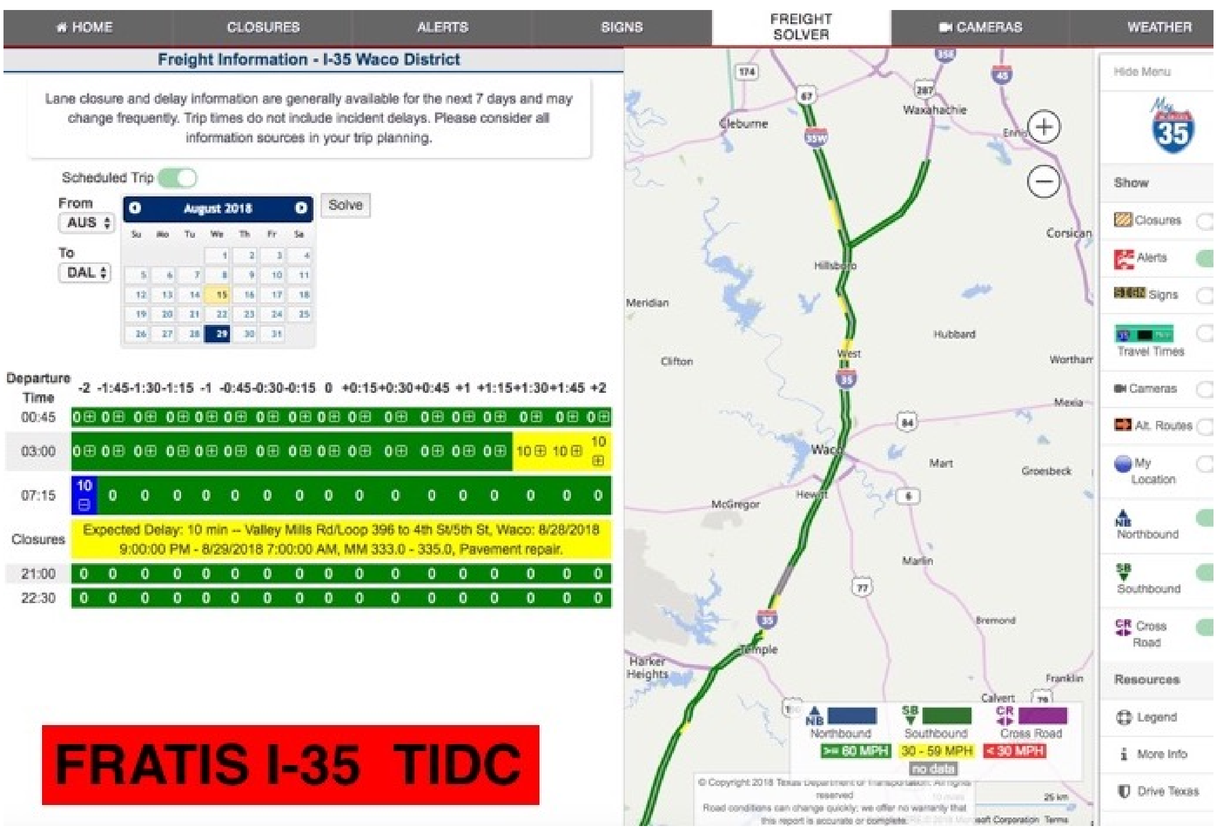
I-35 Freight Advanced Traveler Information System (FRATIS) Impacts Assessment

Final Report

www.its.dot.gov/index.htm

Final Report—September 2018

FHWA-JPO-18-694



U.S. Department of Transportation

Produced by Cambridge Systematics, Inc. and Washington State Transportation Center at the University of Washington
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Intelligent Transportation Systems—Joint Program Office

Notice

(Cover Image by Texas A&M Transportation Institute)

Technical Report Documentation Page

1. Report No. **FHWA-JPO-18-694**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle I-35 Freight Advanced Traveler Information System (FRATIS) Impacts Assessment—Final Report		**5. Report Date** September 2018 **6. Performing Organization Code**
7. Author(s) Mark Hallenbeck, Alice Chu, Ed McCormack, Dimitri Zyuzin, John Ishimaru, Mark Jensen, Robert Campbell		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Cambridge Systematics, Inc. 3 Bethesda Metro Center, Suite 1200 Bethesda, MD 20814 University of Washington P.O. Box 354802 Seattle, WA 98195		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-12-D-00042
12. Sponsoring Agency Name and Address U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, D.C. 20590		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** HOP
15. Supplementary Notes The Government Task Manager for this task is Tom Kearney.		

16. Abstract

Under the Dynamic Mobility Applications (DMA) Program, the U.S. Department of Transportation (U.S. DOT) has sponsored the development of the Freight Advanced Traveler Information System (FRATIS) bundle, which seeks to transform freight mobility by leveraging a system of "connected vehicles" and mobile devices to maximize freight flow. The TxDOT I-35 Traveler Information During Construction (TIDC) system has been enhanced to help maximize freight operators' productivity, improve operational efficiency, and reduce safety related incidents, by providing freight traveler information such as pre-construction closure notifications, delay predictions, and near real-time construction delay information.

The report evaluates the benefits of the delivery of the TIDC's information to the trucking firms using the system. It is based on a year-long before/after analysis of two major trucking firms, with six months of data collected before the firms started using TIDC information, and six months of after data collection after TIDC information started being used by the companies. At the conclusion of the project, both participating trucking firms remain enthusiastic supporters of the TIDC and are seeking internal company resources for improving the ability of their companies to ingest TIDC data into their existing business processes, however, no quantifiable change in trucking performance was observed. Reasons for the lack of measurable benefit include the limited opportunity to route around the I-35 construction delays, and the lack of automated ingest of TIDC data into the trucking firms' business systems.

17. Keywords Freight Advanced Traveler Information, FRATIS, traveler information, Traveler Information During Construction, TIDC, I-35, Texas, before/after analysis.	**18. Distribution Statement** No Restrictions.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 128	**22. Price** NA

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgments

The following individuals provided significant support in the development of this document:

- Texas A&M Transportation Institute (TTI)—Bob Brydia
- Noblis—Barbara Staples, Sampson Asare
- North American Strategy for Competitiveness (NASCO)—Tiffany Melvin
- Texas Department of Transportation (TxDOT)—Jianming Ma
- Productivity Apex (PAI)—Sam Fayez, Ahmed El-Nashar
- Participating trucking firms (names removed to preserve anonymity)

Table of Contents

List of Tables

List of Figures

Executive Summary

Introduction

Under the Dynamic Mobility Applications (DMA) Program, the U.S. Department of Transportation (U.S. DOT) has sponsored the development of the Freight Advanced Traveler Information System (FRATIS) bundle, which seeks to transform freight mobility by leveraging connected vehicle technologies to maximize freight flow. The TxDOT I-35 Traveler Information During Construction (TIDC) system has been enhanced to help maximize freight operators' productivity, improve operational efficiency, and reduce safety related incidents, as part of the Texas Corridor Optimization for Freight (COfF) program, which is a component of the Federal Government-Texas Department of Transportation (TxDOT) cooperative agreement.

This report describes the evaluation of the impact of different information delivery efforts on freight operations in the I-35 corridor, as TxDOT works to use information delivery as a way to mitigate the impacts of required construction activity on freight mobility and productivity.

This evaluation project was initially focused on measuring the benefits of providing construction work zone delay information to trucking companies through freight delivery optimization software. Because trucking companies were uninterested adopting that software, the evaluation focuses on the impacts of delivery of the TIDC information through the existing trucking company business processes. The TIDC provides:

- Pre-construction closure notifications.
- Delay predictions.
- Near real-time construction delay information.

One regional and one national trucking firm (to be referred to as the Regional Carrier and the National Carrier to preserve anonymity) provided information on the performance of their truck deliveries which moved through the construction zone during the I-35 construction activity.

Project Objective

The I-35 FRATIS pilot test utilizing the enhanced TIDC information delivery program is intended to:

- Empower dispatchers with historical and near real-time information to enable faster and better decisions.
- Allow trucking firms to determine optimized truck routing if they so desired.
- Determine the best dispatch time for each truck trip to avoid congestion.
- Help trucks avoid or efficiently accommodate construction delays and lane closures on the I-35 corridor.
- Deliver near real-time traffic information such as lane closures, incidents, and expected delays.

- Provide dynamic routing for drivers to avoid congestion and deliver advance notifications to customers.

This evaluation examines whether the TIDC's information delivery has resulted in measurable benefits to the trucking firms using the system. It is based on a year-long before/after analysis of two major trucking firms, with six months of data collected before the firms started using TIDC information, and six months of after data collection after TIDC information started being ingested into the truck firms' business processes. The official start of the After Period was September 18, 2017. The official before period ran from March 19, 2017 to August 19, 2017 (National Carrier) and from February 14, 2017 to August 14, 2017 (Regional Carrier). The data from the month between the before and after periods were discarded due to the impacts of Hurricane Harvey.

Impacts Assessment Results

The provision of data from the TIDC had little measurable impact on the travel times or travel time reliability experienced by the participating trucking firms. Table 1 presents the descriptive statistics for the National Carrier.

