Payment and Congestion Pricing	Existing	• To reduce recurring and non-recurring delays with a general goal to reduce travel time variability [14] .	Annual rate of change in regional average commute travel time will not exceed regional rate of population growth through the year Y.	• Annual rate of change in regional average commute travel time will not exceed regional rate of population growth through the year Y.
			Improve average travel time during peak periods by X percent by year Y	• Average travel time during peak periods (minutes)

Area	Status	DOTD Broad ITS Objectives	Potential Match to DOTD Specific Objectives [9]	Proposed Initial Performance Measures [9]
			Increase the percentage of users carrying electronic toll collection (ETC) transponders by X percent by year Y	• Percentage of drivers with ETC transponders
			Increase the share of freeways that are priced to X percent by year Y	• Lane miles that are priced
			Increase the share of toll roadways and bridges that are using variable pricing (e.g., congestion pricing) to X percent by year Y	• Share of toll roads and bridges using variable pricing
			Reduce excess fuel consumed due to congestion by X percent by year Y	• Excess fuel consumed (total or per capita)
			Reduce total energy consumption per capita for transportation by X percent by year Y	• Total energy consumed per capita for transportation
			Reduce total fuel consumption per capita for transportation by X percent by year Y	• Total fuel consumed per capita for transportation
			Reduce hours of delay per capita by X percent by year Y	• Hours of delay (person-hours) • Hours of delay per capita. • Hours of delay (person-hours) • Hours of delay per driver • Travel time index
Emergency Management	Existing	• To minimize the effects of unexpected crashes or incidents, bad weather, construction, and irregular congestion causes [14]. • Increase the number of people receiving accurate traveler information [14]. • Ensure citizens timely reach safe locations during emergency evacuations through the continuous	Reduce mean incident notification time (time between the first agency's awareness of an incident and time to notify needed response agencies) by X percent over Y years	• Average incident notification time of necessary response agencies
			Reduce mean time for needed responders to arrive on-scene after notification by X percent over Y years.	• Meantime for needed responders to arrive on-scene after notification
			Reduce mean incident clearance time per incident by X percent over Y years (time between awareness of an incident and time last responder left scene.)	• Mean incident clearance time per incident
			Reduce mean roadway clearance time per incident by X percent over Y years. (Defined as the time between awareness of an incident and restoration of lanes to full operational status.)	• Mean roadway clearance time per incident

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
		monitoring and management of traffic and communication [14].	Reduce mean time of incident duration (from awareness of incident to resumed traffic flow) on transit services and arterial and expressway facilities by X percent in Y years.	• Mean time of incident duration
			Reduce the person hours (or vehicle hours) of total delay associated with traffic incidents by X percent over Y years	• Person hours (or vehicle hours) of delay associated with traffic incidents
			Time to evacuate region (or subarea)	• Per capita time to evacuate
			Increase customer satisfaction with the region's incident management by X percent over Y years.	• Percentage of customers satisfied with region's incident management practices
			Reduce time between incident/emergency verification and posting a traveler alert to traveler information outlets (e.g., variable message signs, agency website, 511 system) by X minutes in Y years.	• Time to alert motorists of an incident/emergency.
			Increase number of repeat visitors to traveler information website (or 511 system) by X percent in Y years.	• Number of repeat visitors to traveler information website (or 511 system)
			Reduce the time between recovery from incident and removal of traveler alerts for that incident	• Time between recovery from incident and removal of traveler alerts
			Increase percentage of incident management agencies in the region (that participate in a multi-modal information exchange network, use interoperable voice communications, participate in a regional coordinated incident response team, etc.) by X percent in Y years.	• Percentage of incident management agencies in region participating in multi-modal information exchange network. • Number of agencies in the region with interoperable voice communications. • Number of participating agencies in a regional coordinated incident response team.
			Increase the number of corridors in the region covered by regional coordinated incident response teams by X percent in Y years.	• Number of TIM corridors in the region covered by regional coordinated incident response teams.
			Hold at least X multi-agency after-action review meetings each year with attendance from at least Y percent of the agencies involved in the incident's response.	• Number of multi-agency after-action reviews per year. • Percentage of responding agencies participating in after-action review.
			At least X percent of transportation operating agencies have a plan in place for a representative to be at the local or State	• X percent of transportation operating agencies that have a plan in place for a representative to be at the local EOC or

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
			Emergency Operations Center (EOC) to coordinate strategic activities and response planning for transportation during emergencies by year Y.	State EOC to coordinate strategic activities and response planning for transportation during emergencies.
			Increase number of ITS-related assets (e.g., roadside cameras, dynamic message signs, vehicle speed detectors) in use for incident and emergency detection by X in Y years	- Number of ITS-related assets in use for incident detection
			Increase number of regional road miles covered by ITS-related assets (e.g., roadside cameras, dynamic message signs, vehicle speed detectors) in use for incident detection by X percent in Y years.	- Number of regional roadway miles covered by ITS-related assets in use for incident detection.
			Increase number of traffic signals equipped with emergency vehicle preemption by X percent in Y years	- Number of traffic signals equipped with emergency vehicle preemption
			Conduct X joint training exercises among operators and emergency responders in the region by year Y	- Number of joint training exercises conducted among operators and emergency responders.
Freeway Management	Existing	- To reduce recurring and non-recurring delays with a general goal to reduce travel time variability [14]. - Increase the number of people receiving accurate traveler information [14]. - Increase the number of people receiving transit schedule information [14].	Reduce the number of person hours (or vehicle hours) of delay experienced by travelers on the freeway system.	- Hours of delay (vehicle-hours or person-hours) - Hours of delay per capita or driver
			Reduce the share of freeway miles at Level of Service (LOS) X by Y by year Z	- Miles at LOS X or V/C > 1.0 (or other threshold)
			Reduce buffer index on the freeway system during peak and off-peak periods by X percent in Y years.	- Buffer index
			Reduce delay associated with incidents on the freeway system by X percent by year Y	- Hours of delay associated with incidents
			Increase the miles of managed lanes in the region from X to Y by year Z	- Miles of managed lanes
			Provide options for reliable travel times for certain types of travel (e.g., transit, carpools, trucks, etc.) on at least X percent of the freeway network by year Y	- Share of freeway network with managed lanes (by class of traveler)
			Ensure that all managed lanes (e.g., HOV lanes, HOT lanes) operate at no less than 50 mph during their hours of operation	- Average speeds in managed lanes
			Ensure that all managed lanes (e.g., HOV lanes, HOT lanes) operate with a volume of at least X vehicles per hour	- Vehicle volumes in managed lanes

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
				- Passenger volumes in managed lanes.
			Increase the number of HOV lane miles from X to Y by year Z.	- Total number of HOV lane miles in a region
			Provide options for reliable travel times for carpools and transit on at least X percent of the freeway network by year Y	- Share of freeway network with HOV lanes
			Ensure that all HOV lanes operate at no less than 50 mph during their hours of operation.	- Minimum and Average speeds in HOV lanes
			- Ensure that all HOV lanes operate with a volume of at least X vehicles per hour. - Ensure that all HOV lanes carry a throughput of at least Y persons per hour. - Increase the average vehicle occupancy rate in HOV lanes to X by year Y.	- Vehicle volume and persons per hour per lane.
			'Increase the compliance rate for HOV lanes to X percent by year Y	- Percent of vehicles violating HOV restrictions
			'Increase the percentage of users carrying electronic toll collection (ETC) transponders by X percent by year Y.	- Percentage of drivers with ETC transponders
			'Increase the share of toll roadways and bridges that are using variable pricing (e.g., congestion pricing) to X percent by year Y	- Share of toll roads and bridges using variable pricing
			'Increase the share of freeways that are priced to X percent by year Y	- Lane miles that are priced
			'Increase the percent of freeway interchanges operating at LOS Z or higher during peak periods by X percent by year Y.	- Percent of interchanges operating at LOS Z or above during peak periods (per year).
			'Reduce the number of congestion-inducing incidents occurring at freeway ramps by X percent by year Y.	- Total number of congestion-inducing incidents at freeway interchanges during peak period (per year).
			'Increase the number freeway ramps currently metered by X percent by year Y.	- Total number of ramp meters (by year of installation).
			'Increase the level of traffic management center (TMC) field hardware (cameras, variable message signs, electronic toll tag readers, ITS applications, etc.) by X percent by year Y.	- Total amount of TMC equipment.

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
			'Increase the hours of TMC operation and level of staffing by X percent by year Y	• Number of hours of TMC operation and number of staff serving the TMC
			'Increase the percent of regional transportation system monitored by the TMC for real time performance	• Percent of regional transportation system monitored by the TMC for real-time performance
Incident Management	Existing	Note: Same objectives as emergency management	Note: Same objectives as emergency management	• Note: Same performance measures as emergency management
Information Management	Planned	• Provide real-time, accurate traveler information: ○ Leverage DOTD as the trusted source for traveler information ○ Offer a comprehensive suite for public and partner access to traffic and travel information. ○ Disseminate enhanced information on incidents, construction projects, emergencies, and special events [1] .	Enhance planning with better data	• Amount of data gathered from ITS enhancements used in infrastructure and operations planning. • Number of planning activities using data from ITS systems. • Years of data in database that is easily searchable and extractable. • Amount of data gathered from ITS enhancements used in infrastructure and operations planning. • Number of planning activities using data from ITS systems. • Years of data in database that is easily searchable and extractable
			Field data collection conducted either through floating car studies or other methods at least once every Y years on major signalized arterials and X years on minor signalized arterials.	• Number of field data collection studies performed every Y and X years on major and minor signalized arterials, respectively.
			Increase the percent of modes in the region that share their traveler information with other modes by X percent by Y year.	• Percent of modes in the region that share their traveler information with other modes.
			Increase the percent of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc. to X percent by Y year.	• Percent of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc.
			Increase the percent of transportation facilities whose owners share their traveler information with other agencies in the region to X percent by Y year.	• Percent of transportation facilities whose owners share their traveler information with other agencies in the region.

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
			X percent of intersections in the region that are equipped and operating with traffic signals that enable real-time monitoring and management of traffic flows by year Y.	• Percent of intersections in the region equipped and operating with traffic signals that enable real-time monitoring and management of traffic flows.
			X percent of major and minor arterials are equipped and operating with arterial link traffic data detection stations (appropriate technology) per Z distance by year Y.	• Percent of major and minor arterials equipped and operating with arterial link traffic data detection stations (appropriate technology) per Z distance.
			X percent of major and minor arterials are equipped and operating with closed circuit television (CCTV) cameras per Z distance by year Y.	• Percent of major and minor arterials equipped and operating with closed circuit television (CCTV) cameras per Z distance.
Infrastructure Monitoring and Security	Planned	• To optimize existing transportation system by maintaining infrastructure assets in a state of good repair and implement intersection and signal improvements [1]	Distressed pavement condition lane-miles not to exceed X percent of total state highway system	• Distressed pavement condition lane miles
			Enhance asset and resource management	• Extended pavement life due to truck weight enforcement • Number of assets tracked in real-time. • Percentage of geographic jurisdiction covered by agency electronic communications. • Percentage of maintenance activities completed in required time-frame. • Rate at which equipment is utilized. • Vehicle operating costs.
			Maintain pavement condition index (PCI) of X or greater for local streets and roads	• Pavement condition index
			Establish a work zone management system within X years to facilitate coordination of work zones in the region.	• Presence of an established work zone management system.
			Field data collection is conducted either through floating car studies or other methods at least once every Y years on major signalized arterials and X years on minor signalized arterials.	• Number of field data collection studies performed every Y and X years on major and minor signalized arterials, respectively.
			Increase number of ITS-related assets (e.g., roadside cameras, dynamic message signs, vehicle speed detectors) in use for incident and emergency detection by X in Y years.	• Number of ITS-related assets in use for incident detection.

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
			Increase number of regional road miles covered by ITS-related assets (e.g., roadside cameras, dynamic message signs, vehicle speed detectors) in use for incident detection by X percent in Y years.	• Number of regional roadway miles covered by ITS-related assets in use for incident detection.
			Decrease by X percent on an annual basis the number of complaints per 1,000 boarding passengers.	• Complaint rate.
			Decrease the number of personal safety incidents by X percent within Y years.	• Number of reported personal safety incidents.
			Increase customer service and personal safety ratings by X percent within Y years.	• Personal safety and customer service ratings.
			Increase the number of closed-circuit television (CCTV) cameras installed by X percent in Y years on platforms, park-n-ride lots, vehicles, and other transit facilities.	• Number of CCTV cameras on platforms, park-n-ride lots, vehicles, and other transit facilities.
			Reduce mean incident notification time (defined as the time between the first agency's awareness of an incident and the time to notify needed response agencies) by X percent over Y years	• Average incident notification time of necessary response agencies.
			Reduce mean time of incident duration (from awareness of incident to resumed traffic flow) on transit services and arterial and expressway facilities by X percent in Y years.	• Mean time of incident duration.
			Reduce security risks to motorists and travelers	• Number of critical sites with security surveillance • Number of security incidents on roadways
			Enhance tracking and monitoring of sensitive Hazmat shipments	• Number of Hazmat shipments tracked in real-time
			Reduce security risks to transit passengers and transit vehicle operators	• Number of security incidents at transit facilities • Number of security incidents on transit vehicles • Number of transit facilities and vehicles under security surveillance
			Reduce security risks to transportation infrastructure	• Number of critical sites with hardened security enhancements • Number of critical sites with security surveillance

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
				• Number of security incidents on transportation infrastructure
			Enhance tracking and monitoring of sensitive Hazmat shipments	• Number of Hazmat shipments tracked in real-time
			Reduce exposure due to Hazmat & homeland security incidents	• Homeland security incident response time • Number of Hazmat incidents • Number of homeland security incidents
			Enhance tracking and monitoring of sensitive Hazmat shipments	• Number of Hazmat shipments tracked in real-time
Maintenance of ITS Devices	Existing	• To optimize existing transportation system by maintaining infrastructure assets in a state of good repair and implement intersection and signal improvements [1].	*Note: partly covered under Infrastructure Monitoring and Security*	• Note: partly covered under Infrastructure Monitoring and Security
			Install ITS applications according to the recommended coverage and priorities presented in this plan.	• Percentage of system coverage for each device type
			Maintain the ITS devices such that they are available and accurate.	• Uptime for each device type
			'Develop construction and integration standards for incorporation into design and construction standards.	• Percentage complete for integration of construction standards
			Integrate planning-level guidance for the installation of ITS applications into planning and design processes.	• Percentage complete for integration of planning processes
			Install target level of communications to devices, facilities, and partners for whom they have been identified.	• Percentage of devices with a target level of connectivity
			Provide physical and device redundancy	• Percentage of sites with target redundancy
			Maintain network operations for high availability	• Network uptime
			Maintain a high level of network security.	• Number of thwarted security attempts
			Develop and implement network operations and network security plans, policies, processes, and procedures.	• Percentage complete for network security plans, policies, processes, procedures • Successful execution of developed network and security plans

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
Motorist Assistance Patrol	Existing	• To minimize the effects of unexpected crashes or incidents, bad weather, construction, and irregular congestion causes [14].	Increase customer satisfaction with the region's incident management by X percent over Y years.	• Percentage of customers satisfied with region's incident management practices.
			Increase the number of corridors in the region covered by regional coordinated incident response teams by X percent in Y years.	• Number of TIM corridors in the region covered by regional coordinated incident response teams.
			Reduce buffer index on arterials during peak and off-peak periods by X percent in Y years.	• Buffer index
			Reduce delay associated with incidents on arterials by X percent by year Y.	• Hours of delay associated with incidents.
			Reduce mean incident clearance time per incident by X percent over Y years. (Defined as the time between awareness of an incident and the time the last responder has left the scene.)	• Mean incident clearance time per incident.
			Reduce mean incident notification time (defined as the time between the first agency's awareness of an incident and the time to notify needed response agencies) by X percent over Y years (i.e., through "Motorist Assist" roving patrol programs, reduction of inaccurate verifications, etc.).	• Average incident notification time of necessary response agencies.
			Reduce mean roadway clearance time per incident by X percent over Y years. (Defined as the time between awareness of an incident and restoration of lanes to full operational status.)	• Mean roadway clearance time per incident.
			Reduce mean time for needed responders to arrive on-scene after notification by X percent over Y years.	• Mean time for needed responders to arrive on-scene after notification.
			Reduce mean time of incident duration (from awareness of incident to resumed traffic flow) on transit services and arterial and expressway facilities by X percent in Y years.	• Mean time of incident duration.
			Reduce the annual monetary cost of congestion per capita for the next X years.	• Cost (in dollars) of congestion or delay per capita.
			Reduce the person hours (or vehicle hours) of total delay associated with traffic incidents by X percent over Y years.	• Person hours (or vehicle hours) of delay associated with traffic incidents.
Traffic Management Centers	Existing	• Ensure citizens timely reach safe locations during emergency evacuations through the continuous	'Increase the level of traffic management center (TMC) field hardware (cameras, variable message signs, electronic toll tag readers, ITS applications, etc.) by X percent by year Y.	• Total amount of TMC equipment.