Table 1. Change in National Carrier travel time descriptive statistics.

Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80^{th} Percentile travel time (min., % of baseline)	Change in 80^{th} Percentile travel time minus Mean	Change in 80^{th} Percentile minus Mean (% of mean)
Dallas	Waco	-0:01 (-1%)	0:07 (50%)	-0:04 (-4%)	-0:03	-3%
Dallas	San Antonio	-0:02 (-1%)	0:05 (23%)	-0:02 (-1%)	0:00	0%
Dallas	Austin	-0:03 (-1%)	-0:02 (-9%)	-0:08 (-4%)	-0:05	-2%
Dallas	Laredo	0:01 (0%)	0:05 (13%)	-0:26 (-5%)	-0:27	-6%
San Antonio	Laredo	-0:02 (-1%)	0:00 (0%)	-0:03 (-2%)	-0:01	-1%
Waco	Dallas	0:02 (2%)	0:17 (106%)	0:03 (3%)	0:01	1%
San Antonio	Dallas	-0:02 (-1%)	0:03 (12%)	-0:02 (-1%)	0:00	0%
Austin	Dallas	0:02 (1%)	0:02 (9%)	-0:02 (-1%)	-0:04	-2%
Laredo	Dallas	-0:24 (-5%)	-0:13 (-28%)	-0:20 (-4%)	0:03	1%
Laredo	San Antonio	0:01 (1%)	0:03 (23%)	0:03 (2%)	0:02	1%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

No significant changes were observed in:

- Mean travel times between similar origins and destinations.
- Travel times by time of day.
- The fraction of trips operating during specific times of the day.
- The 80th percentile travel times for individual origin/destination pairs.
- The standard deviation of travel times between those origin/destination pairs.

Consequently, no significant changes in fuel use, delay, labor hours, or other benefits occurred.

This lack of quantifiable change is not due to any failure in the design or implementation of the TIDC. Instead, it is due to the geography of the location in which the TIDC was operating during the project evaluation. I-35 between Dallas and Austin lacks alternative routes whose use makes business sense for the vast majority of the construction delays that occurred during the evaluation. This resulted in the firms having limited interest in changing the start or arrival times of their trips or the routes used during those trips.

Despite the lack of quantifiable benefits, both participating trucking firms remain enthusiastic supporters of the TIDC. Both see sufficient value in construction delay information that they are actively seeking internal company resources for improving the ability of their companies to ingest TIDC data to their existing business processes.

The direct benefits the trucking firm participants cited included those typically cited by the public when expressing support for improved traveler information. That is, TIDC information was readily passed to drivers to help them understand expected conditions along their routes. Drivers used this information to:

- Prepare for unusual queues during their trips, thereby lowering their crash risk.
- Pre-select when and where to stop for breaks during those trips.

Both participating trucking firms reported that they expect to obtain more quantifiable benefits from work zone delay information:

1. If construction delay information such as that provided by the TIDC was available in geographic locations where alternative routes existed.
2. If the TIDC information could be automatically fed into their existing business systems.

The first of these issues is simply a function of the location of I-35 construction activity that was present for this study. As I-35 construction moves to the Austin metropolitan area in the near future, the trucking firms will have considerably more opportunity to make changes in their travel plans, and the resulting benefits should be more quantifiable.

The second requirement points out specific areas of work identified in this evaluation that need to be pursued by U.S. DOT. Most moderate to large trucking companies already use sophisticated scheduling and routing software to optimize their deliveries. These systems are directly integrated into their fleet management systems and their other business systems. To effectively take advantage of construction delay prediction and near real-time information, that information needs to be integrated into these existing systems. The TIDC information currently arrives as a separate data feed. As a result, the information contained in the TIDC data feed must be considered outside of each company's regular business process. This limits how effectively that information can be used by the firms, as staff must perform additional work to consider the impact of that information and then manually adjust the plans provided by their business systems.

If TIDC information was directly included in the data being used by those business systems, it would be more effectively considered in those business system optimization routines. This would increase the number of decisions that it effects. Having the data inside the fleet management data stream also greatly simplifies the delivery of that information to drivers and dispatchers, as it places that data in the information stream that companies want their staff to pay attention to, rather than requiring them to pay attention to multiple information sources.

This same finding also applies to the Work Zone Mitigation Tool developed as part of this project. The Work Zone Mitigation Tool was built to allow the evaluation team and others to directly analyze the benefits of alternative routes or departure times. The functionality of the Work Zone Mitigation Tool was well received. However, for trucking companies, that functionality will be more effectively used if it is embedded into their existing schedule optimization, navigation and fleet management systems. That same routing and trip planning activity also would be of significant benefit for individual travelers, and like freight travel, the best way to get that information to the public is to help bring the TIDC information into the navigation and trip planning tools the public already is using. These findings lead directly to the recommendations in the section below.

Finally, it must be noted that while both participating trucking firms used and appreciated the TIDC information, they used the information differently. The National Carrier preferred using the Freight Solver. The Freight Solver is a near real-time Web site updated once per minute to reflect the latest closures and delay estimates and presents the optimum departure time to the National Carrier based on the origin and destination pair selected by the site's user. The Regional Carrier used the TIDC email notifications. Both companies also valued near real-time notifications of changing travel conditions, but need the ability to adjust the frequency of the notifications they receive. They also expressed an interest in obtaining better information on the expected duration of unexpected events and delays.

Project Recommendations

The recommendations from this evaluation are split into long term and short term actions.

Long Term Actions

<u>The U.S. DOT should actively pursue the development of standard data feeds that could be consumed by private companies.</u> In addition, it is recommended that the companies providing scheduling, routing, and fleet management to trucking companies be engaged in this discussion—along with providers of general navigation software—to ensure that these data streams can be directly absorbed into the software that drive the vast majority of trucking company routing and scheduling business decisions. The experience TTI and TxDOT have gained in working with the National and Regional Carriers on what data are needed and how it needs to be presented offer considerable insight into the types of data and data structures that need to be accommodated in these formats.

U.S. DOT should actively work with highway agencies to collect data on current construction delays, estimate expected delays for future construction activities, and publish those data using the standards to be developed above.

U.S. DOT needs to perform detailed market studies prior to finalizing the design of future technology development and deployment studies. This includes both determining whether stakeholders are willing to adopt those technologies, and whether commercial products already exist in that market. Stakeholder input obtained as part of those market studies should be carefully considered and used to shape the final design of those technology studies.

Short Term Actions

Until the uniform and more universal availability of work zone delay information is available, the TIDC is an excellent resource for the trucking community. Minor improvements to the TIDC were requested by the trucking firms, and the Impacts Assessment (IA) team supports those requests. They include:

- In the Freight Solver, minimize the number of clicks needed to obtain the information requested.
- Allow companies to more easily tailor the information they receive from the TIDC. This can include:
    - Restricting information delivery to specific or individual trips.
    - Providing more control over how many or how often alerts are received.
    - Providing more direct ways to deliver TIDC information directly to the truck drivers (e.g., pushing information directly to smart phones or in-cab communication devices).

Both trucking companies participating in this project expressed significant appreciation to the entire project team for the team's high level of communication, willingness to listen, and willingness to incorporate their needs into a user-friendly solution. For both the short-term and long-term actions, it is highly recommended that U.S. DOT continue that approach to working with trucking companies and the businesses that support them. The businesses are very interested in working together to find solutions to problems that we all experience, but are leery of agencies pushing their own agendas.

At the very beginning of this project, the overall project team was slow to bring the trucking firms into the project design. This led to false assumptions about the market for specific products by trucking firms, subsequent delays in getting the project started, and eventually the need to redesign the project. These early project outcomes suggest that for future FRATIS projects, the trucking companies be brought in at the very beginning of the project design effort in order to ensure that the design of those future projects fits with the interests, capabilities, and desires of the trucking firms. While this project did listen effectively to the trucking firms, the project team was slow to adopt that approach.

Chapter 1. Introduction

The objective of the I-35 Freight Advanced Traveler Information Systems (FRATIS) Impacts Assessment (IA) project for the U.S. DOT Intelligent Transportation Systems Joint Program Office (ITS-JPO) is to examine the impacts that the delivery of pre-construction closure notifications along with near real-time construction delay information has on trucking firms operating along I-35.

The original design of the I-35 FRATIS project assumed that participating trucking firms lacked freight delivery optimization software, and would be interested in adopting a version of freight delivery optimization software previously developed with Federal Highway Administration (FHWA) assistance and used successfully to optimize drayage movements, where the version of that optimization software also included specific ties to information on predicted travel delays due to planned construction activities on I-35.

In practice, it was determined that most trucking firms already used freight delivery optimization software, and that software was intricately tied to each firm's business information systems. As a result, trucking firms were not interested in adopting FHWA's optimization software. Firms were, however, interested in obtaining information on predicted and actual construction delays, so that they could incorporate that information within their own business practices, adjusting freight deliveries as appropriate.

This report documents the outcomes of the use of information provided by the Texas Department of Transportation (TxDOT) and the Texas A&M Transportation Institute's (TTI) Traveler Information During Construction (TIDC) system by two trucking firms. These firms will be referred to as the "Regional Carrier" and "National Carrier" (based on the extent of their service areas), to preserve their anonymity and thus protect proprietary business information. Both firms provided information on the performance of their truck deliveries which moved through the construction zone during I-35 construction activity.

During the timeframe of this project, I-35 construction activity is taking place south of Dallas, Texas and north of Austin, Texas. Construction already was underway prior to the start of this project. In September 2017, both carriers started to receive electronic data feeds from the TIDC system describing both expected delays due to planned construction activity, and near real-time reports about delays being experienced in the construction zone. The two companies provided data on their trucking activities and fleet performance for time periods both prior to their receipt of TIDC information, and after they were given access to TIDC information and incorporated that information into their daily business process.

This report describes the independent assessment of the outcomes of their use of that information. The document includes the measured changes in travel time, travel time reliability, and other quantifiable metrics. In addition, it presents the qualitative feedback obtained from both firms.

Introduction to the Report

This report is divided into nine chapters, in addition to the Executive Summary provided earlier. The chapters are:

1. **Introduction:** Provides background on the motive to initiate this project and an overview of the main project components.
2. **Project Objectives:** Introduces the trucking firm participants and covers the structure of the I-35 FRATIS impacts assessment.
3. **Project Methodology:** Describes the before/after analysis approach used, in addition to the user satisfaction surveys conducted.
4. **Traveler Information Provided:** Details the content available to the trucking firms through the Traveler Information During Construction system.
5. **Truck Travel and Roadway Performance Data:** Outlines the Before and After Periods and summarizes the descriptive statistics of each trucking firm's pilot data.
6. **User Satisfaction Surveys:** Lists the main interview questions covered during the user satisfaction surveys and main takeaways from user feedback.
7. **Impacts Assessment:** Provides an in-depth look into the before/after analysis conducted.
8. **Work Zone Mitigation Tool:** Describes the software developed as part of this project that allows the estimation of travel times between trucking origins and destinations given actual traffic conditions.
9. **Summary and Conclusions:** Concludes the final report by summarizing the evaluation results, conclusions, and project recommendations.

Introduction to the Impacts Assessment Project

The scope of the Impacts Assessment Project included the following tasks:

- **Task 1:** Project Management.
- **Task 2:** Plan Impacts Assessment.
- **Task 3:** Archive Data.
- **Task 4:** Develop Tools.
- **Task 5:** Conduct Impacts Assessment.

Table 2 summarizes the scope of the main project components after it became apparent that trucking firms were not interested in using the FHWA provided delivery optimization software.

While participating trucking firms were unwilling to share the details of their optimization algorithms or use the optimization software that was part of the planned freight traveler information system being tested, they were willing to incorporate the pre-construction closure and near real-time construction delay information being developed and distributed by TxDOT and TTI into their own optimization process.

Table 2. Summary of project scope.

Project Component	Scope
Experimental Plan	Compare actual truck trip performance data from the before period (prior to receiving delay information) against actual truck trip performance data from the after period (after receiving actionable freight traveler information).
Tool Development Plan	Develop a Work Zone Mitigation Scenario Planning Tool designed to help trucking companies understand the impacts of construction zone traffic delays on their delivery schedules and an Outcome Predictor Tool that computes the summary truck trip performance metrics (Note: the Outcome Predictor Tool maintains the same functionality as outlined in the original scope).
Data Archival Plan	These data types will be archived: Traffic Data: travel times, incident information, lane closure information. Trucking Company Performance Data: origin, destination, trip start time, expected arrival time, actual arrival time, miles driven, trip time. Ancillary Data: traffic volumes, weather. Detailed Truck Routing Data: GPS trajectory data (on an as needed basis).
User Satisfaction/ Acceptance Plan	User acceptance/satisfaction surveys will be conducted via phone.
Impacts Assessment Plan	Conduct a before-and-after analysis that specifically accounts for exogenous. factors such as major travel disruptions via a clustering approach.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

The following unpublished technical memorandums, available from FHWA, were written as part of this project, and provide background information on the impacts assessment:

- **Task 2:** Summary of Scope Revisions.
- **Task 3:** Data Archival Report—Before Period.
- **Task 3:** Data Archival Report—After Period.
- **Task 4:** Work Zone Mitigation Scenario Planning Tool Methodology and Validation Plan.
- **Task 4:** Work Zone Mitigation Scenario Planning Tool and Outcome Predictor Report.
- **Task 5:** User Acceptance and Satisfaction Surveys.

These additional unpublished technical memorandums were developed prior to the project scope changes and can be read in conjunction with the Summary of Scope Revisions technical memorandum:

- **Task 2.1:** Mobility and Environmental Experimental Plan.
- **Task 2.2:** Tool Development Plan.
- **Task 2.3:** Data Archival Plan.
- **Task 2.4a:** Final User Acceptance and Acceptance Plan for Web Portal.

- **Task 2.4b:** Final User Acceptance and Acceptance Plan for Smartphone/Tablet Apps.
- **Task 4:** Expert System Methodology and Validation Plan.

This report documents the findings from all project tasks, and summarizes information found in these earlier technical documents.

Chapter 2. Project Objectives

The objective of the I-35 FRATIS Impacts Assessment Project was to assess the benefits and other impacts associated with FRATIS by taking real world trucking company daily trip performance data (e.g., origin, destination, trip start time, expected and actual trip end time, etc.) and summaries made from those data, and determining the benefits of providing trucking firms with pre-construction closure notifications along with near real-time construction delay information. Pre-construction closure notifications include estimates of delay in each work zone. The Freight Solver, accessible by the National Carrier, also provides aggregated trip delay,

One regional and one national trucking firm (to be referred to as the Regional Carrier and the National Carrier to preserve anonymity) provided information on the performance of their truck deliveries which moved through the construction zone during the I-35 construction activity. Data were being provided during two time periods: the first, known as baseline data, was *before* information on expected delays was provided; the second was *after* the trucking firms had been given information on upcoming construction events and road closures, and were thus able to incorporate that information into their own logistic optimization software. The IA team then performed a before/after analysis of the truck deliveries.

The initial assessment plan assumed that information would be accessible on exactly what changes occurred in truck delivery schedules based on data obtained from FHWA's optimization software. Since the trucking firms used their own delivery optimization software, that information was no longer available to the IA team. Thus, the assessment of project outcomes was centered on a before/after analysis of data that was available, travel time data from both companies' fleet management systems. To supplement that data, the IA team also obtained roadway performance data and data on exogenous events (e.g., bad weather, size and scope of each construction event, and presence and scope of major incidents).

Using the combination of fleet management and exogenous data it was possible for the IA team to perform a before/after analysis that also considered the impacts of those exogenous events. This was done by adopting a cluster analysis approach to the before/after analysis which clustered travel time performance by the types of exogenous events taking place during each trip.

In addition to the basic before/after analysis the original impacts assessment required the construction of software which allowed the estimation of travel times between trucking origins and destinations given actual traffic conditions. This software tool was intended to facilitate a comparison between actual trip outcomes and the outcome of trips that would have been made if the FHWA optimization software was not used to account for construction delays. However, because trucking firms were not interested in using the FHWA optimization software for planning their deliveries, this tool, while still built for this project, could not be used as part of the assessment. Chapter 8 of this report describes the Tool, and describes the benefits such a tool has if made widely available to trucking firms.

Chapter 3. Project Methodology

The analysis results presented in chapter 7 were the result of a classic before/after analysis, but one that specifically accounted for exogenous factors such as major travel disruptions. A cluster approach was used to group summary truck trip records provided by the trucking firms based on the type, size and significance of different events which impact truck travel time and trip reliability. The clustering approach ensures that the before and after comparisons were made for similar conditions. This ensures that the outcomes of the analysis were the result of the new availability of information and the behavioral changes made in response to that information, rather than simply a result of changes to background travel conditions.

The Before and After Periods were defined based on when each firm started to use the TIDC information. Before/after analyses were performed for each company independently in order to address the differences in origins and destinations, as well as company policies.

The results presented in chapter 7 include a detailed assessment of changes in travel time, travel distance, and trip reliability between the before and after periods. These differences are then converted into estimates of savings in fuel consumption and emissions. The project team also looked at monetizing the benefits of operational efficiency improvements to the firms, but found this task impossible to accomplish given the data available from the firms.

The assessment also included the results of user satisfaction surveys conducted with trucking companies. These surveys measured the interest of the trucking companies to use work zone scheduling and delay information from the public sector. These interviews were performed with the trucking company personnel—primarily fleet managers and dispatchers—that were directly involved with either using the TIDC information, or pushing for resources within their companies to obtain the resources necessary for permanently making the inclusion of TIDC-like information part of their routine business practice.

Finally, as a result of information obtained through the performance of this project, the report documents two specific outcomes intended to provide FHWA with key guidance concerning future freight planning and operations in considerations of work zones on major freeways:

Factors that resulted in challenges with performing the original I-35 FRATIS deployment concept for this project.

The benefits, challenges, demand, and feasibility of creating a standardized, single data source, and/or a standard data format, for construction information and congestion predictions across the country.