Area	Status	DOTD Broad ITS Objectives	Potential Match to DOTD Specific Objectives [9]	Proposed Initial Performance Measures [9]
		monitoring and management of traffic and communication [14].	'Increase the hours of TMC operation and level of staffing by X percent by year Y	- Number of hours of TMC operation and number of staff serving the TMC
		- To reduce recurring and non-recurring delays with a general goal to reduce travel time variability [1].	'Increase the percent of regional transportation system monitored by the TMC for real time performance	- Percent of regional transportation system monitored by the TMC for real-time performance
Travel Demand Management	Planned	- To reduce recurring and non-recurring delays with a general goal to reduce travel time variability [14]. - Increase the number of people receiving accurate traveler information [14]. - Increase the number of people receiving transit schedule information [14].	Increase the percentage of major employers actively participating in transportation demand management programs by X percent within Y years	- Percent of major employers with active TDM programs.
			Reduce commuter vehicle miles traveled (VMT) per regional job by X percent in Y years.	- Commuter VMT per regional employee.
			Annually promote shuttle service between X major activity centers and major destinations that are not already accommodated within 1/4 mile by other transit services.	- Percent of residents in region receiving marketing material on shuttle service opportunities.
			- Increase the number of carpools by X percent over the next Y years. - Increase use of vanpools by X percent over the next Y years.	- Share of household trips by each mode of travel.
			'Provide carpool/vanpool matching and ridesharing information services by year Y	- Number of trips in region
			'Reduce trips per year in region by X percent through carpools/vanpools.	- Availability of carpool/vanpool matching and ridesharing information services.
			'Create and share regional carpool/vanpool database with Z number of employers per year	- Number of employers with access to regional carpool/vanpool database.
			'Increase the number of travelers commuting via walking and/or bicycling by X percent over Y years.	- Number of travelers commuting via walking and/or bicycling.
			'Annually update bicycle/pedestrian map for accuracy.	- Number of months since the last update of the bicycle/pedestrian map.
			'Increase the number of available tools for travelers that incorporate a bicycle/pedestrian component by X percent by year Y.	- Number of traveler tools with a bicycle/pedestrian component.

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
			'Implement shared parking for X communities every Y year.	• Number of communities with shared parking. • Number of communities with priced parking stalls.
			'Install parking meters along X corridors by year Y in the urban core/transit supportive areas.	• Number of corridors in urban core/transit supportive areas with parking meters.
			'Increase park-and-ride lot capacity by X percent over Y years.	• Capacity of park and ride lots.
			'Biannually increase preferred parking spaces for carpool/vanpool participants within downtown, at special events, and among major employers by X percent within Y years	• Number of preferred parking spaces for carpool/vanpool participants
			'Increase the number of residents/commuters receiving information on parking pricing and availability within Y years.	• Number of residents/commuters receiving information on parking pricing and availability.
			'Develop and provide travel option services to X identified communities and audiences within Y years.	• Number of communities receiving travel option services.
			'Construct visitor information centers in X communities by year Y.	• Number of communities in which visitor information centers are constructed.
			'Create a transportation access guide, which provides concise directions to reach destinations by alternative modes (transit, walking, bike, etc.) by year Y.	• Implementation of transportation access guide.
			'Develop and enhance (e.g., through ease of navigation techniques) X number of web-based traveler information tools.	• Number of web-based traveler information tools developed or enhanced
Traveler Information	Existing	• Increase the number of people receiving accurate traveler information [14]. • Ensure citizens timely reach safe locations during emergency evacuations through the continuous monitoring and management of traffic and communication [14].	Increase number of 511 calls per year by X percent in Y years.	• Number of 511 calls per year.
			Increase number of visitors to traveler information website per year by X percent in Y years.	• Number of visitors to traveler information website per year.
			Increase number of users of notifications for traveler information (e.g., e-mail, text message) by X percent in Y years.	• Number of users of notifications for traveler information (e.g., e-mail, text message) per year.
			Increase number of web apps (e.g., Twitter, Facebook) followers by X percent in Y months.	• Number of web (e.g., Twitter, Facebook) followers.
			Increase the accuracy and completeness of traveler information posted (on variable message signs, websites etc.) by reducing the	• Number of complaints received from system users about inaccurate or missing information.

Area	**Status**	**DOTD Broad ITS Objectives**	**Potential Match to DOTD Specific Objectives** [9]	**Proposed Initial Performance Measures** [9]
		- Increase the number of people receiving transit schedule information [14].	number of incomplete and inaccurate reports by X percent in Y years.	
			Enhance regional multimodal trip planning tools to X data sources by year Y	- The number of data sources providing information for multi-modal trip planning tools.
			Increase the ease of use of trip planning tools by X percent by year Y	- Trip planning tools ease of use rating
			Increase the number of uses of multimodal trip planning tools by X percent by year Y.	- Number of uses of trip planning tools.
			Increase the percent of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc. to X percent by Y year.	- Percent of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc.
			Increase the percent of transportation facilities whose owners share their traveler information with other agencies in the region to X percent by Y year.	- Percent of transportation facilities whose owners share their traveler information with other agencies in the region.
			Increase the percent of modes in the region that share their traveler information with other modes in the region to 100 percent by Y year.	- Percent of modes in the region that share their traveler information with other modes.
			Increase customer satisfaction rating of the timeliness, accuracy, and usefulness of traveler information in the region by W, X, and Z percent, respectively, over Y years.	- Customer satisfaction ratings of timeliness, accuracy, and usefulness of traveler information.
Work Zone Management	Planned	- To minimize the effects of unexpected crashes or incidents, bad weather, construction, and irregular congestion causes [14].	Reduce the person hours (or vehicle hours) of total delay associated with work zones by X percent over Y years.	- Person hours (or vehicle hours) of delay associated with work zones.
			Increase the rate of on-time completion of construction projects to X percent within Y years.	- Percent of construction projects completed on-time according to established schedule.
			Increase the percentage of construction projects that employ night/ off-peak work zones by X percent in Y years.	- Percent of construction project employing night /off-peak work zones.
			Reduce the percentage of vehicles traveling through work zones that are queued by X percent in Y years.	- Percentage of vehicles experiencing queuing in work zones.
			Reduce the average and maximum length of queues, when present, by X percent over Y years.	- Length of average and maximum queues in work zones.

Area	Status	DOTD Broad ITS Objectives	Potential Match to DOTD Specific Objectives [9]	Proposed Initial Performance Measures [9]
			Reduce the average time duration (in minutes) of queue length greater than some threshold (e.g., 0.5 mile) by X percent in Y years.	• Average duration in minutes of queue length greater than X miles.
			Reduce vehicle-hours of total delay in work zones caused by incidents (e.g., traffic crashes within or near the work zone).	• Vehicle-hours of delay due to incidents related to work zones.
			Increase the number of capital projects reviewed for regional construction coordination by X percent in Y years.	• Percent of capital projects whose project schedules have been reviewed.
			Decrease the number of work zones on parallel routes/along the same corridor by X percent in Y years.	• Percent of work zones on parallel routes/along the same corridor.
			Establish a work zone management system within X years to facilitate coordination of work zones in the region.	• Presence of an established work zone management system.
			Provide traveler information regarding work zones using variable message signs (VMS), 511, traveler information websites, and/or web technologies for at least X percent of work zones on major arterials, freeways, and transit routes over the next Y years.	• Percent of work zones on major arterials, freeways, and transit routes for which traveler information is available via variable message signs (VMS), 511, traveler information websites, and/or web technologies.
			Provide travelers with information on multimodal alternatives to avoid work zones for at least X percent of work zones on major arterials, freeways, and transit routes over the next Y years.	• Percent of work zones on major arterials, freeways, and transit routes for which information on multimodal alternatives to avoid work zones is available to travelers.
			Provide work zone information (for upcoming and ongoing construction projects) to all impacted businesses or tenants of business centers with X employees or more by year Y.	• Number of impacted businesses or tenants of business centers of X employees or more receiving work zone information (for upcoming and ongoing construction projects).
			Increase customer satisfaction with region’s work zone management by X percent over Y years.	• Percentage of customers satisfied with region’s work zone management practices.

Table B2. Final list of performance measures

Program Area	#	Objectives	Performance Measures	Data	Data Sources	Extent of Study
Arterial Management	1	Increase percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras	Percent of major and minor arterials equipped and operating with closed-circuit television (CCTV) cameras per Z distance.	• Inventory and installed locations of CCTV cameras	Data available to the team	Assess coverage of closed-circuit television (CCTV) cameras on significant highways in Louisiana. ArcGIS will be used to develop a coverage map.
	2	Reduce delay associated with incidents on arterials	Delay associated with incidents	• Travel time data	Crash database/RITIS	Evaluate change in incident response time on highway segments with CCTV coverage.
Commercial Vehicle Operations	1	Decrease point-to-point travel times on selected freight-significant highways	Point-to-point travel times on selected freight-significant highways	• Travel time data	RITIS	An assessment of travel time of commercial vehicles on freight significant highways in Louisiana.
	2	Decrease hours of delay per 1,000 vehicle miles traveled on selected freight significant highway	Hours of delay per 1,000 vehicle miles on selected freight-significant highways.			
	3	Decrease the annual average travel time index for selected freight-significant highways	Travel time index on selected freight-significant highways.			
	4	Reduce commercial vehicle crash rate.	Number of crashes involving large trucks and buses	Number of crashes involving large trucks and buses	Crash database	
Electronic Payment and Congestion Pricing	1	Improve average travel time during peak periods	Average travel time during peak periods (minutes)	• Travel time data • Person travel along links	RITIS	Evaluation of peak travel time on tolled southbound Causeway Blvd.
	2	Reduce hours of delay per capita	Hours of delay (person-hours)			
Emergency Management and Motorist Assistance Patrol	1	Reduce mean incident clearance time per incident	• Roadway clearance duration. • Number of ITS-related assets in use for incident detection • Hours of delay associated with incidents. • Person hours (or vehicle hours) of delay associated with traffic incidents.	• Incident notification time, On-scene arrival time for incident, time full traffic operational status returns. • Travel time data • Count of deployed technology – roadside cameras, dynamic message signs, vehicle speed detectors	Crash database	An assessment of incident clearance time on Louisiana's roadways with MAP coverage.
	2	Increase number of ITS-related assets				
Freeway Management & Traffic Management Centers	1	Increase the level of traffic management center (TMC) field hardware.	• Total number of TMC equipment • Number of hours of TMC operation and number of staff • Percent of regional transportation system monitored by the TMC for real-time performance	• Inventory of TMC field hardware • Number of TMC staff per location • Number of transportations systems monitored in real-time • Percent/Number of transportation systems targeted to be monitored in real-time	TMCs to assist	Inventory of statewide TMC (ITS) resources and an evaluation of transportation systems monitored by TMC for real-time performance.
	2	Increase the hours of TMC operation and level of staffing				
	3	Increase the percent of regional transportation systems monitored by the TMC for real-time performance				

Program Area	#	Objectives	Performance Measures	Data	Data Sources	Extent of Study
	4	Determine the effect of DMS signs on driving behavior.	Effect of DMS signs on driving behavior.	Travel Speeds	RITIS	Evaluate changes in driving behavior (change in speeds) on roadway segments with DMS installation in Louisiana.
	5	Determine effects of Ramp Meters on traffic flow and safety at merge sections.	• Queue Length • Number of Crashes	• Queue Length • Number of Crashes	Crash database/ Localized data	Assess safety (number of crashes) and operations (queue length) performance of active ramp meters in Louisiana.
Traveler Information	1	Increase the number of traveler information portals	• Number of 511 calls per year. • Number of visitors to traveler information website per year. • Number of users of notifications for traveler information (e.g., e-mail, text message) per year. • Number of web (e.g., Twitter, Facebook) followers. • Number of complaints received from system users about inaccurate or missing information.	• Count of users of 511 channels • Count of traveler information website users • Count of users of notifications of traveler information (e.g., e-mail, text message) • Count of web followers (e.g., Twitter, Facebook, etc.) • Number of customer complaints regarding incomplete or inaccurate traveler information.	Louisiana 511 Program	Evaluation of the current state of Louisiana's traveler information program area.
	2	Increase the accuracy of traveler information posted				