Chapter 4. Traveler Information Provided

The TxDOT's TIDC system produces information about construction delays occurring on I-35 between Salado and Hillsborough. In the near future, the section of I-35 in, and south of, the Austin area will also experience major construction delays in the next 5 to 6 years and it is expected that the TIDC will be expanded to include those portions of I-35.

TxDOT and Texas A&M Transportation Institute (TTI) are trying to improve freight delivery in the corridor, despite the construction delays that are expected. The I-35 FRATIS project was designed to provide the participating trucking firms with this information in an effective manner, so that it could be used to more effectively plan and operate freight delivery plans. The motivation for this project was therefore to determine if the TIDC could help trucking firms maintain delivery efficiency through major construction zones. If so, TxDOT and TTI plan to continue operation of the TIDC in order to maintain the same level of communication and data coverage for the next 80 to 90 miles south of this project study area, an area spanning multiple districts and jurisdictions.

TIDC User Classes

The primary target users for the TIDC system can be classified into three groups:

- **Dispatchers** and other staff that use the pre-construction closure and near real-time construction delay information to prepare and deliver daily schedules of orders to the drivers. The information provided includes estimates of delay by hour associated with each closure.
- **Drivers** that use the closure and delay information to adjust travel schedules as necessary or that simply use the information to help identify road segments on that day's trips where they need to be aware of atypical queues forming.
- **Planners** that use the value of this additional traveler information to modify existing internal processes for increased operational efficiencies.

TIDC Dissemination Methods

The TIDC system initially developed two options for freight information dissemination:

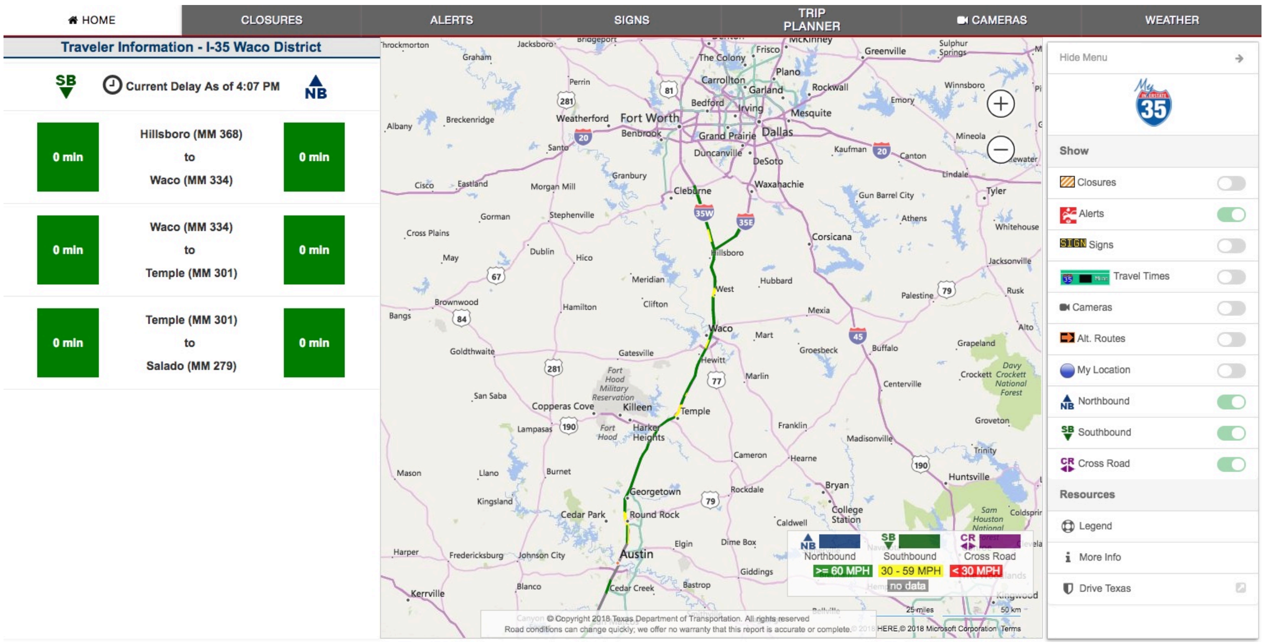
1. **I-35 Central Texas Traffic Map:** A Web-based application that is available around the clock and allows the user to view delays at various departure times based on an user inputted trip origin and destination.
2. **My I-35 Traveler Information Emails:** Two types of emails are distributed, one containing estimated delay impacts for each closure on the mainlanes, and one containing near real-time corridor delay alerts.

The National Carrier opted to access the I-35 Central Texas Traffic Map for the duration of the pilot test, while the Regional Carrier wanted instead to receive the My I-35 Traveler Information emails.

During the course of this project, a third mechanism, the Freight Solver was developed and delivered.

I-35 Central Texas Traffic Map

Figure 1 below illustrates the basic web map which depicts current conditions within the I-35 construction zone.



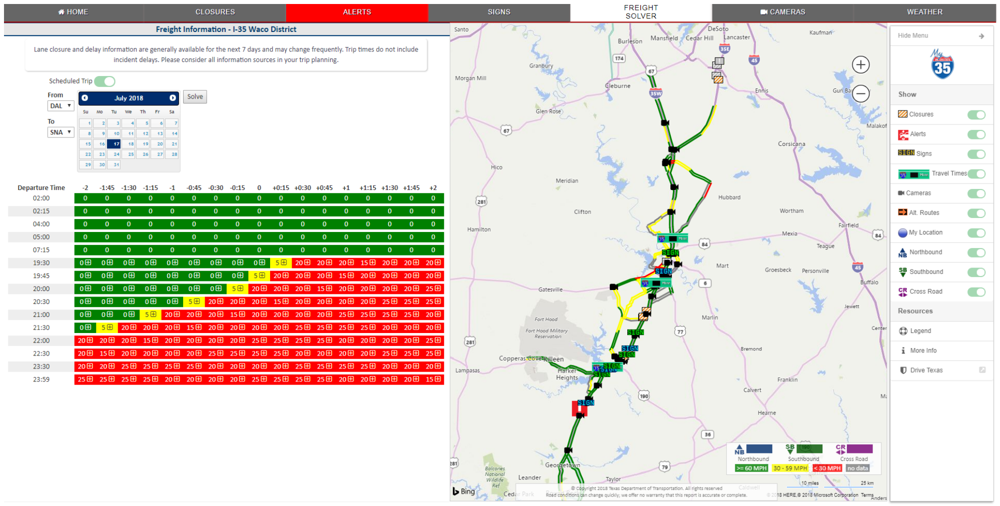
Source: Texas A&M Transportation Institute, 2018.

Figure 1. Interface. I-35 Central Texas Traffic Map.

Freight Solver

The Freight Solver is an extension of the basic functionality constructed by TTI with the goal of providing information about how expected delays change over time for specific origin/destination pairs along the I-35 corridor. An example of the Freight Solver output is shown in figure 2. In the Freight Solver, a green/yellow/red matrix on the left side of the figure describes the expected delays in the corridor for a trip that departs at the time specified at the “departure time” indicated in the left most column of the matrix.

An enlarged version of this delay matrix is shown in figure 3. Each color coded cell in the matrix displays the expected delay. The columns represent the outcome if the departure time changed in 15-minute increments. The “planned” departure time is the central column in the matrix. In figure 3, no delays are expected prior to the departures starting near 7:30 p.m. Starting with departures around 7:30 p.m., a driver can expect to be delayed if their trip start is delayed by 15 minutes. The expected delay is 5 minutes. Travel delays are expected to be higher, the later that trip starts, rising to 20 minutes if the trip start is delayed by 30 minutes.



Source: Texas A&M Transportation Institute, 2018.

Figure 2. Interface. I-35 Central Texas Traffic Map—Freight Solver interface.

Departure Time	-2	-1:45	-1:30	-1:15	-1	-0:45	-0:30	-0:15	0	+0:15	+0:30	+0:45	+1	+1:15	+1:30	+1:45	+2
02:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:30	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	5 ⊞	20 ⊟	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞
Closures	Expected Delay: 15 min -- Lofland Rd to US-287, Waxahachie: 7/17/2018 8:00:00 PM - 7/18/2018 6:00:00 AM, MM 404.0 - 403.5, Painting Lofland bridge.																
	Expected Delay: 5 min -- US-287 to Cantrell, Waxahachie: 7/17/2018 8:00:00 PM - 7/18/2018 6:00:00 AM, MM 403.0 - 399.0, Allowing trucks to get in and out of the median.																
	Expected Delay: 0 min -- Behrens to Forrest St, Bellmead: 7/17/2018 7:00:00 PM - 7/18/2018 7:00:00 AM, MM 338.0 - 336.0, Full depth pavement repair.																
	Expected Delay: 0 min -- W Nugent Ave to BNSF (South), Temple: 7/17/2018 7:00:00 PM - 7/18/2018 7:00:00 AM, MM 302.0 - 301.0, Paving at the underpass.																
19:45	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	5 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞
20:00	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	5 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞
20:30	0 ⊞	0 ⊞	0 ⊞	0 ⊞	0 ⊞	5 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞
21:00	0 ⊞	0 ⊞	0 ⊞	5 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞
21:30	0 ⊞	5 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞
22:00	20 ⊞	20 ⊞	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞
22:30	20 ⊞	15 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞
23:30	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞
23:59	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	25 ⊞	25 ⊞	25 ⊞	25 ⊞	20 ⊞	20 ⊞	20 ⊞	20 ⊞	15 ⊞