Appendix C

Figure C1. CCTV camera coverage in Louisiana to greater details

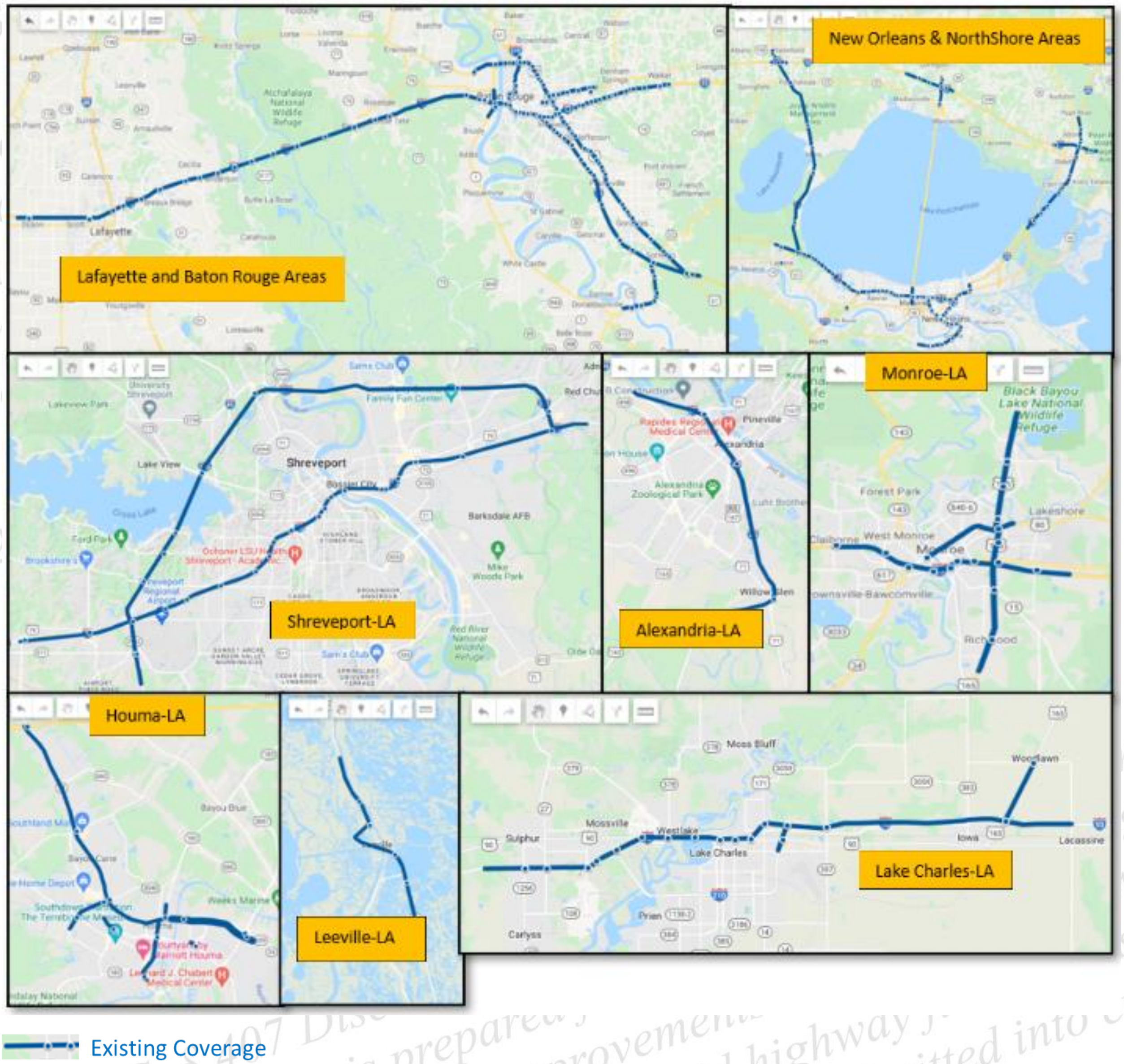


Figure C2. Crash frequencies per year on I-10 Louisiana

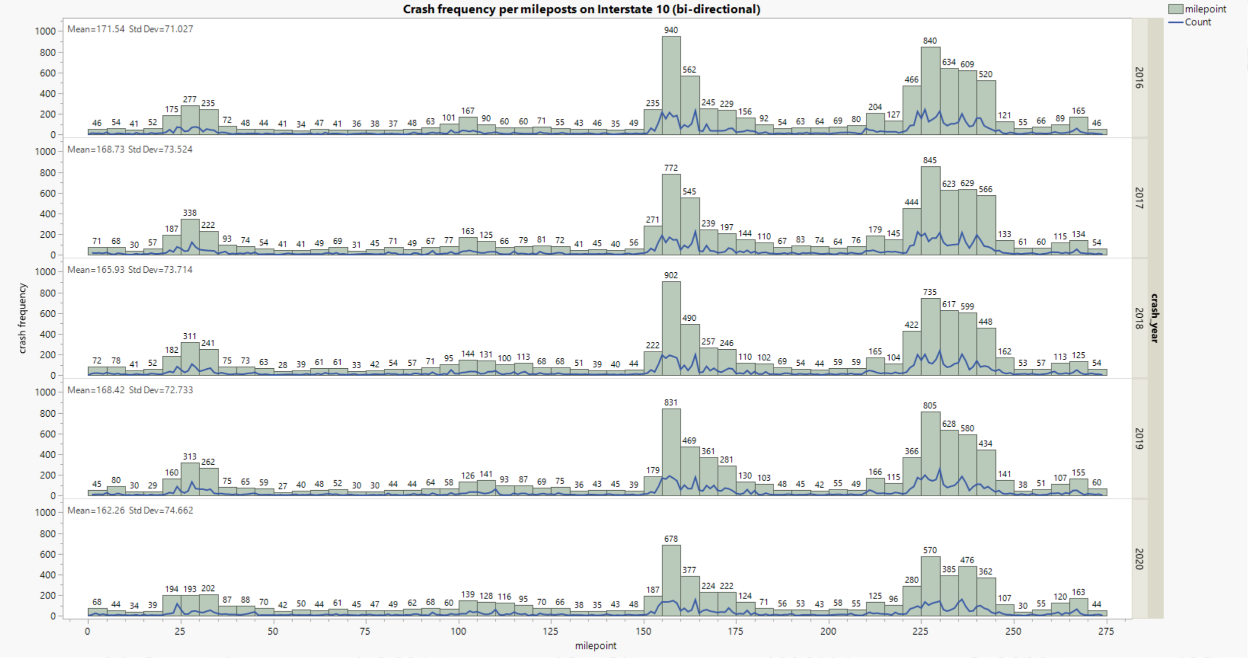


Figure C3. Crash frequencies per year on I-12 Louisiana

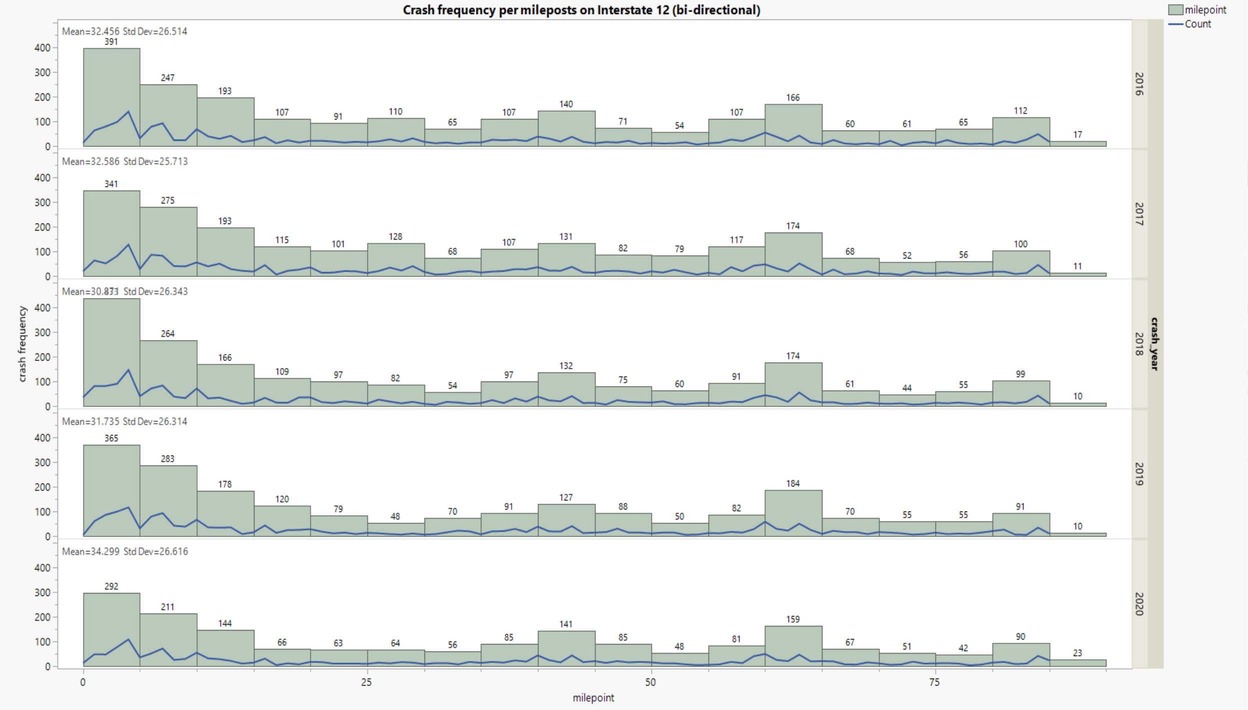


Figure C4. Crash frequencies per year on I-20 Louisiana

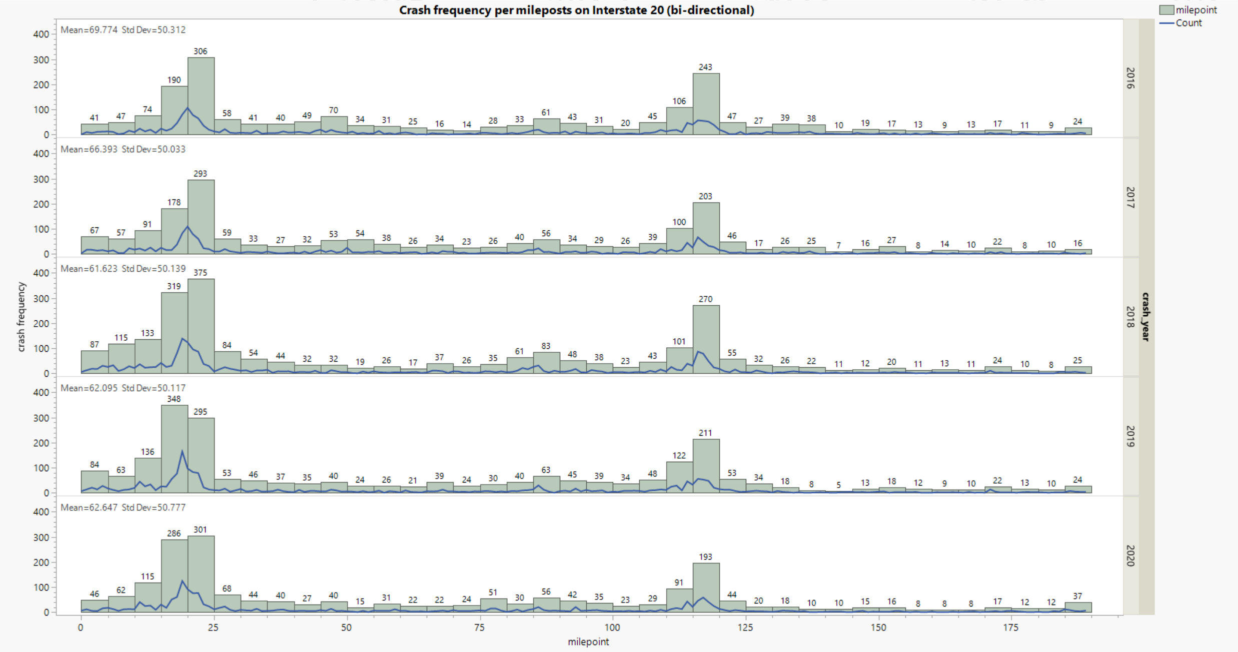


Figure C5. Crash frequencies per year on I-49 Louisiana

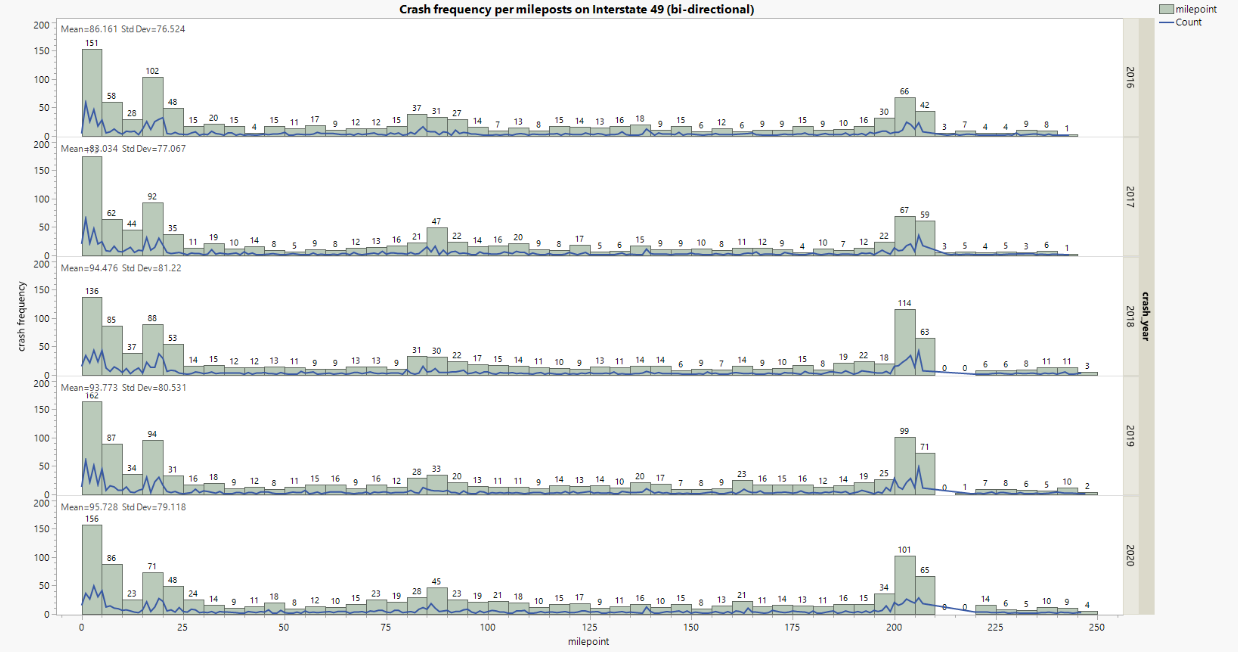


Figure C6. Crash frequencies per year on I-55 Louisiana

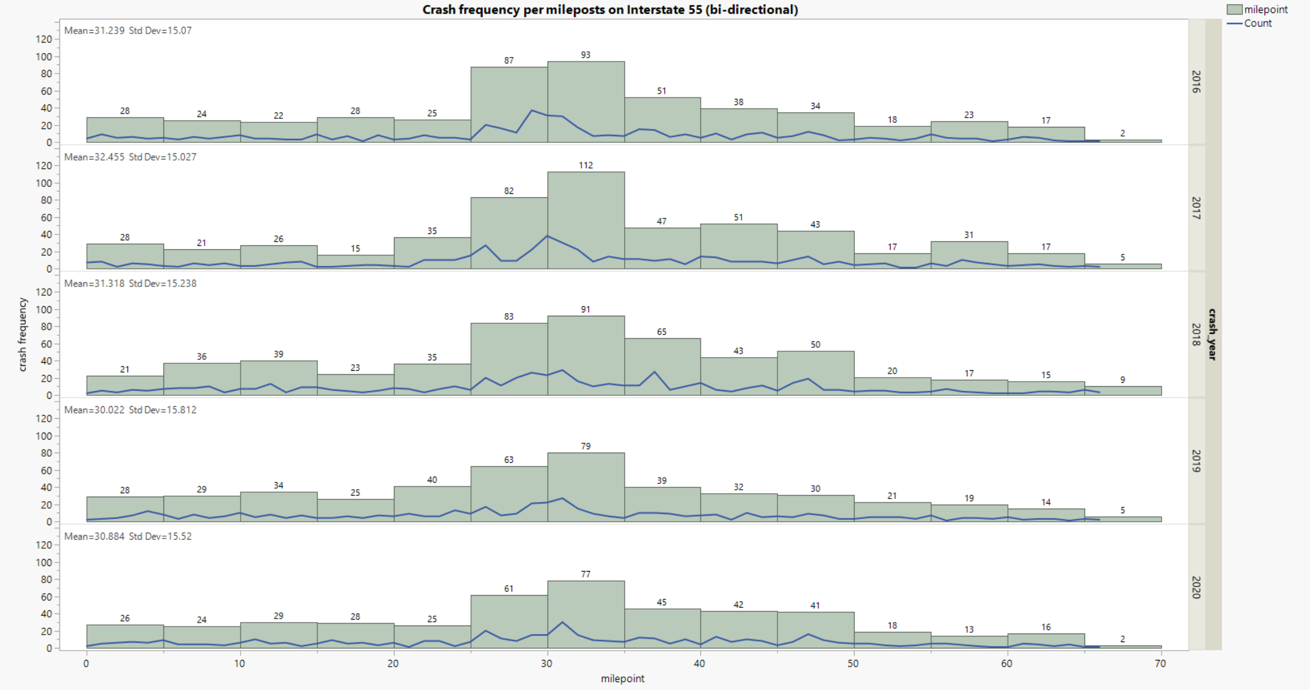


Figure C7. Crash frequencies per year on I-59 Louisiana

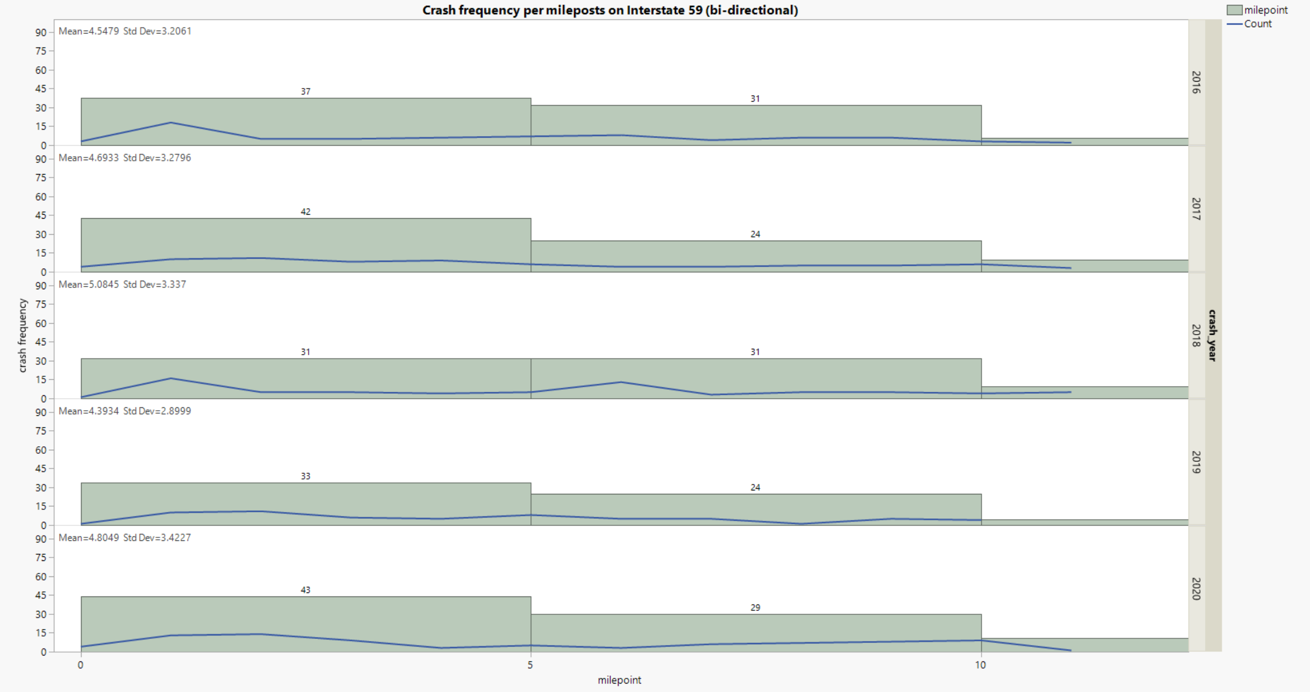