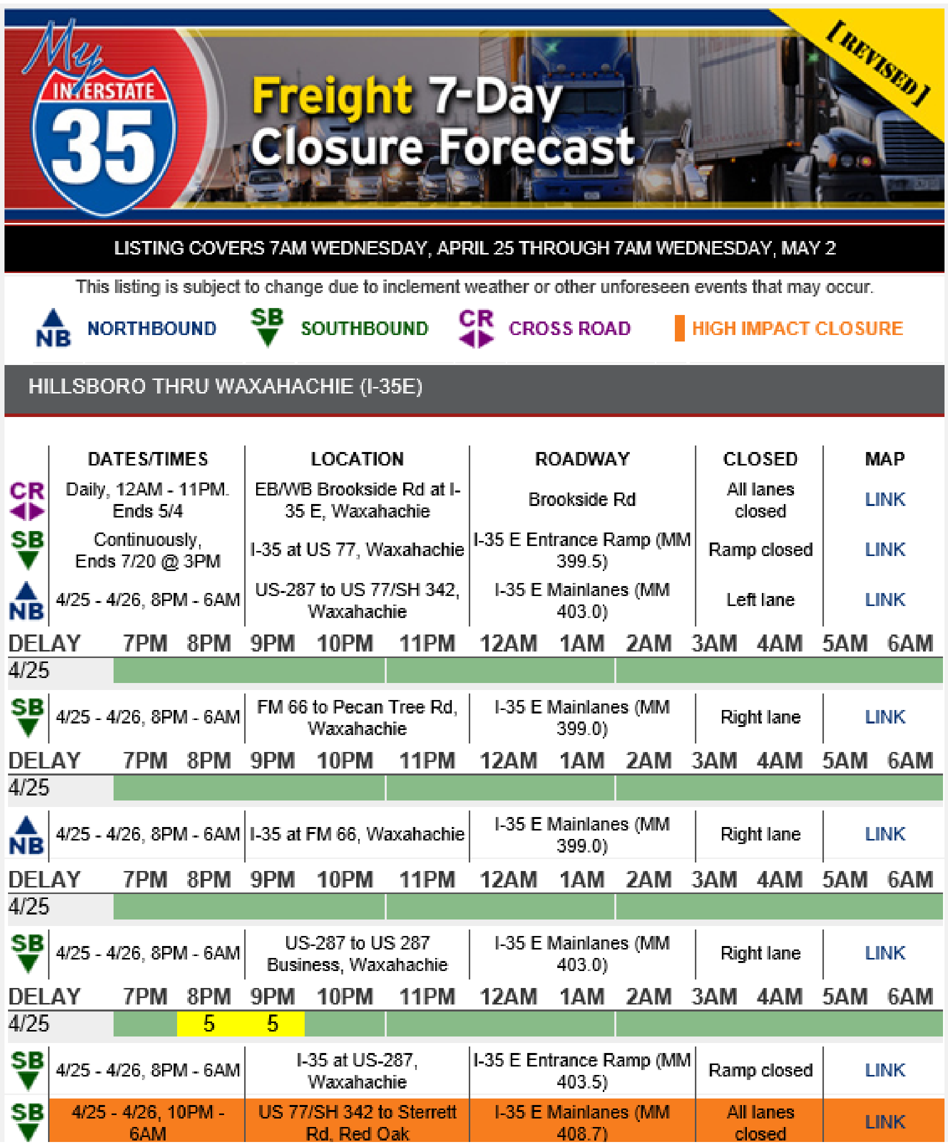
Source: Texas A&M Transportation Institute, 2018.

Figure 3. Chart. I-35 Central Texas Traffic Map—Freight Solver delay details.

The Freight Solver information was provided to the National Carrier. They worked with TTI and TxDOT on the design and delivery of this information.

My I-35 Traveler Information Emails

In contrast, the Regional Carrier received construction event emails developed and delivered by TxDOT and TTI. An example of these emails is shown in figure 4. This type of email is sent on a daily basis at 5:00 a.m., with a 7-day rolling outlook. It lists the estimated delay impacts for each closure on the mainlanes.



Source: Texas A&M Transportation Institute, 2018.

Figure 4. Chart. My I-35 traveler information emails—freight 7-day closure forecast.

TEMPLE

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
NB	Continuously, Ends 2/1 @ 5PM	NB S 57th St at I-35, Temple	S 57th St	All lanes closed	LINK
SB	Continuously, Ends 7/31 @ 5PM	Central Ave/Adams Ave to BNSF (South), Temple	I-35 Frontage Road (MM 300.5)	Left lane	LINK
NB	Continuously, Ends 9/15 @ 7AM	I-35 at W Nugent Ave, Temple	I-35 Frontage Road (MM 301.3)	Left lane	LINK
SB NEW	Daily, 4/30 - 5/1, 9AM - 5PM	Saulsbury Dr to Central Ave/Adams Ave, Temple	I-35 Frontage Road (MM 301.0)	Various lanes closed	LINK
SB NEW	Daily, 5/1 - 5/2, 9AM - 5PM	Saulsbury Dr to Central Ave/Adams Ave, Temple	I-35 Frontage Road (MM 301.0)	Various lanes closed	LINK

FOR MORE INFORMATION, CONTACT:
Jodi Wheatley
I-35 Information Specialist
TxDOT Waco District
100 S. Loop Dr.
Waco, TX 76704
254/867-2836
jodi.wheatley@txdot.gov

Today's listing was generated at 4pm, Wednesday, April 25, 2018

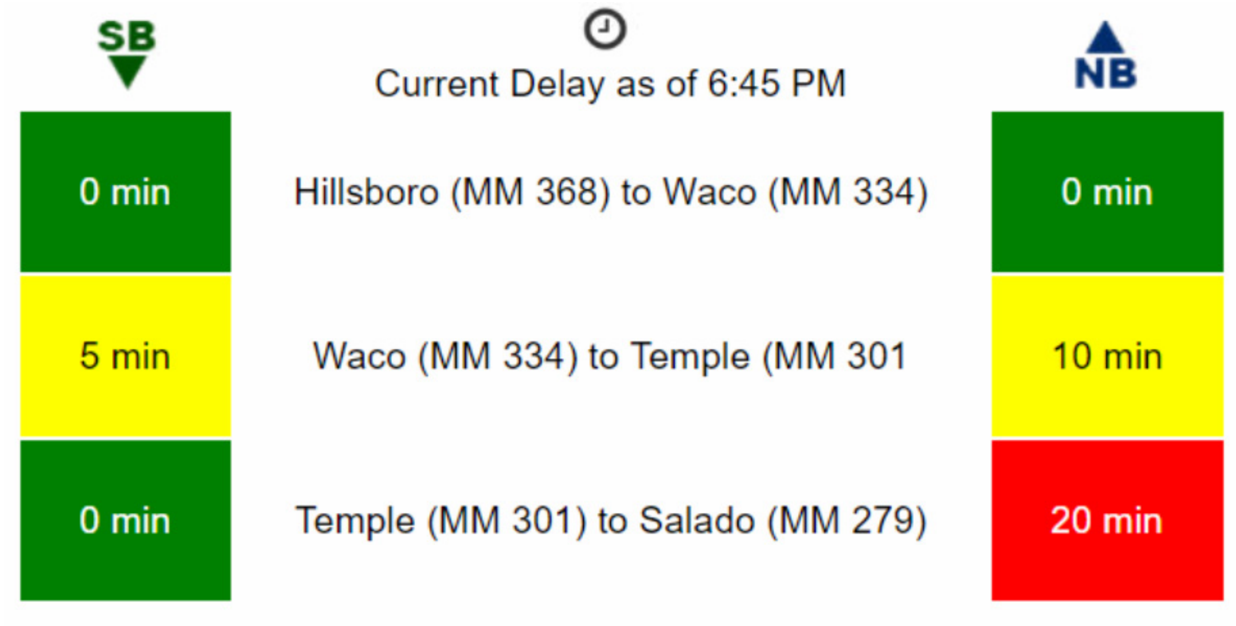
Please observe all warning signs, traffic control devices, and police officers in the project area. As a reminder, traffic fines double in construction areas when workers are present, whether or not they are visible.

Efforts to improve the I-35 corridor throughout the state would not be possible without the support of local governments, the Texas Legislature and the U.S. Congress. in addition to the ongoing $1.9 billion dollar expansion of I-35 through TxDOT's Waco District, a number of critical projects are underway in the Dallas/Fort Worth region to improve I-35 connections to I-820 and I-635 thanks to a partnership with the private sector. Meanwhile, TxDOT continues to plan for the long-term future of the I-35 corridor through the MY 35 citizen-driven planning process.

Source: Texas A&M Transportation Institute, 2018.

Figure 4. Chart. My I-35 traveler information emails—freight 7-day closure forecast (continuation).

Figure 5 is an example of a "Corridor Delay Status Update." This type of information also is delivered by email. An email such as this is sent out only if there is a change in delay. Email is sent out at most every 15 minutes.