Figure C8. Crash frequencies per year on I-110 Louisiana

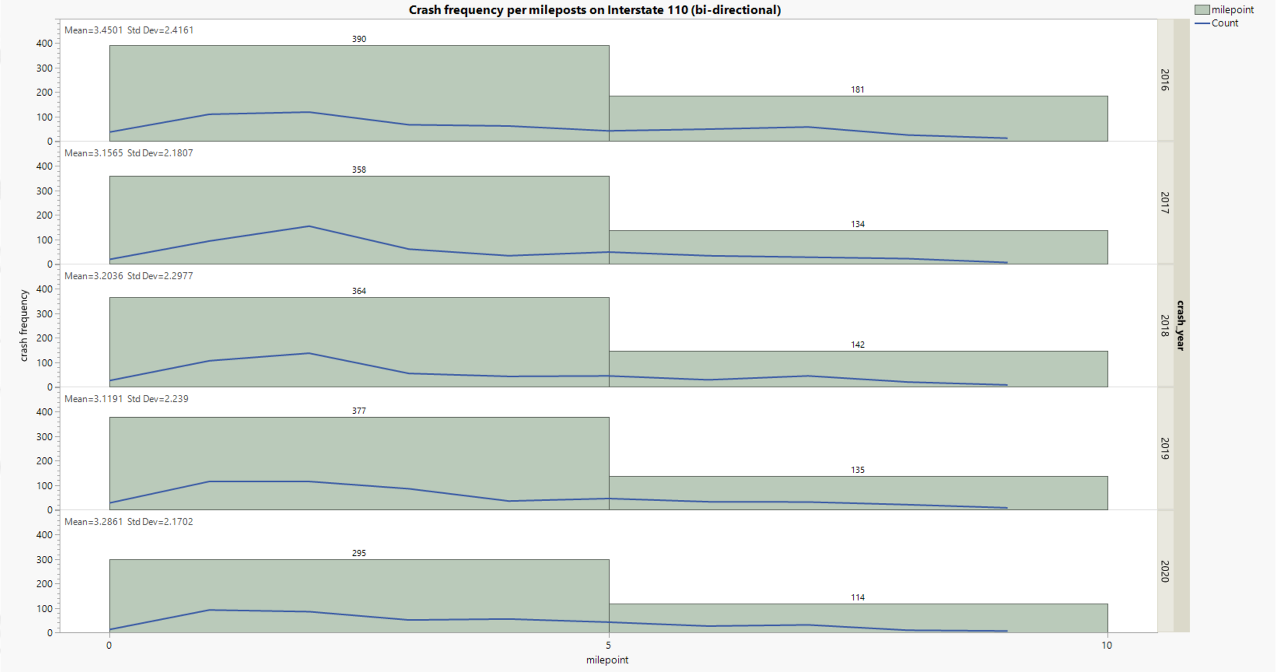


Figure C9. Crash frequencies per year on I-210 Louisiana

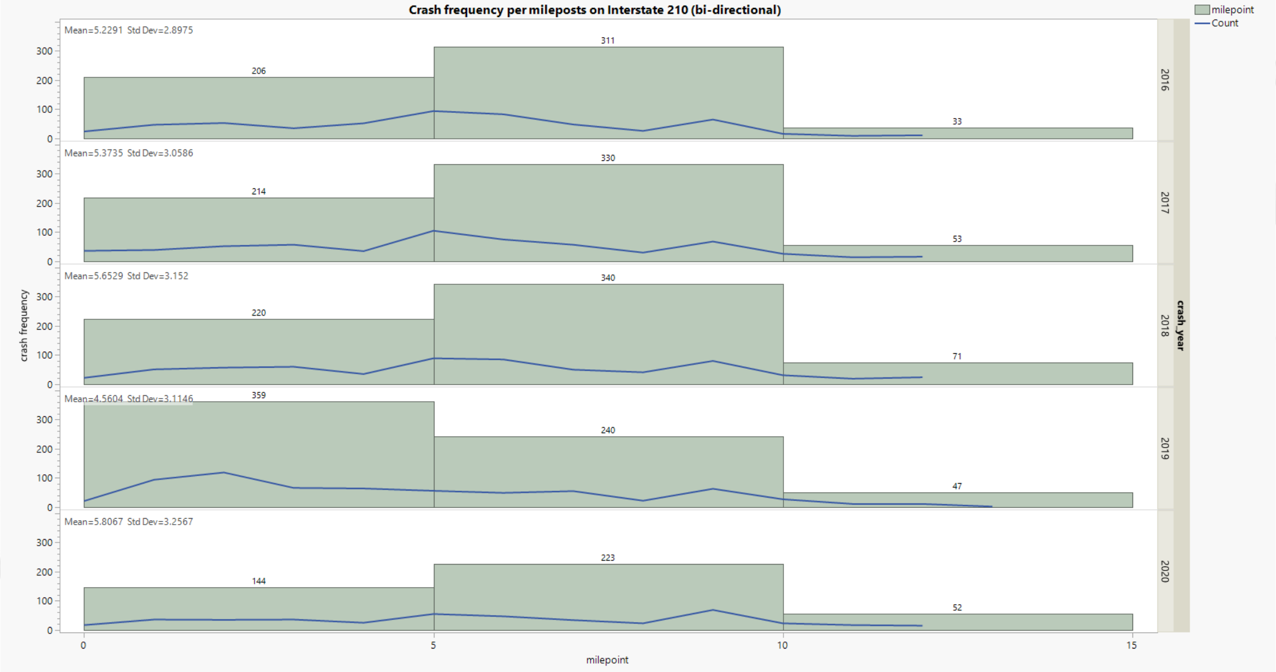


Figure C10. Crash frequencies per year on I-220 Louisiana

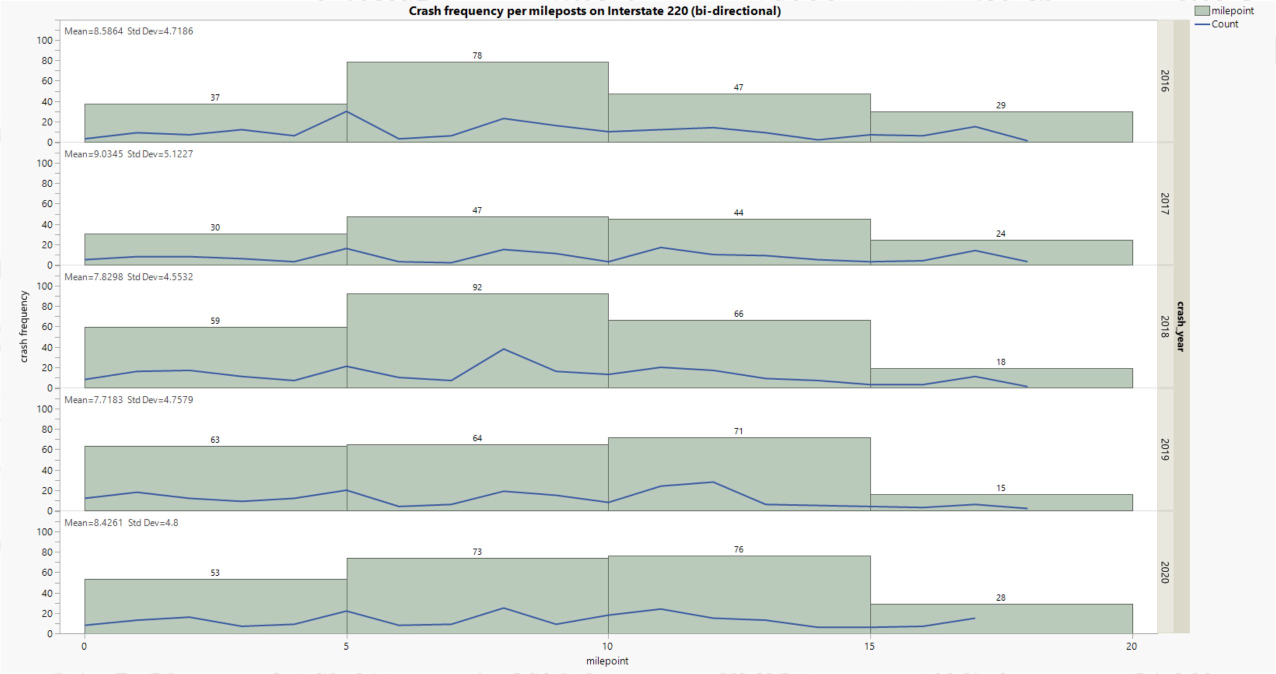


Figure C11. Crash frequencies per year on I-310 Louisiana

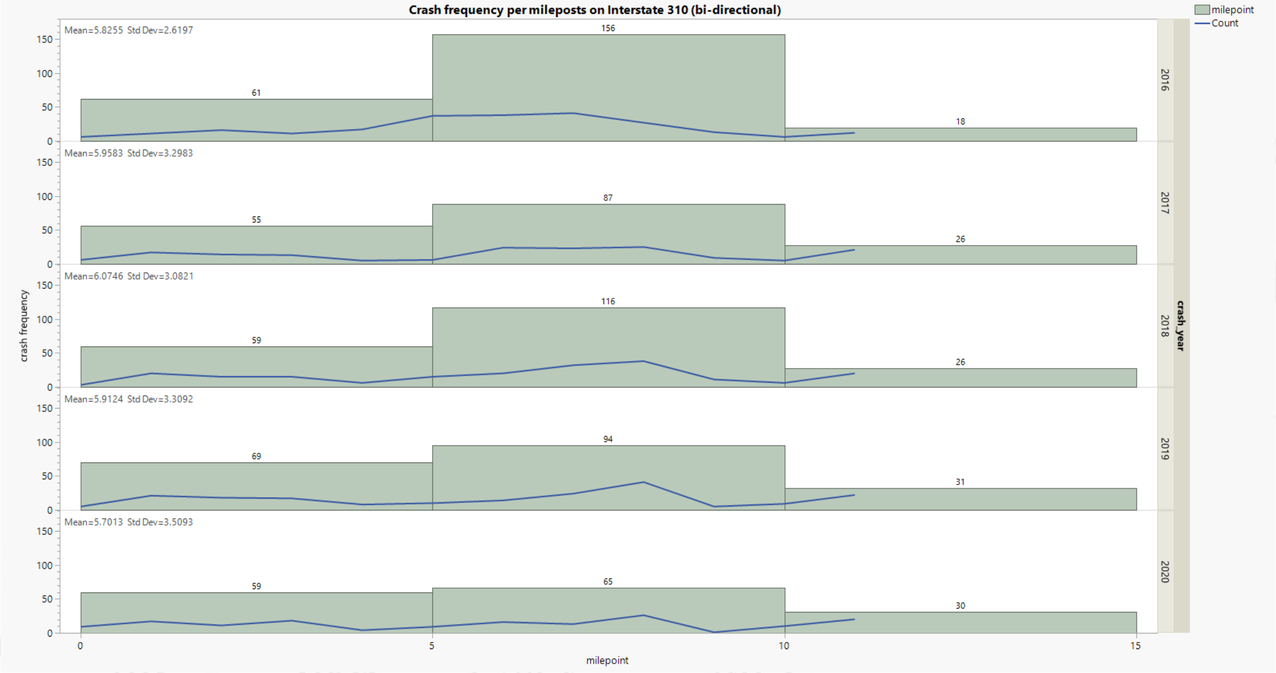


Figure C12. Crash frequencies per year on I-510 Louisiana

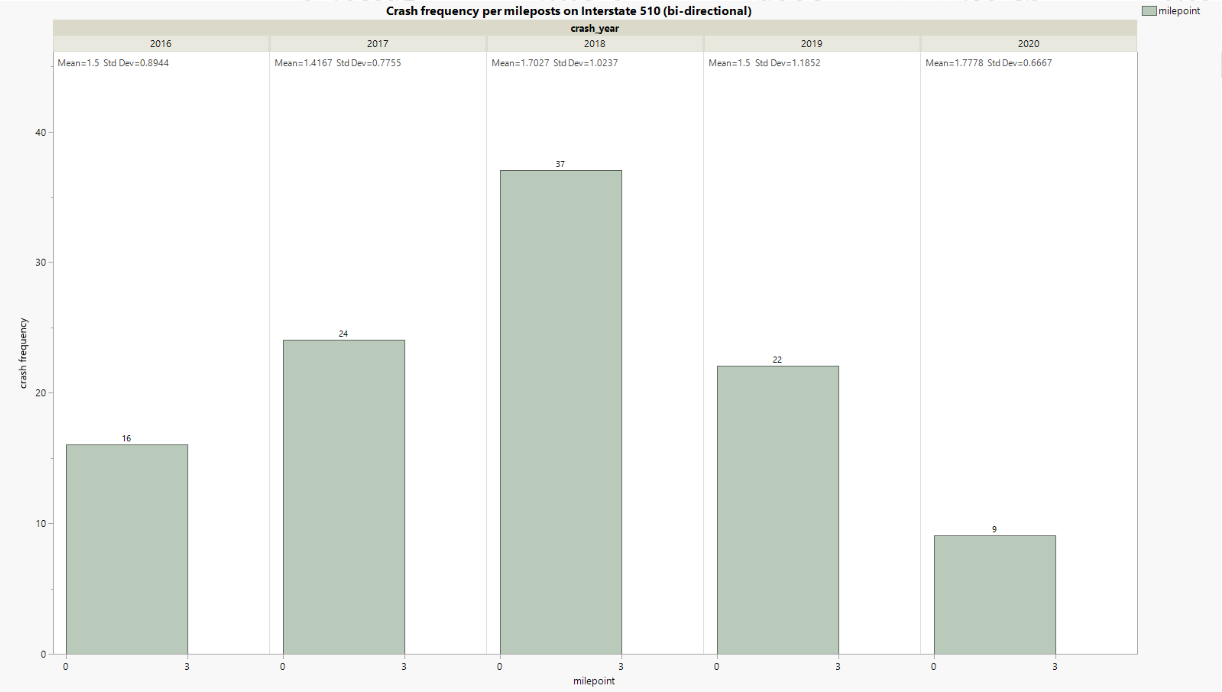


Figure C13. Crash frequencies per year on I-610 Louisiana

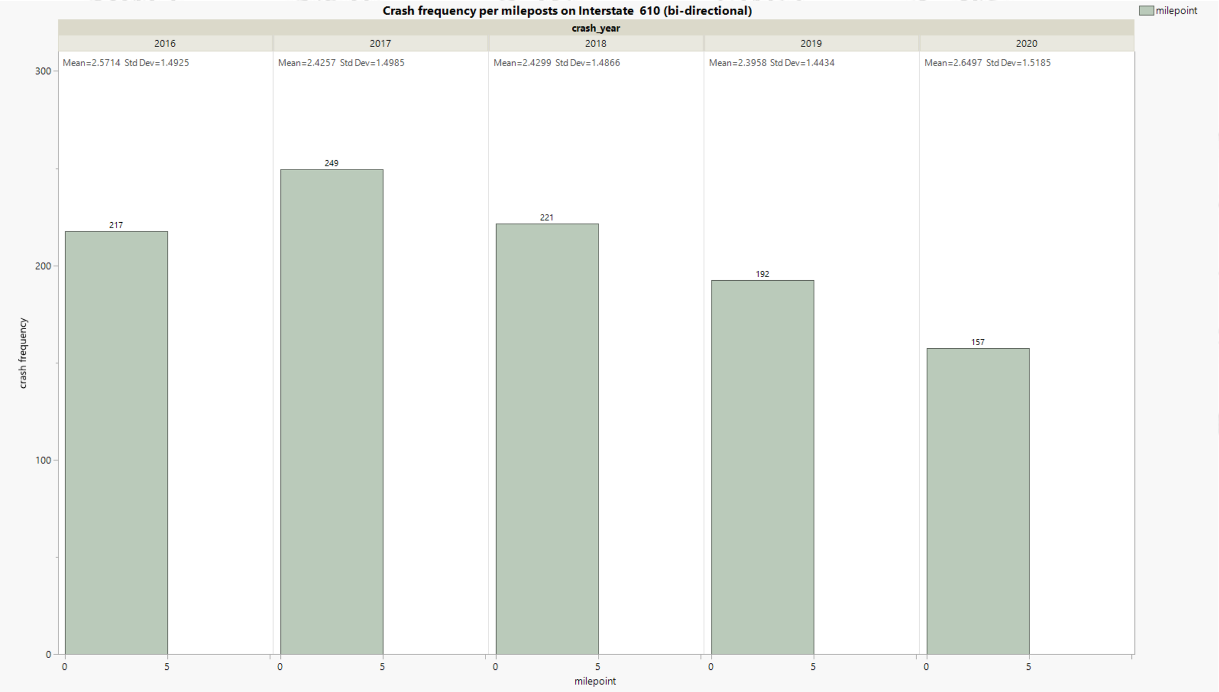


Figure C14. Current CCTV coverage and segment with high crash frequencies in Louisiana