Source: Texas A&M Transportation Institute, 2018.

Figure 5. Chart. My I-35 traveler information emails—corridor delay status update.

Chapter 5. Truck Travel and Roadway Performance Data

This chapter describes the data collected during the project. It reflects the data that the participating trucking firms were willing to extract and share from their fleet management and dispatch systems. These data were used to assess the benefits obtained from the use of pre-construction closure notifications and near real-time construction delay information dissemination with the intent of providing actionable freight traveler information to improve the efficiency of trucking operations.

Data Archival Periods

The study design requested that the trucking firms provide data for at least six months prior to the date when they were given direct access to the construction delay information. Data collection then concluded on March 18, 2018, six months after the start of the official After Period. The Regional Carrier was able to provide data for eight months prior to the start of the pilot data collection period. The National Carrier was able to provide data for five months prior to the start of the pilot. One month of data were excluded from the assessment due to impacts to trucking on I-35 as a result of Hurricane Harvey. That one month suspension of data collection occurred between the Before Period and After Period for the project.

The break in data collection was adopted because the hurricane caused both the temporary suspension of planned roadway maintenance and construction events, and a significant reduction in the number of truck trips on I-35. All I-35 mainline construction closures were canceled from August 25, 2017 through September 4, 2017. Table 3 summarizes the timeframes of the before and after periods for each carrier, with the impacts of Hurricane Harvey taken into consideration.

Table 3. Summary of data archival periods.

Carrier	Baseline Data Available	Pilot Start Date	I-35 Canceled Closures due to Hurricane Harvey	Official Before Period	Official After Period
National Carrier	3/19/2017 to 9/17/2017	9/18/2017	8/25/2017 to 9/4/2017	3/19/2017 to 8/19/2017 (5 mo)[1]	9/18/2017 to 3/18/2018 (6 mo)
Regional Carrier	12/1/2016 to 8/14/2017	8/15/2017	8/25/2017 to 9/4/2017	2/14/2017 to 8/14/2017 (6 mo)	9/18/2017 to 3/18/2018 (6 mo)

Source: I-35 FRATIS Impacts Assessment Team, 2018.

1 The five months of Before Period data for the National Carrier (one month short because of the data excluded due to the impacts of Hurricane Harvey) are considered sufficient for this I-35 FRATIS impact assessment.

Data Sources

Data were obtained from two primary data sources plus a number of ancillary data sources. The main sources of data are:

- The TxDOT TIDC system, which provides historical and near real-time roadway performance, event, and disruption data on the I-35 corridor.
- The participating trucking firms' trip planning, dispatching, and fleet management systems, which provide travel performance details about the trips that are made within the I-35 corridor.

The main ancillary data sources include:

- Weather databases.
- The national performance management research dataset.
- TxDOT traffic volume data that describe the level of use for specific days and/or time periods.

Archived Data Elements

An overview of all data required by the IA Team to support the Impacts Assessment is provided in table 4. This table also summarizes the specific types of data that were collected, the sources for those data, the methods and procedures for gathering and archiving those data, and any checks that were performed on the data.

Data Set Descriptions

A description of each archived data element listed in table 4 is included below.

I-35 Performance Data

A database of external factors has been prepared for use in the evaluations. I-35 performance data such as travel times along I-35, incident and crash information, and lane closure information have been stored in the database. The data was formatted into a Structured Query Language (SQL) database to facilitate querying, and the database design can be modified (e.g., updates to the list of stored variables) at any point during the development process. The I-35 performance data were used to determine whether slower trips in the Before and After Periods are correlated with specific incidents or external conditions.

Travel time data for I-35 have been obtained from Bluetooth detectors operated by TxDOT. For this project, Bluetooth-based travel times are reported for 21 distinct segments of I-35 and some connecting roads. Data were accessed by roadway segment via an XML feed that is updated every thirty seconds. Reader locations and segments lengths were mapped via GPS locations for exact distances.

Table 4. Summary of Before and After Period data archived in support of the I-35 FRATIS Impact Assessment.

Data Type	Specific Data	Source, Method, Process	Checks (QA/QC)
I-35 Performance Data	• Travel time data for I-35 in 5-minute increments. • Incident and crash data. For each incident: location of incident, time, duration, nature, and any official alternate routes. • Lane closure information. For each closure: location, time, duration, nature, and expected delay impacts.	TIDC XML feeds with these data are downloaded and stored on a server located at the Washington State Transportation Center (TRAC). In addition, TxDOT provides an API for obtaining these data for historical analysis.	Sanity checks (extreme changes in travel time between consecutive data points) are performed to ensure that unusual data are not included in the analysis.
Trucking Company Daily Trip Performance Data	• Origin/destination. • Trip start date and time. • Expected arrival time and time associated with a late delivery. • Actual delivery date and time. • Miles driven. • Trip time.	Provided in a spreadsheet format (Excel or comma separated values (CSV)) by trucking firms once per month, with baseline travel supplied in a single delivery of six months of data.	Trip O/D pairs are confirmed against base data, to ensure that trips supplied use the I-35 corridor. Sanity checks are made on travel times and dates.
Ancillary Data	• Weather data in hourly increments, including precipitation amount, visibility, and wind speed. • Hourly traffic volumes on I-35. • Explanatory information from participating trucking firms. • National Performance Management Research Data Set (NPMRDS) geographic information systems (GIS) data (e.g., segment location, length). • NPMRDS segment and time period specific travel time data.	Direct download of volume data from TxDOT TIDC system, as well as Weather Underground data feed downloads for stations in the corridor. Explanatory information provided directly from participating trucking firms as needed. NPMRDS was obtained from the NPMRDS national repository.	Volume data are checked for time-of-day, day-of-week, and time series consistency to ensure that data are valid. QA/QC were applied as described in chapter 8 of this report

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Data also have been obtained from the TxDOT incident response data feed. Incident data on current and recent incidents are retrieved via a JSON data feed. The incident logs indicate whether an alternate route was suggested, and what that route was (if applicable). The incident data extracted include location (X/Y), date, time of occurrence, duration of incident, and nature of the incident (lane blocking, multi-lane blocking, shoulder only, fatality, serious injury, fire involved, hazardous material spill, etc.). Incident data are linked to specific roadway segments and time periods in order to associate these disruptions with specific deliveries (note that additional data are not always available for every incident of the data set).

TIDC information also describes when lanes are closed on I-35. Lane closure data were obtained for the construction closures occurring on I-35 during the FRATIS pilot. A comprehensive lane closure data feed was accessed via XML which included location (X/Y coordinates), date, time of occurrence, duration of incident, and nature of the closure. Also retrieved for each closure include the estimate produced by TxDOT for expected delays and queues, which was a separate, but associated data stream, also available via XML and linked via the unique closure identification number.

These data serve to provide the IA team with the context for analyzing travel times between defined origins and destinations. That is, the fact that a trip from Dallas to Austin takes longer than usual is not surprising when travel on I-35 is slower than normal. Similarly, the IA team will use these data to be able to compare predicted travel times through the construction area to actual travel times. This information can in turn be used in the analysis of the effectiveness of each trucking firm's response to expected construction delays.

For all of these data sets, simple range and value quality assurance tests are performed. For example, travel times on I-35 are capped at the time required to travel the road segment at 80 mph. Lane closure and incident data are checked to ensure that dates are in the expected date ranges and that locations are on roads being used in the study.

National Performance Management Research Data Set (NPMRDS) data were obtained for use within the Work Zone Mitigation Tool. Both NPMRDS geographic information system (GIS) shape files and segment and time period specific travel time data were downloaded. The data for the NPMRDS can be downloaded by any State DOT or metropolitan planning organization (MPO) from the NPMRDS resource Web site for which credentials are required, but those credentials are freely available to State DOTs and MPOs. To gain access to these data, contact the group within your agency responsible for reporting roadway performance to FHWA.

A specific subset of the NPMRDS network for the State of Texas was selected for use in this project. The geographic boundaries of the network were identified from the location of origins and destinations of the Regional and National Carrier trips that had previously been determined to travel on I-35 through the construction zones. More on this subject is presented in chapter 8, which describes the Work Zone Mitigation Tool.

Trucking Company Daily Trip Performance Data

This subsection provides a description of the data collected from the two participating trucking companies. The data collected by the firms include location and time information for the individual vehicles during each trip that can be used to estimate the geographic distribution (origin-destination patterns) of trips, as well as the trip durations. These data are then used by each carrier's fleet management system to record trip details for individual delivery movements.

For this project each carrier provided the IA team with a **baseline** trip data set that described the movements of individual delivery vehicles over a specified period prior to the date when they were given access to the TIDC construction delay information. Each carrier also collected a similar data set that describes individual delivery vehicle movements following the date they were given access to that construction delay information. These Before and After data sets were then used to evaluate how trip characteristics changed following the introduction of access to construction delay information.

Each trucking company provided trip information in a format that was appropriate and convenient for the company, given their internal database systems, data archiving procedures, data query tools, staff resources, and information dissemination policies. While the basic information was similar between the two companies, there were differences in format and content. The following is a summary of the contents of each data set:

1. **National Carrier data set**: The National Carrier data set was configured as an Excel-compatible spreadsheet, where each row of the spreadsheet represented one trip (i.e., a single origin-destination pair).

   The trips in the National Carrier data set were pre-grouped into ten specific origin-destination pairs, based on carrier-defined origin and destination boundaries:

   - Austin to Dallas.
   - Dallas to Austin.
   - Dallas to Laredo.
   - Laredo to Dallas.
   - Dallas to San Antonio.
   - San Antonio to Dallas.
   - Dallas to Waco.
   - Waco to Dallas.
   - San Antonio to Laredo.
   - Laredo to San Antonio.

   Several of these trips did not fall within the I-35 construction activity currently being performed by TxDOT. These trips were used as control data in the before and after analysis.

   For each trip, the following attributes (fields) were provided:

   - Trip origin (a pre-defined location such as DAL, or AUS).
   - Trip destination (a pre-defined location such as DAL, or AUS).
   - Trip planned miles (the original planned length of the trip).
   - Trip actual miles (the actual length of the trip).
   - Dispatch date and time.
   - Arrival date and time.
   - Trip duration.

2. **Regional Carrier data set**: The Regional Carrier data set was configured as an Excel-compatible spreadsheet, where each row of the spreadsheet represented one endpoint of one trip (i.e., a single trip was defined using two rows, one for the origin and one for the destination). For each trip, the following attributes (fields) were provided:
   - Vehicle number (a unique identifier for a given tractor).
   - Dispatch number (a unique identifier for a specific load, which can include a number of stops/ deliveries).
   - Stop ID (indicator of stop sequence along a trip; 0 = origin, 1 = first stop, etc.).
   - Landmark ID (internal identifier of each stop/delivery).
   - Record type/e_type (identifier of the nature of the stop, e.g., trip start, arrival, etc.).
   - Stop profile ID (indicator of trip origin versus stop along a route).
   - Load type.
   - Expected arrival/departure time;
   - Actual arrival/departure time.
   - Status (on-time, not on-time).
   - Odometer reading at arrival or departure.
   - Latitude at arrival or departure.
   - Longitude at arrival or departure.

   Unlike the National Carrier data set, the Regional Carrier data set did not pre-group the trips into specific origin-destination pairs (e.g., city name). Therefore, additional processing was necessary to define origin and destination boundaries and assign the trips to those specified locations. (this process is described further in the Data Archival Report for the Before Period). The trips in the Regional Carrier data set were grouped into seven specific origin-destination pairs, based on the origin and destination boundaries developed during data processing. The trips all originate at a terminal in Temple, Texas, on I-35 between San Antonio and Dallas.

   The Regional Carrier origin-destination pairs that were processed were:
   - Temple to Dallas.
   - Temple to Fort Worth.
   - Temple to Waco.
   - Temple to Tyler.
   - Temple to Austin.
   - Temple to San Antonio.
   - Temple to Laredo.

   Three of the Regional trip routes (Temple to Waco, Temple to Tyler, and Temple to Laredo) were defined based on trip distributions observed in the post-implementation data. These routes were not originally defined when the baseline data were originally processed; the baseline data was therefore re-processed to extract Before data for the additional routes, to facilitate before versus after comparisons.

The resulting sample size for eight of the ten individual national route origin/destination pairs varied from 600 to 3100 trips, depending on the route. The Dallas-Laredo pair in both directions had a sample size too small to be useful to this study, and was thus ignored in the final analysis effort. Overall, for the National Carrier data there were 13,041 usable trips—across all origin/destination pairs combined—during the Before Period, and 11,516 usable trips during the After Period. For the Regional Carrier trips, the sample size per origin/destination pair varied from 150 to 2600. Overall, there were 6,508 usable Regional trips—across all origin/destination pairs combined—during the Before Period, and 4,033 usable trips during the After Period.

Ancillary Data

A database of external factors has been prepared for use in the evaluations. Ancillary data such as hourly traffic volumes on I-35 and weather data in hourly increments were stored in the database. The data have been formatted into a SQL database to facilitate querying, and the database design can be modified (e.g., updates to the list of stored variables) at any point during the development process. The ancillary data were collected for use in the before/after analysis to determine whether specific external conditions are causal factors for observed differences in the travel time performance of the Regional and National Carriers during the Before and After Periods. These impacts have been reported in chapter 7 Impacts Assessment.

Hourly and daily traffic volumes on I-35 were obtained from TxDOT. Weather data are used to identify where specific trips are impacted by bad weather. The weather data are downloaded from the National Oceanic and Atmospheric Administration (NOAA) archives. The current format contains various types of weather data in hourly increments as well as daily and monthly totals/averages. At present, data for the Waco, Texas weather station have been archived. However, additional locations can easily be added if a more refined algorithm is developed to calculate weather variations at different locations along a trip route. The current available data that is relevant to this project includes: visibility, temperature, wind speed/gust, and precipitation, with daily averages and peaks for all of the above, and total snowfall.

Data Set Descriptive Statistics: Overall Observations

The following are descriptions of the trip data sets from the National Carrier and Regional Carrier. The descriptions were based on a set of trip metrics that describe the central tendency of key trip characteristics and the variability of those characteristics, from trip to trip and by time of day. These metrics were then compared for the Before and After Periods (i.e., to what extent did those characteristics change following the start of new traveler information services). The metrics used for this discussion are the same ones previously used to describe the baseline data sets in the Task 3 Data Archival Report for the Before Period.

National Carrier Data Set

The baseline data provided by the National Carrier contains trip data from March 19 to August 19, 2017, while the post-implementation data contains trip data from September 18, 2017 to March 18, 2018. The National Carrier provided trip data for ten specific origin-destination sets that used the I-35 corridor in central and southern Texas.

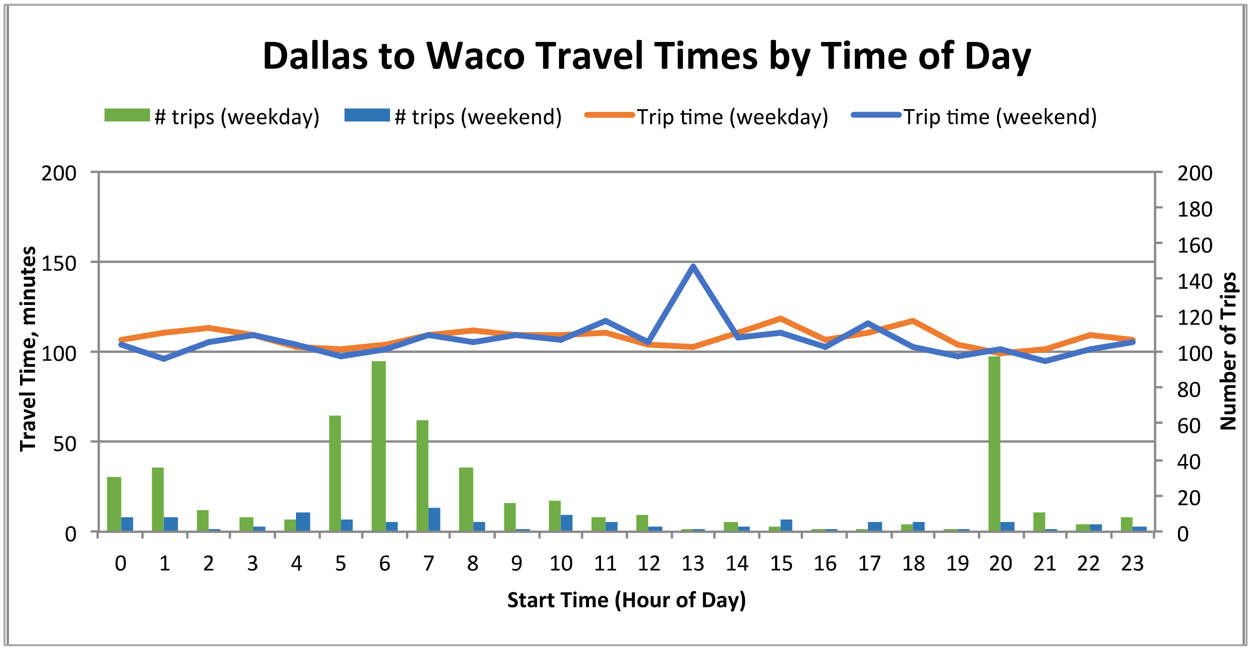
Table 5a displays descriptive trip statistics for the National travel time data collected during the baseline (Before) period. Table 5b displays descriptive trip statistics for the National travel time data collected during the post-implementation (After) period. The analysis of the differences between these Before and After Periods is presented in chapter 7 of this report.

Table 5. National Carrier descriptive statistics.