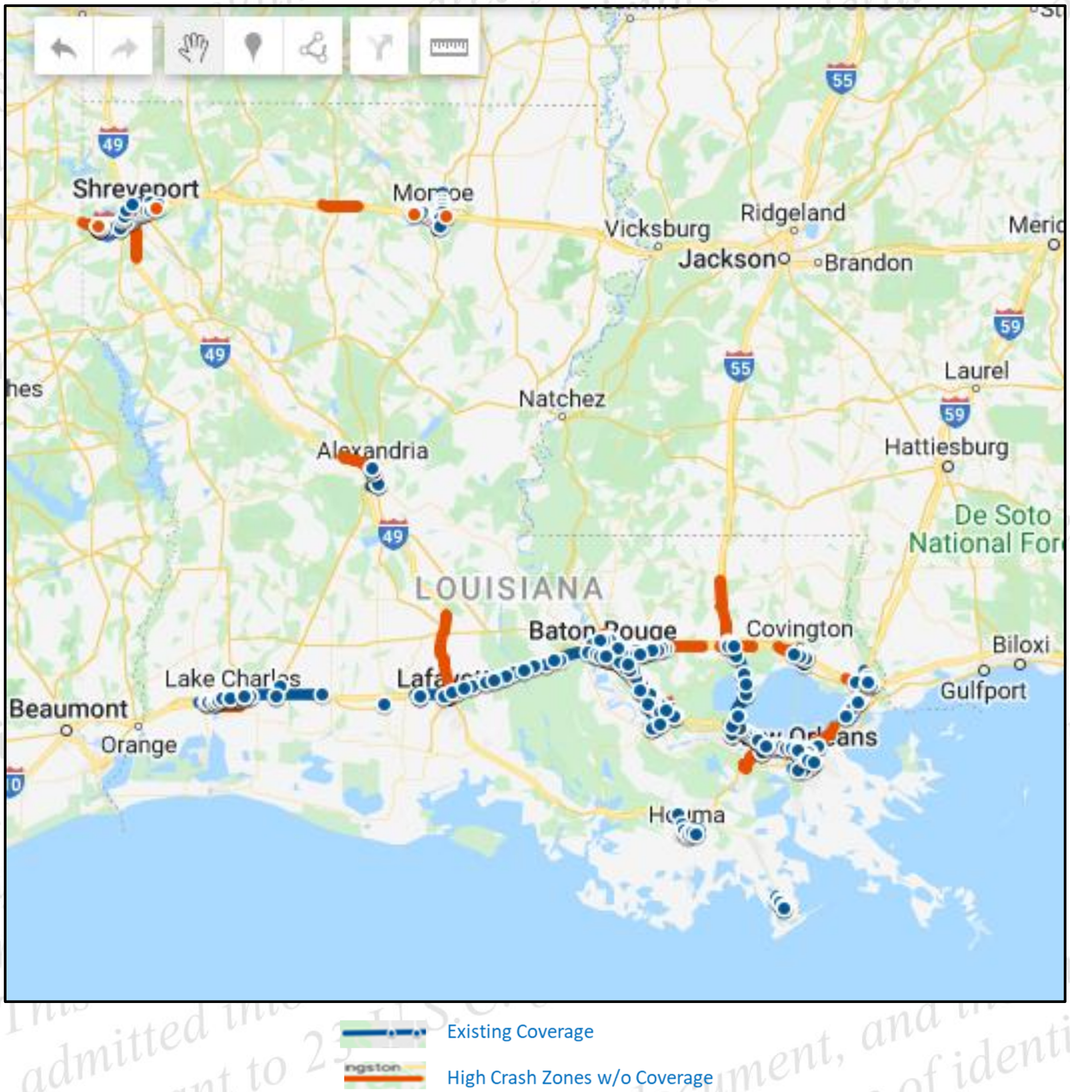
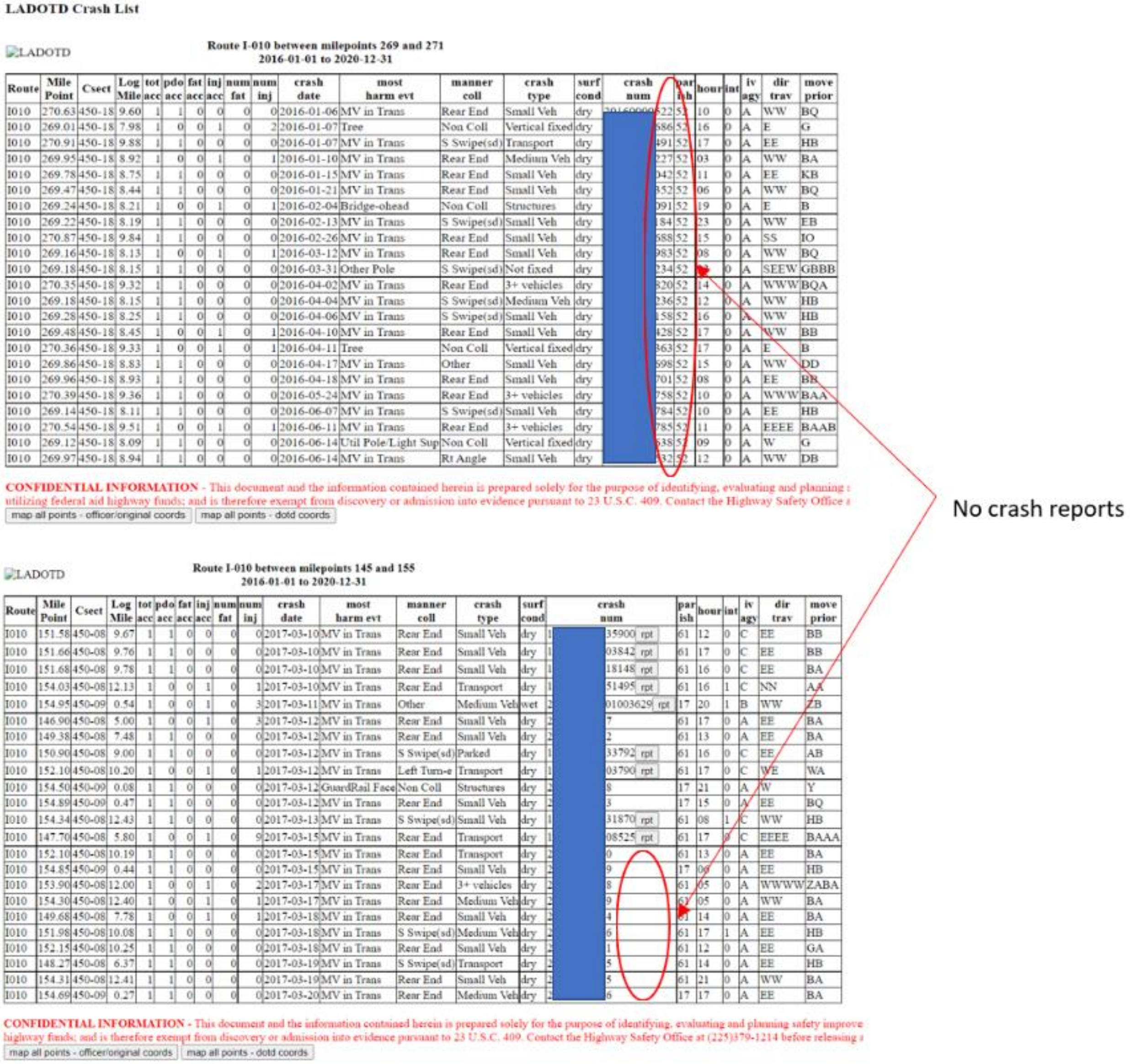


Figure C15. Missing (unattached) crash reports in the crash database



LADOTD Crash List

Route I-010 between milepoints 269 and 271
2016-01-01 to 2020-12-31

Route	Mile Point	Csect	Log Mile	tot acc	pdo acc	fat acc	inj acc	num fat	num inj	crash date	most harm evt	manner coll	crash type	surf cond	crash num	parish	hour	int	iv agy	dir trav	move prior
I010	270.63	450-18	9.60	1	1	0	0	0	0	2016-01-06	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	10	0	A	WW	BQ
I010	269.01	450-18	7.98	1	0	0	1	0	2	2016-01-07	Tree	Non Coll	Vertical fixed	dry	[redacted]	52	16	0	A	E	G
I010	270.91	450-18	9.88	1	1	0	0	0	0	2016-01-07	MV in Trans	S Swipe(sd)	Transport	dry	[redacted]	52	17	0	A	EE	HB
I010	269.95	450-18	8.92	1	0	0	1	0	1	2016-01-10	MV in Trans	Rear End	Medium Veh	dry	[redacted]	52	03	0	A	WW	BA
I010	269.78	450-18	8.75	1	1	0	0	0	0	2016-01-15	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	11	0	A	EE	KB
I010	269.47	450-18	8.44	1	1	0	0	0	0	2016-01-21	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	06	0	A	WW	BQ
I010	269.24	450-18	8.21	1	0	0	1	0	1	2016-02-04	Bridge-ohead	Non Coll	Structures	dry	[redacted]	52	19	0	A	E	B
I010	269.22	450-18	8.19	1	1	0	0	0	0	2016-02-13	MV in Trans	S Swipe(sd)	Small Veh	dry	[redacted]	52	23	0	A	WW	EB
I010	270.87	450-18	9.84	1	1	0	0	0	0	2016-02-26	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	15	0	A	SS	IO
I010	269.16	450-18	8.13	1	0	0	1	0	1	2016-03-12	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	08	0	A	WW	BQ
I010	269.18	450-18	8.15	1	1	0	0	0	0	2016-03-31	Other Pole	S Swipe(sd)	Not fixed	dry	[redacted]	52	[illegible]	0	A	SEEW	GBBB
I010	270.35	450-18	9.32	1	1	0	0	0	0	2016-04-02	MV in Trans	Rear End	3+ vehicles	dry	[redacted]	52	14	0	A	WWW	BQA
I010	269.18	450-18	8.15	1	1	0	0	0	0	2016-04-04	MV in Trans	S Swipe(sd)	Medium Veh	dry	[redacted]	52	12	0	A	WW	HB
I010	269.28	450-18	8.25	1	1	0	0	0	0	2016-04-06	MV in Trans	S Swipe(sd)	Small Veh	dry	[redacted]	52	16	0	A	WW	HB
I010	269.48	450-18	8.45	1	0	0	1	0	1	2016-04-10	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	17	0	A	WW	BB
I010	270.36	450-18	9.33	1	0	0	1	0	1	2016-04-11	Tree	Non Coll	Vertical fixed	dry	[redacted]	52	17	0	A	E	B
I010	269.86	450-18	8.83	1	1	0	0	0	0	2016-04-17	MV in Trans	Other	Small Veh	dry	[redacted]	52	15	0	A	WW	DD
I010	269.96	450-18	8.93	1	1	0	0	0	0	2016-04-18	MV in Trans	Rear End	Small Veh	dry	[redacted]	52	08	0	A	EE	BB
I010	270.39	450-18	9.36	1	1	0	0	0	0	2016-05-24	MV in Trans	Rear End	3+ vehicles	dry	[redacted]	52	10	0	A	WWW	BAA
I010	269.14	450-18	8.11	1	1	0	0	0	0	2016-06-07	MV in Trans	S Swipe(sd)	Small Veh	dry	[redacted]	52	10	0	A	EE	HB
I010	270.54	450-18	9.51	1	0	0	1	0	1	2016-06-11	MV in Trans	Rear End	3+ vehicles	dry	[redacted]	52	11	0	A	EEEE	BAAB
I010	269.12	450-18	8.09	1	1	0	0	0	0	2016-06-14	Util Pole/Light Sup	Non Coll	Vertical fixed	dry	[redacted]	52	09	0	A	W	G
I010	269.97	450-18	8.94	1	1	0	0	0	0	2016-06-14	MV in Trans	Rt Angle	Small Veh	dry	[redacted]	52	12	0	A	WW	DB

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utilizing federal aid highway funds; and is therefore exempt from discovery or admission into evidence pursuant to 23 U.S.C. 409. Contact the Highway Safety Office a

Route I-010 between milepoints 145 and 155
2016-01-01 to 2020-12-31

Route	Mile Point	Csect	Log Mile	tot acc	pdo acc	fat acc	inj acc	num fat	num inj	crash date	most harm evt	manner coll	crash type	surf cond	crash num	parish	hour	int	iv agy	dir trav	move prior
I010	151.58	450-08	9.67	1	1	0	0	0	0	2017-03-10	MV in Trans	Rear End	Small Veh	dry	[redacted] rpt	61	12	0	C	EE	BB
I010	151.66	450-08	9.76	1	1	0	0	0	0	2017-03-10	MV in Trans	Rear End	Small Veh	dry	[redacted] rpt	61	17	0	C	EE	BB
I010	151.68	450-08	9.78	1	1	0	0	0	0	2017-03-10	MV in Trans	Rear End	Small Veh	dry	[redacted] rpt	61	16	0	C	EE	BA
I010	154.03	450-08	12.13	1	0	0	1	0	1	2017-03-10	MV in Trans	Rear End	Transport	dry	[redacted] rpt	61	16	1	C	NN	AA
I010	154.95	450-09	0.54	1	0	0	1	0	3	2017-03-11	MV in Trans	Other	Medium Veh	wet	[redacted] rpt	17	20	1	B	WW	ZB
I010	146.90	450-08	5.00	1	0	0	1	0	3	2017-03-12	MV in Trans	Rear End	Small Veh	dry	[redacted]	61	17	0	A	EE	BA
I010	149.38	450-08	7.48	1	1	0	0	0	0	2017-03-12	MV in Trans	Rear End	Small Veh	dry	[redacted]	61	13	0	A	EE	BA
I010	150.90	450-08	9.00	1	1	0	0	0	0	2017-03-12	MV in Trans	S Swipe(sd)	Parked	dry	[redacted] rpt	61	16	0	C	EE	AB
I010	152.10	450-08	10.20	1	0	0	1	0	1	2017-03-12	MV in Trans	Left Turn-e	Transport	dry	[redacted] rpt	61	17	0	C	WE	WA
I010	154.50	450-09	0.08	1	1	0	0	0	0	2017-03-12	GuardRail Face	Non Coll	Structures	dry	[redacted]	17	21	0	A	W	Y
I010	154.89	450-09	0.47	1	1	0	0	0	0	2017-03-12	MV in Trans	Rear End	Small Veh	dry	[redacted]	17	15	0	A	EE	BQ
I010	154.34	450-08	12.43	1	1	0	0	0	0	2017-03-13	MV in Trans	S Swipe(sd)	Small Veh	dry	[redacted] rpt	61	08	1	C	WW	HB
I010	147.70	450-08	5.80	1	0	0	1	0	9	2017-03-15	MV in Trans	Rear End	Transport	dry	[redacted] rpt	61	17	0	C	EEEE	BAAA
I010	152.10	450-08	10.19	1	1	0	0	0	0	2017-03-15	MV in Trans	Rear End	Transport	dry	[redacted]	61	13	0	A	EE	BA
I010	154.85	450-09	0.44	1	1	0	0	0	0	2017-03-15	MV in Trans	Rear End	Small Veh	dry	[redacted]	17	06	0	A	EE	HB
I010	153.90	450-08	12.00	1	0	0	1	0	2	2017-03-17	MV in Trans	Rear End	3+ vehicles	dry	[redacted]	61	05	0	A	WWWW	ZABA
I010	154.30	450-08	12.40	1	0	0	1	0	1	2017-03-17	MV in Trans	Rear End	Medium Veh	dry	[redacted]	61	05	0	A	WW	BA
I010	149.68	450-08	7.78	1	0	0	1	0	1	2017-03-18	MV in Trans	Rear End	Small Veh	dry	[redacted]	61	14	0	A	EE	BA
I010	151.98	450-08	10.08	1	1	0	0	0	0	2017-03-18	MV in Trans	S Swipe(sd)	Medium Veh	dry	[redacted]	61	17	1	A	EE	HB
I010	152.15	450-08	10.25	1	1	0	0	0	0	2017-03-18	MV in Trans	Rear End	Small Veh	dry	[redacted]	61	12	0	A	EE	GA
I010	148.27	450-08	6.37	1	1	0	0	0	0	2017-03-19	MV in Trans	S Swipe(sd)	Transport	dry	[redacted]	61	14	0	A	EE	HB
I010	154.31	450-08	12.41	1	1	0	0	0	0	2017-03-19	MV in Trans	Rear End	Small Veh	dry	[redacted]	61	21	0	A	WW	BA
I010	154.69	450-09	0.27	1	1	0	0	0	0	2017-03-20	MV in Trans	Rear End	Medium Veh	dry	[redacted]	17	17	0	A	EE	BA

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highway funds; and is therefore exempt from discovery or admission into evidence pursuant to 23 U.S.C. 409. Contact the Highway Safety Office at (225)379-1214 before releasing a

Figure C16. Incident Response Time (IRT) data distribution (Boxplots)

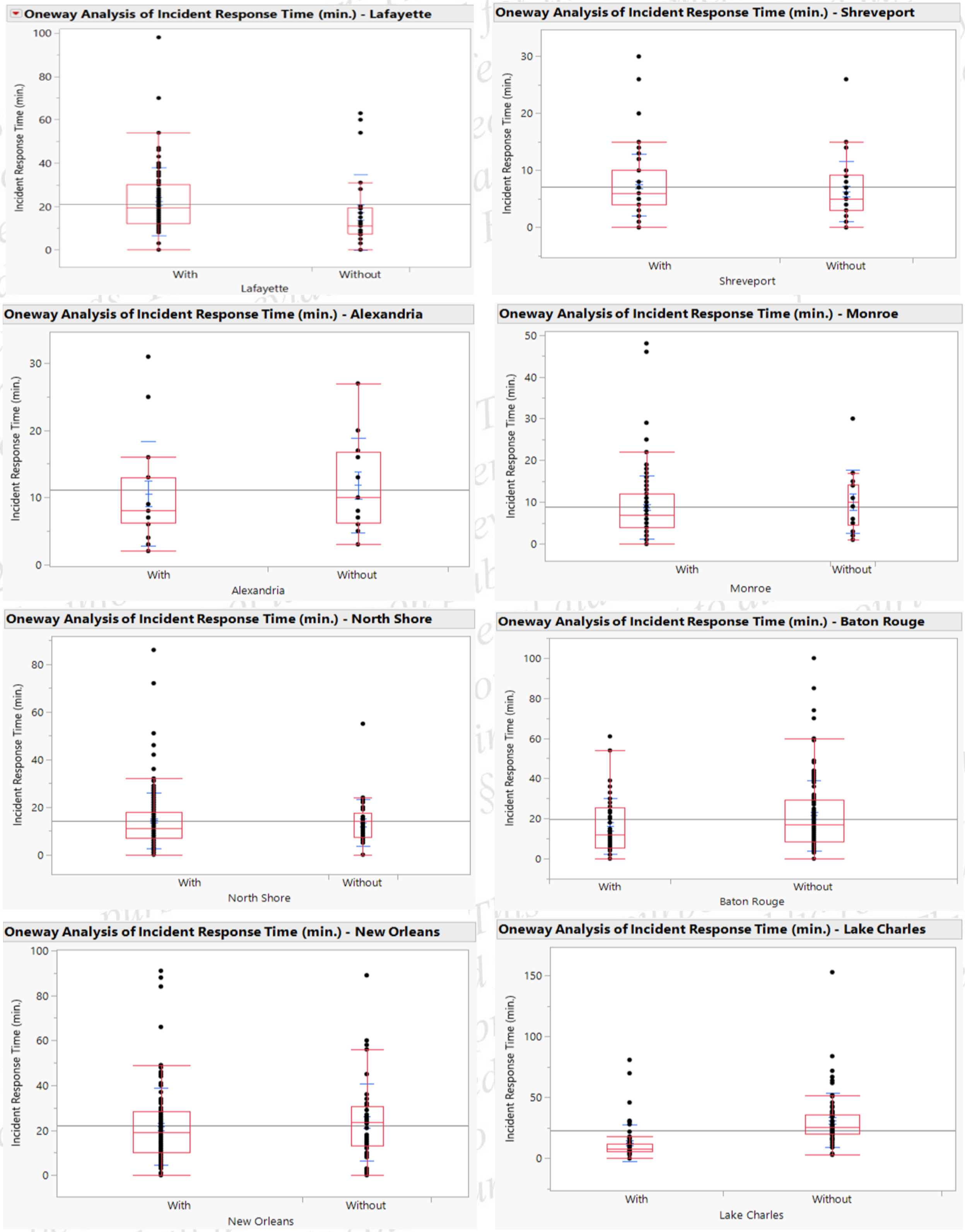


Figure C17. MAP patrol coverage in Louisiana [31]

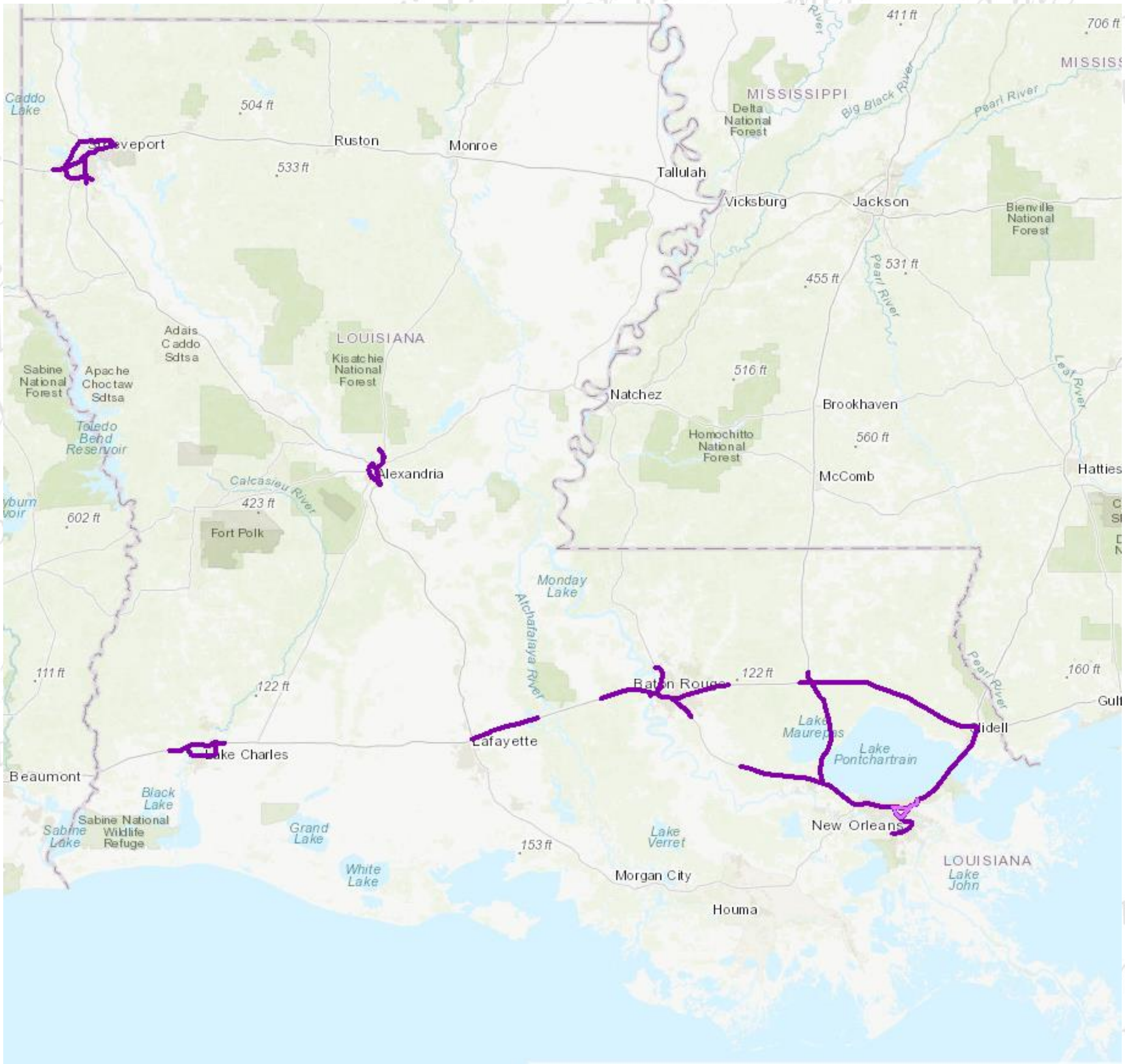
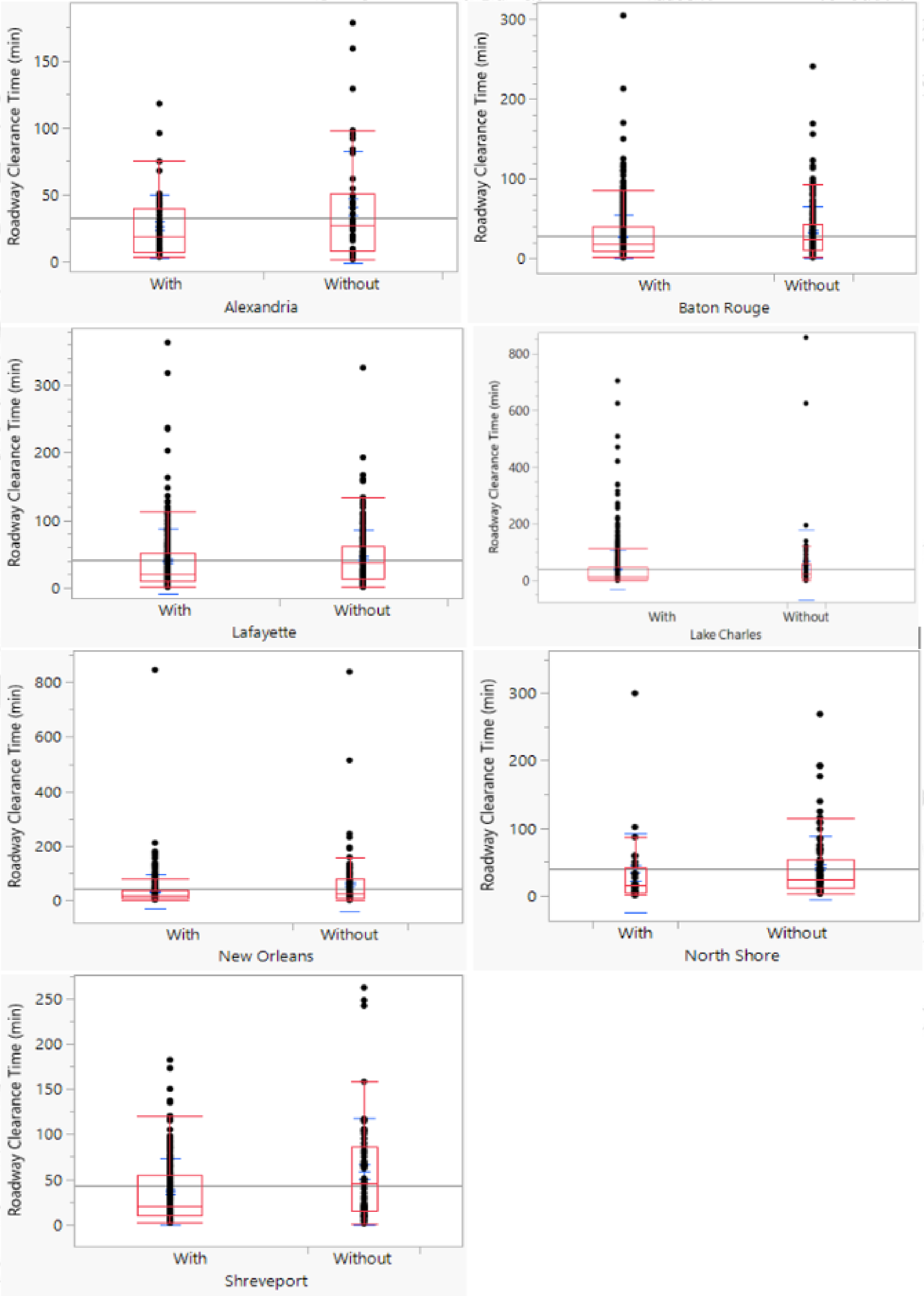


Figure C18. RCT data distribution



Appendix D

Figure D1. Official designated truck routes in Louisiana [67]

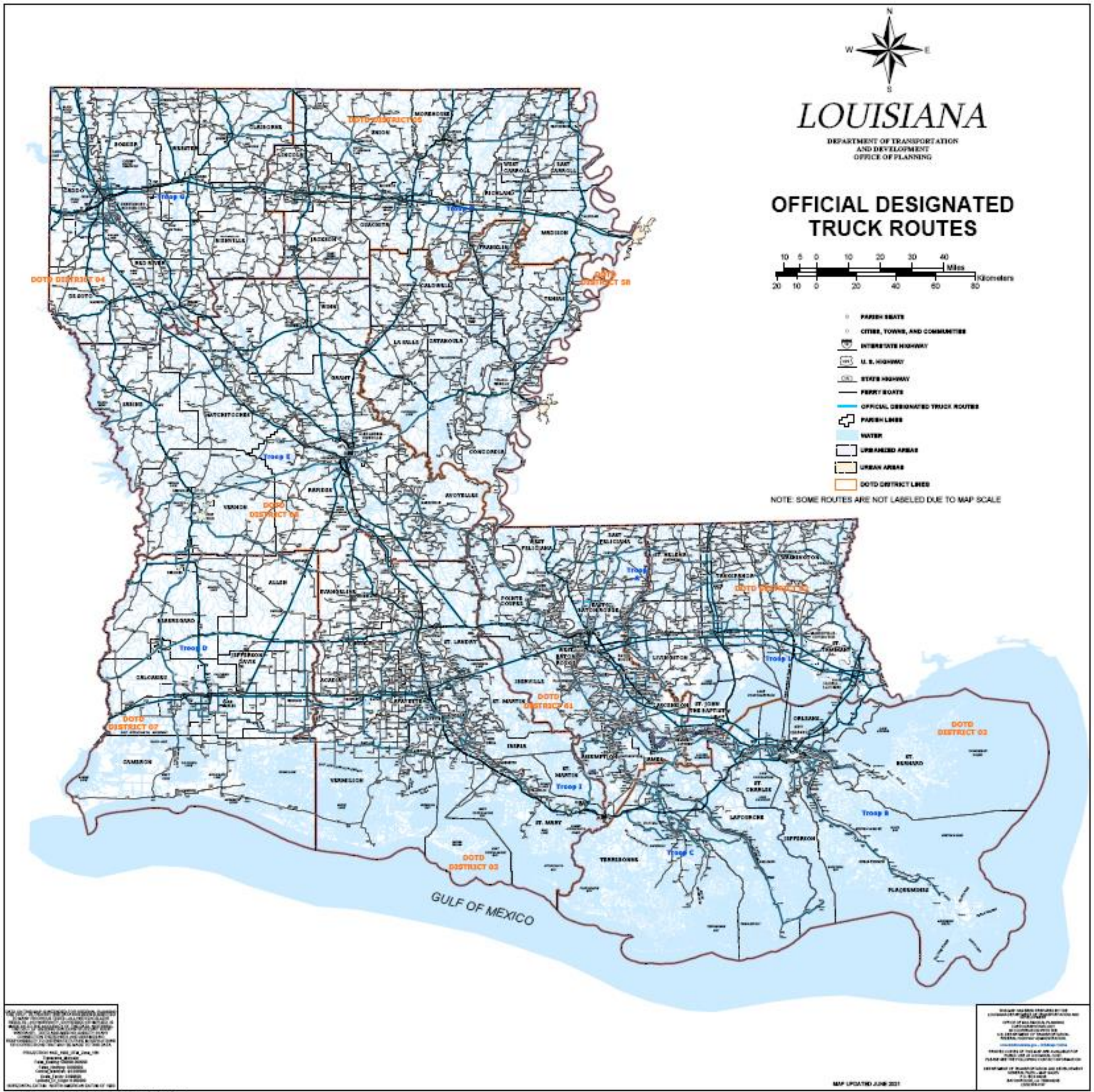


Figure D2. Truck delay in percentiles, 2016 [32]

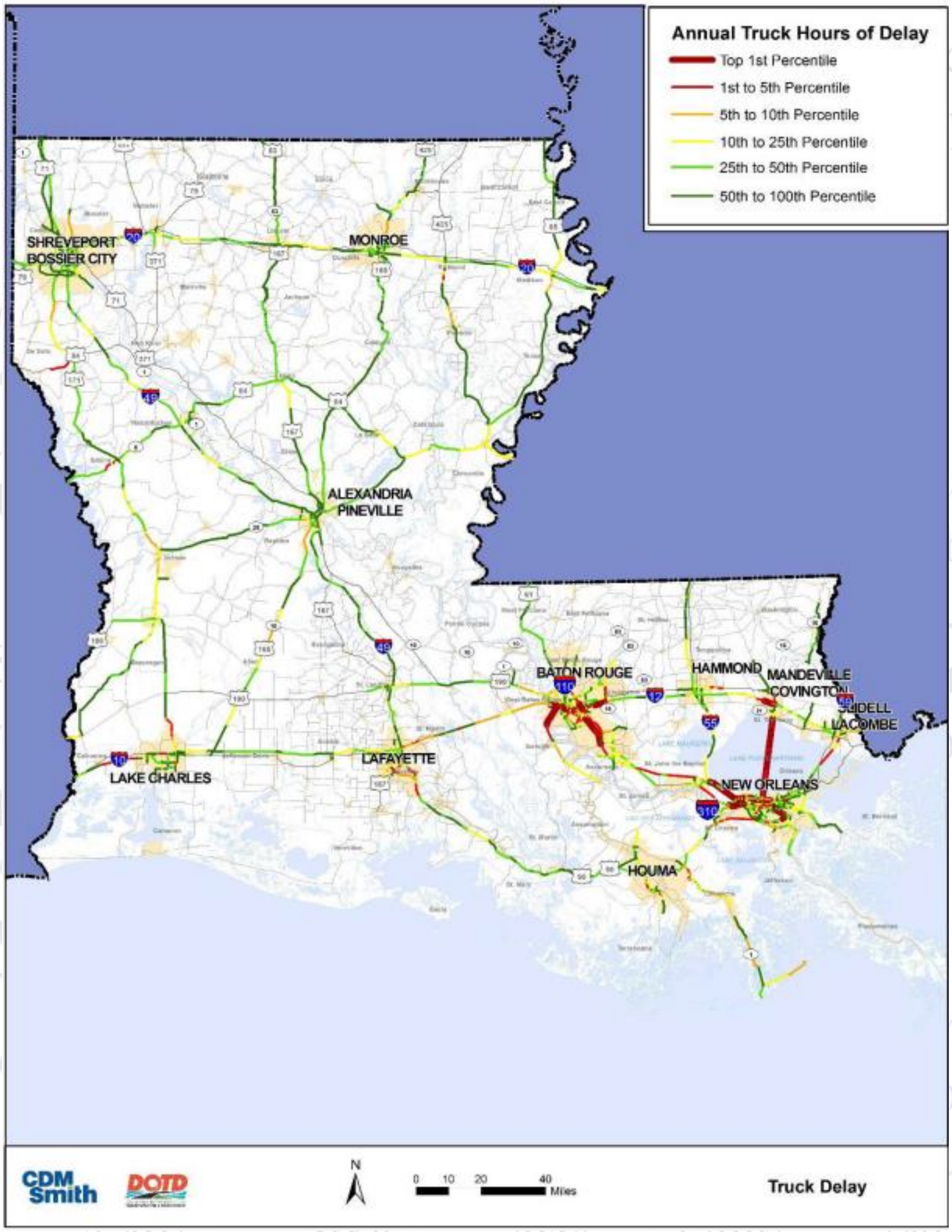


Figure D3. TTTR – Louisiana interstate highway system, 2016

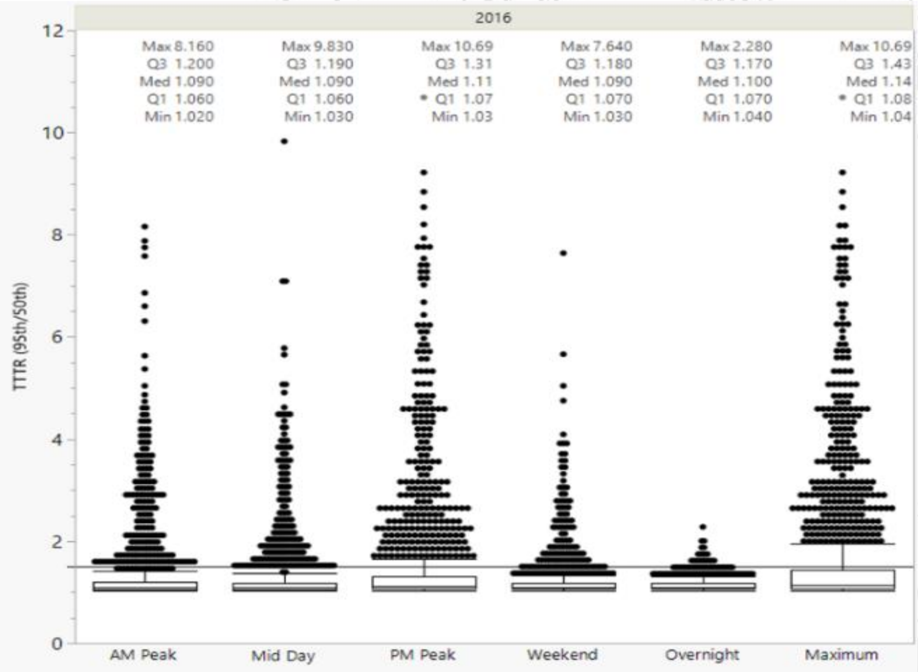


Figure D4. TTTR – Louisiana interstate highway system, 2017

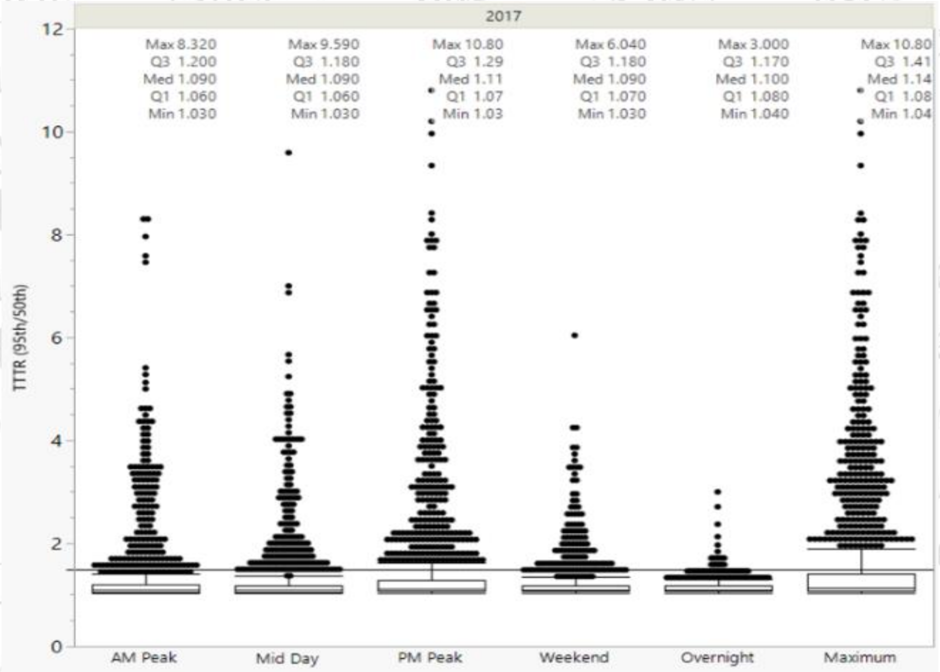


Figure D5. TTTR – Louisiana interstate highway system, 2018

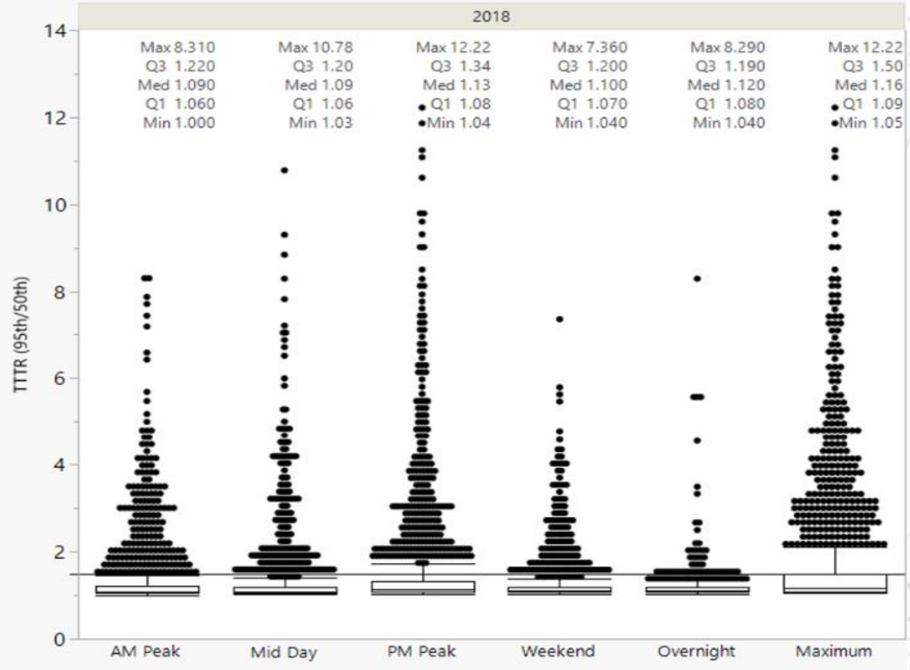


Figure D6. TTTR – Louisiana interstate highway system, 2020

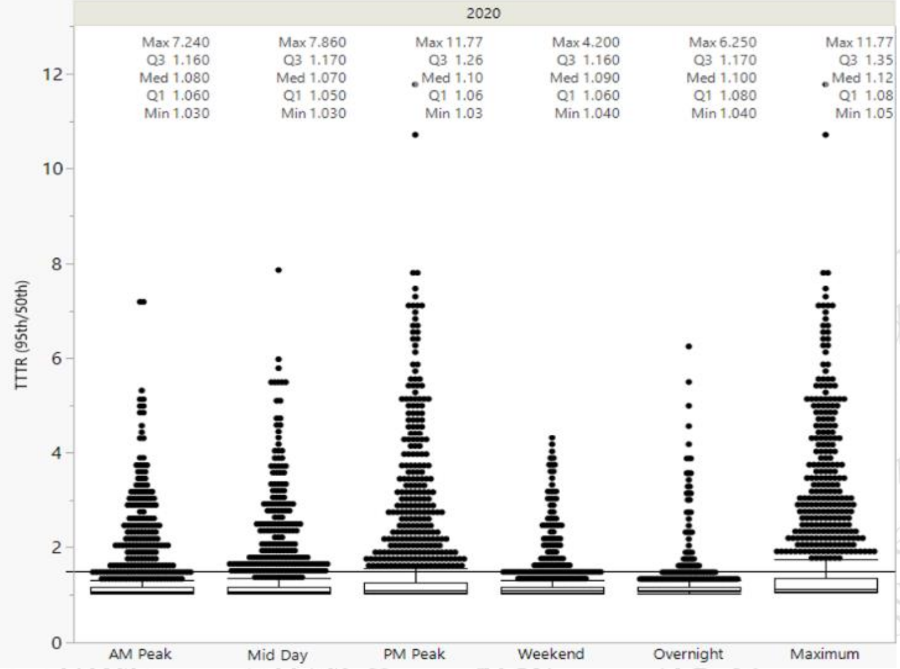
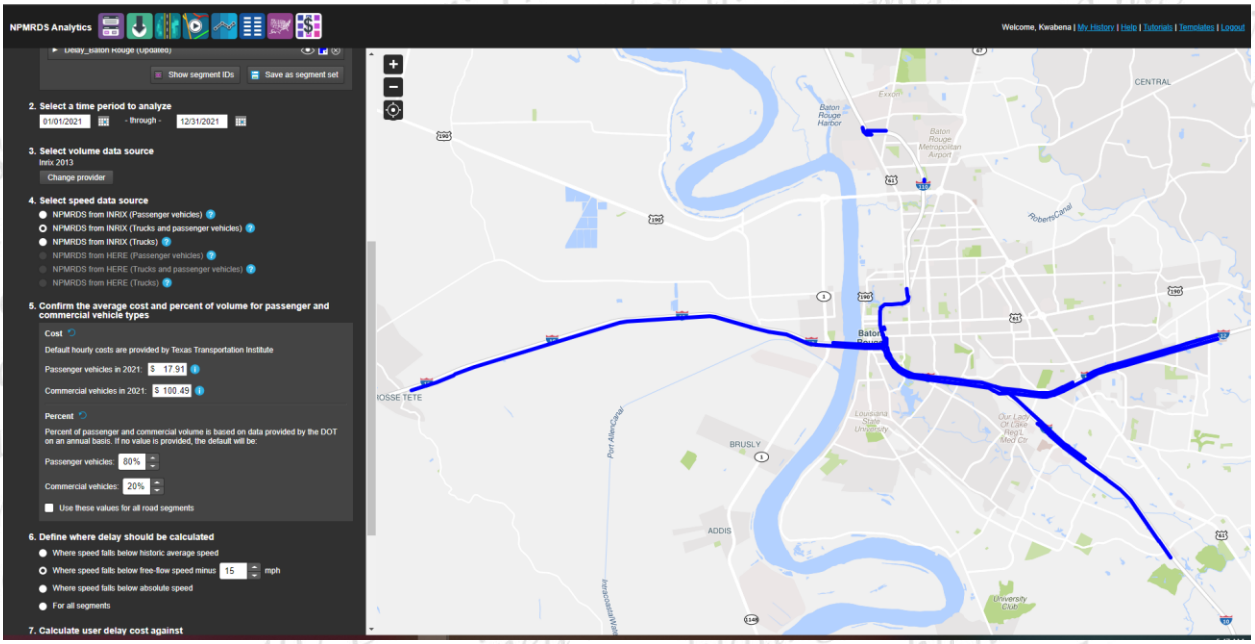


Figure D7. TMC Segments in Baton Rouge with TTTR scores greater than 1.50 (2016-2020)



2. Select a time period to analyze
01/01/2021 - through - 12/31/2021

3. Select volume data source
Inrix 2013

4. Select speed data source
- ● 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

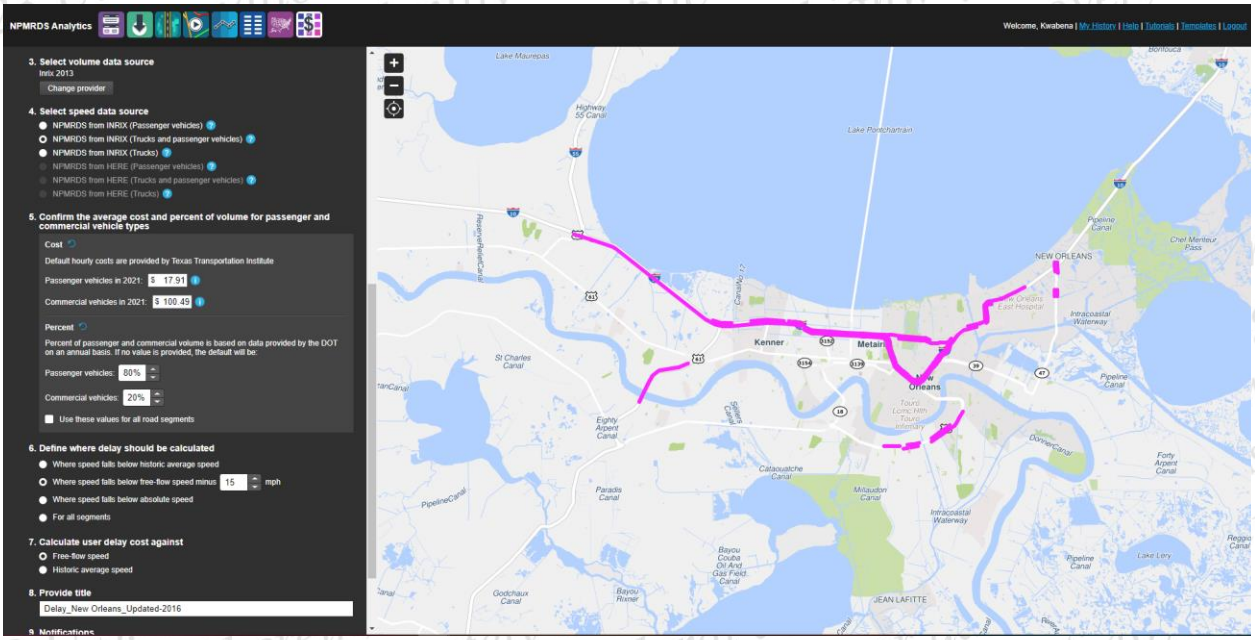
Cost
Default hourly costs are provided by Texas Transportation Institute
Passenger vehicles in 2021: $ 17.91
Commercial vehicles in 2021: $ 100.49

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 historic average speed
- ○ Where speed falls below free-flow speed minus 15 mph
- ● Where speed falls below absolute speed
- ● For all segments

7. Calculate user delay cost against

Figure D8. TMC Segments in New Orleans with TTTR scores greater than 1.50 (2016-2020)



3. Select volume data source
Inrix 2013

4. Select speed data source
- ● 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 2021: $ 17.91
Commercial vehicles in 2021: $ 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 historic average speed
- ○ Where speed falls below free-flow speed minus 15 mph
- ● Where speed falls below absolute speed
- ● For all segments

7. Calculate user delay cost against
- ○ Free-flow speed
- ● Historic average speed

8. Provide title
Delay_New Orleans_Updated-2016

9. Notifications

Appendix E

Overview of Crashes on Individual Interstate Highways

Crashes on I-10

The annual commercial vehicle crash rate on I-10 increased from 13.16 in 2016 to 15.82 in 2018 before it progressively declined to 14.07 in 2020. The proportions of commercial vehicles involved in crashes between 2016 and 2020 were 12.67, 14.50, 15.55, 14.68, and 16.16%, respectively. From this, the highest ratio of commercial vehicles involved in crashes was in 2020, though the number for 2020 was the least compared to the other years.

Crashes on I-12

The annual commercial vehicle crash rates on I-12 between 2016 and 2020 followed an up-down spiked trend between 2016 and 2020, with a downward trend between 2019 and 2020. However, the ratio of commercial vehicles involved in crashes increased steadily between 2016 and 2019, before it decreased in 2020. Though the proportion of commercial vehicles involved in crashes was highest in 2019, the 2020 ratio was higher than the ratios observed from 2016 to 2018, despite 2020 having the least crash frequency and the number of commercial vehicles involved.

Crashes on I-20

The commercial vehicle crash rate on I-20 increased marginally between 2016 and 2018, with a minimal decrease from 2016 to 2020. The ratios of commercial vehicles involved in crashes between 2016 and 2020 were 17.45, 19.69, 18.96, 18.97, and 21.07 percent, respectively. The highest ratio was observed in 2020, though the number of commercial vehicles involved and the crash frequency were the least compared to the other years.

Crashes on I-49

The commercial vehicle crash rates steadily increased from 4.527 in 2016 to 6.199 in 2020. Also, the proportion of commercial vehicles involved per year between 2016 and 2020 increased steadily from 10.62 to 11.79, 13.69, 13.90 to 14.20 percent, respectively. Again, the highest proportion of commercial vehicles was in 2020, with 14.20%.

Crashes on I-55

The commercial vehicle crash rates on I-55 increased to 9.301 in 2017 from 8.262 in 2016 before declining to 7.048 in 2019. The crash rate, however, slightly increased in 2020 to 7.658. The proportion of commercial vehicles involved in crashes also declined from 12.23% in 2017 to 9.55% in 2018 before increasing steadily to 11.49% in 2020.

Crashes on I-59

The commercial vehicle crash rate sharply shot up to 14.704 in 2017 from 9.649 in 2016, before it steadily dropped to 7.207 in 2020. Also, the ratio of the number of commercial vehicles involved from 2016 to 2020 followed a similar trend as the crash rates with 17.07, 25.29, 14.94, 14.47, and 11.24 percent, respectively. Here, the highest ratio of commercial vehicles involved in crashes was observed in 2017, with the least observed in 2020.

Crashes on I-110

The commercial vehicle crash rate declined steadily from 28.286 in 2016 to 20.137 in 2018 before a slight increase to 22.059 in 2019. The crash rate declined again from 2019 to the lowest rate of 15.105 in 2020. The proportion of commercial vehicles involved in crashes between 2016 and 2020 also followed a similar trend with 10.03, 9.91, 7.69, 8.40, and 7.28 percent, respectively.

Crashes on I-210

The commercial vehicle crash rate on I-210 increased sharply from 8.506 in 2016 to 22.340 in 2018. It suddenly dropped to 12.13 in 2019 before a further decrease to 11.33 in 2020. The proportion of commercial vehicles involved in the crashes followed the same trend between 2016 and 2019 but slightly increased from 2019 to 2020.

Crashes on I-220

The commercial vehicle crash rate on I-220 remained relatively constant between 2016 and 2017, increased in 2018, and remained constant between 2018 and 2020. The proportion of commercial vehicles involved, on the other hand, increased continuously between 2016 and 2019 but dropped in 2020.

Crashes on I-310

The commercial vehicle crash rate on I-310 decreased from 19.21 in 2016 to 13.16 in 2018. The rate slightly increased to 14.29 in 2019 but declined marginally to 13.45 in 2020. The ratio of commercial vehicles involved in the crashes was highest in 2017, with 19.80%, from 14.18% in 2016. This ratio decreased to 12.50% in 2018 but increased steadily to 16.13% in 2020.

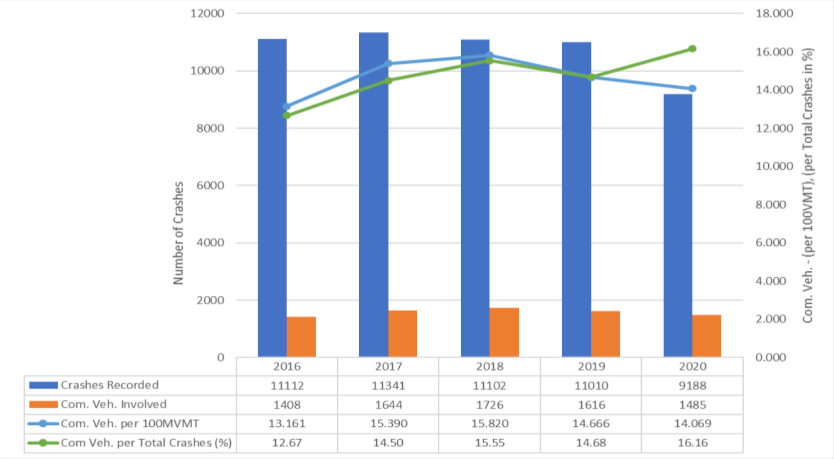
Crashes on I-510

The commercial vehicle crash rate on I-510 increased sharply from 3.13 in 2016 to a peak of 34.05 in 2018. The crash rate dropped to zero in 2019 and increased sharply to 12.38 in 2020. The ratio of commercial vehicles involved also followed the trend of the crash rates, from 4.00% in 2016 to 19.64% in 2018. The ratio dropped to 0% in 2019 and sharply increased to 26.67% in 2020.

Crashes on I-610

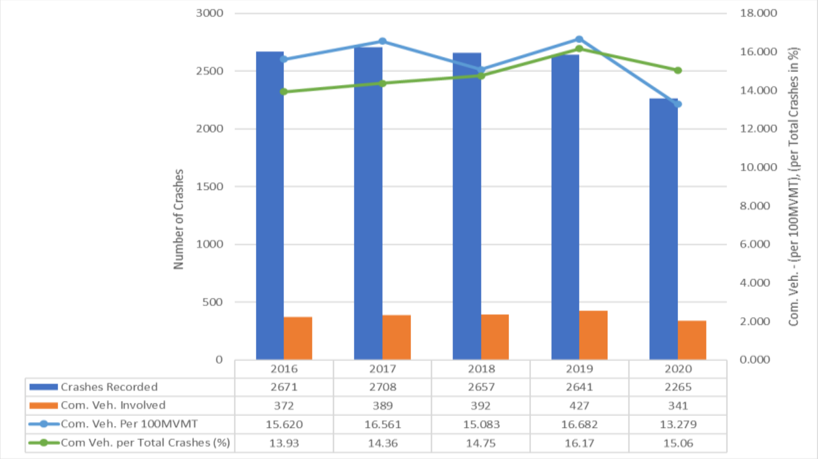
The commercial vehicle crash rates on I-610 increased between 2016 and 2017 but decreased steadily to the lowest in 2020. The ratio of commercial vehicles involved in the crashes between 2016 and 2020 followed a similar trend as the crash rates.

Figure E1. Crashes on I-10



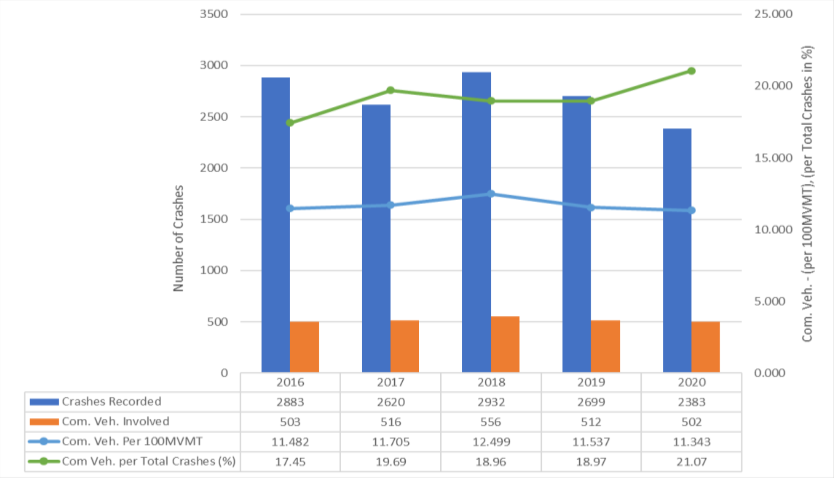
	2016	2017	2018	2019	2020
Crashes Recorded	11112	11341	11102	11010	9188
Com. Veh. Involved	1408	1644	1726	1616	1485
Com. Veh. per 100MVMT	13.161	15.390	15.820	14.666	14.069
Com Veh. per Total Crashes (%)	12.67	14.50	15.55	14.68	16.16

Figure E2. Crashes on I-12



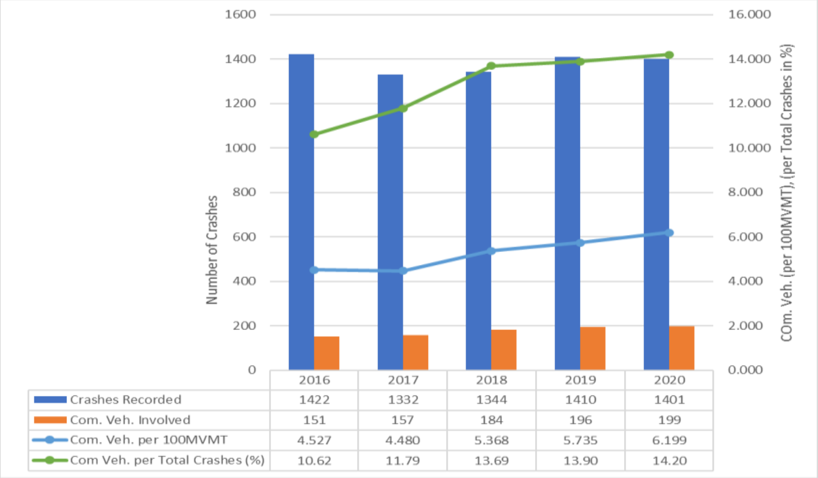
	2016	2017	2018	2019	2020
Crashes Recorded	2671	2708	2657	2641	2265
Com. Veh. Involved	372	389	392	427	341
Com. Veh. Per 100MVMT	15.620	16.561	15.083	16.682	13.279
Com Veh. per Total Crashes (%)	13.93	14.36	14.75	16.17	15.06

Figure E3. Crashes on I-20



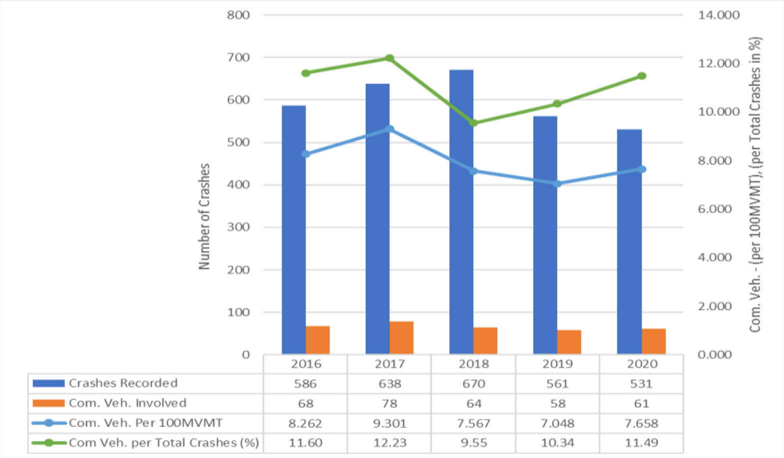
	2016	2017	2018	2019	2020
Crashes Recorded	2883	2620	2932	2699	2383
Com. Veh. Involved	503	516	556	512	502
Com. Veh. Per 100MVMT	11.482	11.705	12.499	11.537	11.343
Com Veh. per Total Crashes (%)	17.45	19.69	18.96	18.97	21.07

Figure E4. Crashes on I-49



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

Figure E5. Crashes on I-55

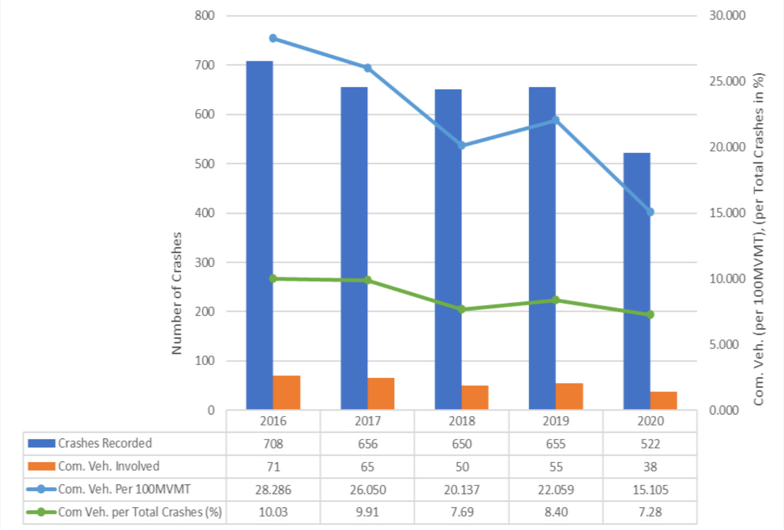


	2016	2017	2018	2019	2020
Crashes Recorded	586	638	670	561	531
Com. Veh. Involved	68	78	64	58	61
Com. Veh. Per 100MVMT	8.262	9.301	7.567	7.048	7.658
Com Veh. per Total Crashes (%)	11.60	12.23	9.55	10.34	11.49

Figure E6. Crashes on I-59

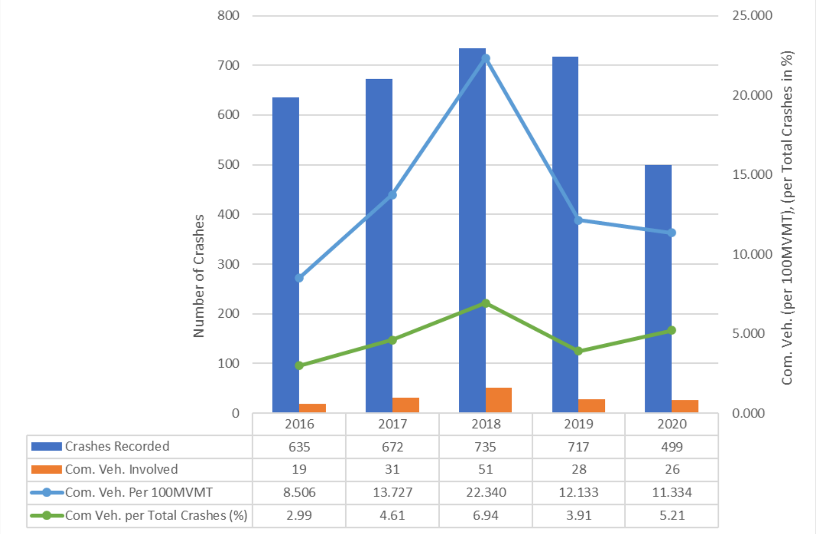
	2016	2017	2018	2019	2020
Crashes Recorded	82	87	87	76	89
Com. Veh. Involved	14	22	13	11	10
Com. Veh. per 100MVMT	9.649	14.704	9.328	7.659	7.207
Com Veh. per Total Crashes (%)	17.07	25.29	14.94	14.47	11.24

Figure E7. Crashes on I-110



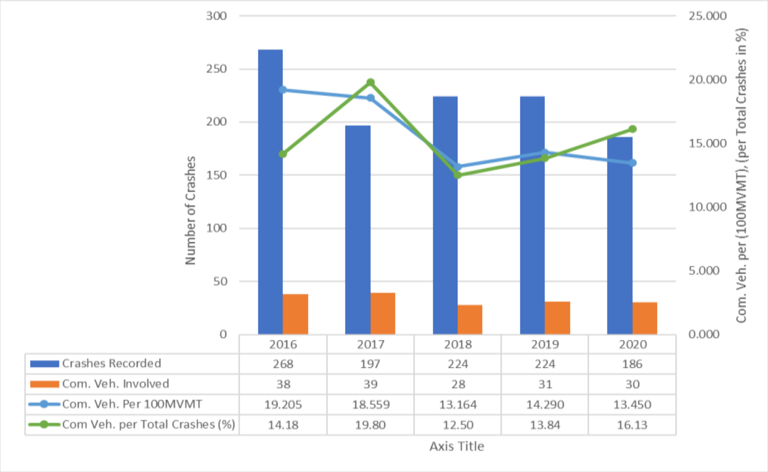
	2016	2017	2018	2019	2020
Crashes Recorded	708	656	650	655	522
Com. Veh. Involved	71	65	50	55	38
Com. Veh. Per 100MVMT	28.286	26.050	20.137	22.059	15.105
Com Veh. per Total Crashes (%)	10.03	9.91	7.69	8.40	7.28

Figure E8. Crashes on I-210



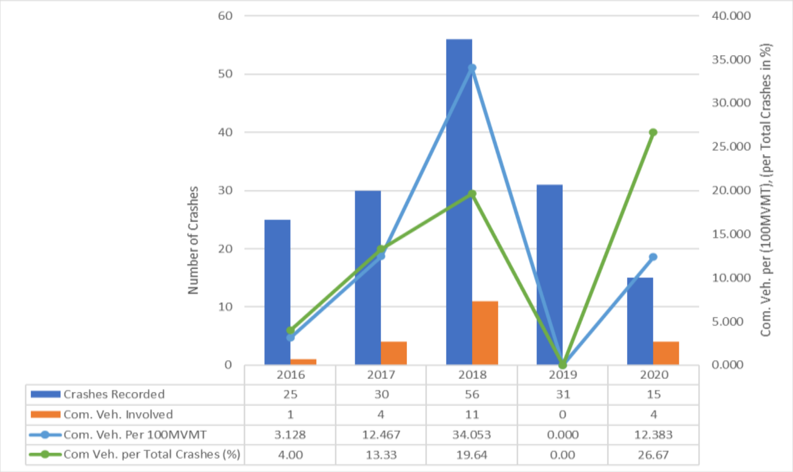
	2016	2017	2018	2019	2020
Crashes Recorded	635	672	735	717	499
Com. Veh. Involved	19	31	51	28	26
Com. Veh. Per 100MVMT	8.506	13.727	22.340	12.133	11.334
Com Veh. per Total Crashes (%)	2.99	4.61	6.94	3.91	5.21

Figure E9. Crashes on I-310



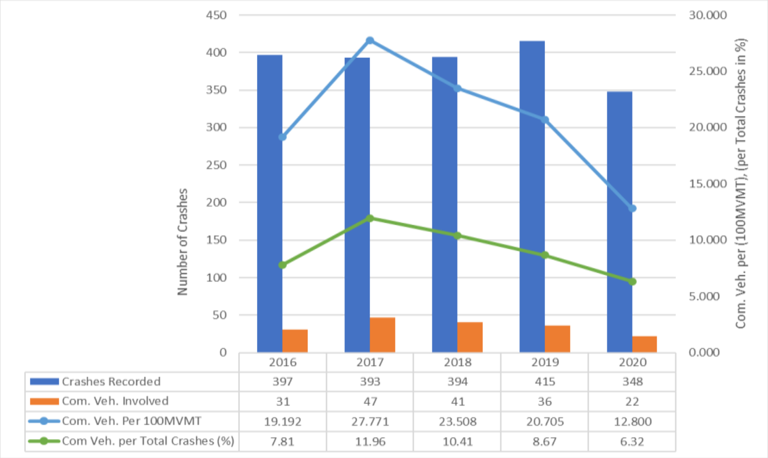
	2016	2017	2018	2019	2020
Crashes Recorded	268	197	224	224	186
Com. Veh. Involved	38	39	28	31	30
Com. Veh. Per 100MVMT	19.205	18.559	13.164	14.290	13.450
Com Veh. per Total Crashes (%)	14.18	19.80	12.50	13.84	16.13

Figure E10. Crashes on I-510



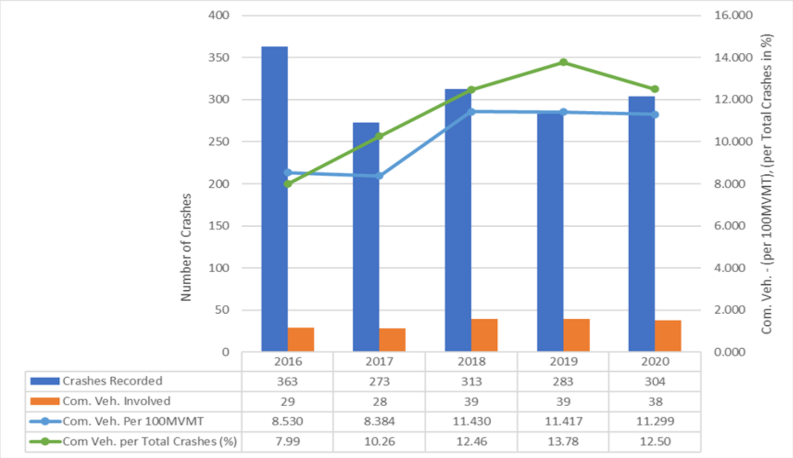
	2016	2017	2018	2019	2020
Crashes Recorded	25	30	56	31	15
Com. Veh. Involved	1	4	11	0	4
Com. Veh. Per 100MVMT	3.128	12.467	34.053	0.000	12.383
Com Veh. per Total Crashes (%)	4.00	13.33	19.64	0.00	26.67

Figure E11. Crashes on I-610



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

Figure E12. Crashes on I-220



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