Origin	Destination	Number of Trips	Mean travel time	Standard Deviation of travel times	80th Percentile travel time	80th Percentile travel time minus Mean	80th Percentile minus Mean (% of mean)
a) Baseline							
Dallas	Waco	657	1:45	0:14	1:49	0:04	4%
Dallas	San Antonio	2622	4:38	0:22	4:55	0:17	6%
Dallas	Austin	738	3:23	0:23	3:35	0:12	6%
Dallas	Laredo	16	7:58	0:40	8:33	0:35	7%
San Antonio	Laredo	1471	2:34	0:17	2:40	0:06	4%
Waco	Dallas	572	1:48	0:16	1:51	0:03	3%
San Antonio	Dallas	2517	4:36	0:26	4:52	0:16	6%
Austin	Dallas	740	3:27	0:23	3:46	0:19	9%
Laredo	Dallas	29	7:57	0:46	8:30	0:34	7%
Laredo	San Antonio	1495	2:35	0:13	2:41	0:06	4%
b) Post-implementation							
Dallas	Waco	723	1:44	0:21	1:45	0:01	1%
Dallas	San Antonio	2859	4:36	0:27	4:53	0:17	6%
Dallas	Austin	756	3:20	0:21	3:27	0:07	4%
Dallas	Laredo	17	7:59	0:45	8:07	0:08	2%
San Antonio	Laredo	1291	2:32	0:17	2:37	0:05	3%
Waco	Dallas	614	1:50	0:33	1:54	0:04	4%
San Antonio	Dallas	2736	4:34	0:29	4:50	0:16	6%
Austin	Dallas	754	3:29	0:25	3:44	0:15	7%
Laredo	Dallas	21	7:33	0:33	8:10	0:37	8%
Laredo	San Antonio	1279	2:36	0:16	2:44	0:08	5%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

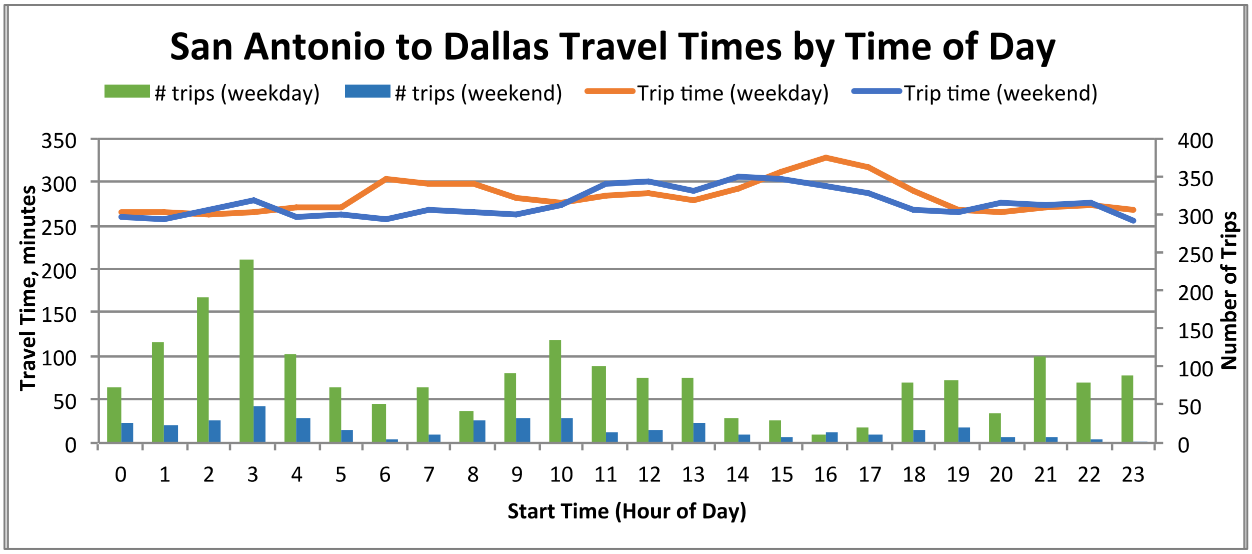
An analysis of travel times by time of day of the departure shows relatively little change in mean travel time for the given hour of the trip start (see figure 6). This data also shows that there were times when trucks make more trips than other times. For example, in figure 6, we see that large numbers of truck start the Dallas and Waco trip between 6:00 and 8:00 a.m. and around 9:00 p.m. on weekdays, with a smaller group starting the trip between midnight and 2:00 a.m. But mean travel times do not appear to be significantly different by time of day (the one exception in the graphic is a low volume weekend anomaly). The modest spread of start times does suggest that there could be some ability for the National Carrier to shift the time when they start their trips. This suggests that this firm could shift its start times to account for expected delays occurring on the freeway due to poor weather, construction, or other disruptions. Note that while figure 6 contains only data from the Before Period, the time-of-day travel patterns do not change between the Before and After Periods.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 6. Graph. National Carrier Dallas to Waco travel times.

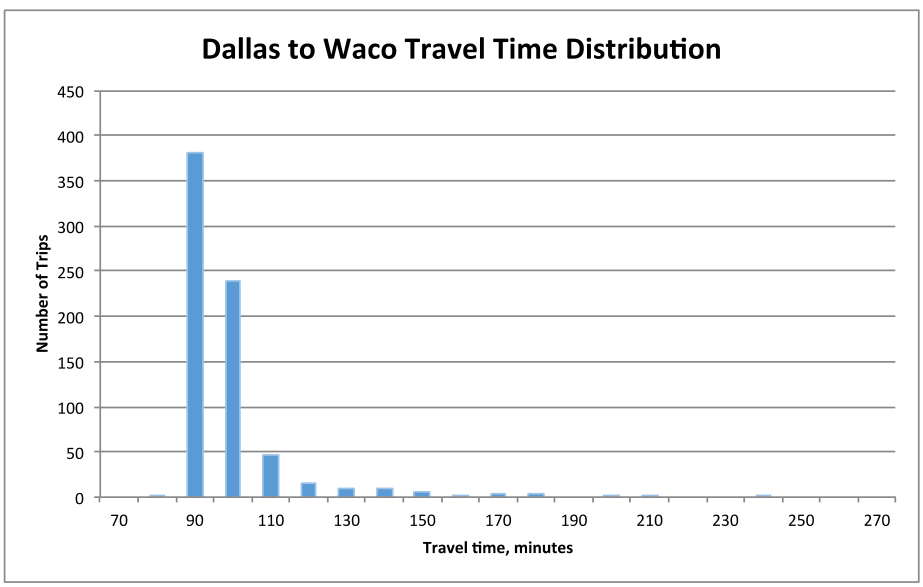
In figure 7, it is possible to see modest increases in trip times for those limited numbers of trips that start during the peak commute hours in San Antonio (i.e., 6:00 to 9:00 a.m. and 3:00 to 6:00 p.m.) and travel to Dallas. This data also suggests that the National Carrier avoids dispatching trucks during the weekday urban commute hours.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

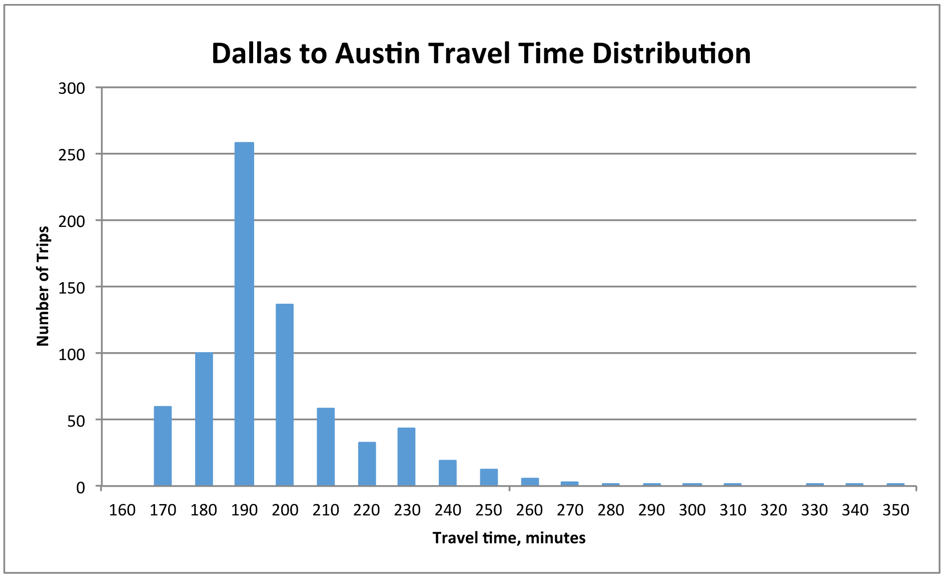
Figure 7. Graph. National Carrier San Antonio to Dallas travel times.

The distribution of travel times varies slightly from city pair to city pair. As expected, the distribution has a small tail to the left of the mean travel time (i.e., there are a few trips that experience no congestion), and a longer tail to the right of the mean (e.g., congestion periodically results in longer trips). The size and nature of these tails differs for each origin/destination (O/D) pair. For example, the distribution of travel times for the Dallas to Waco trip is shown in figure 8 while the distribution of the Dallas to Austin trip is shown in figure 9. The Dallas to Austin trip has almost a normal distribution, while the Dallas to Waco trip is more of a Poisson's shape.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 8. Graph. National Carrier travel time distribution for trips between Dallas and Waco.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 9. Graph. National Carrier travel time distribution for trips between Dallas and Austin.

These two trip distributions are interesting, in that the Dallas to Waco trip is a subset of the Dallas to Austin trip, because it follows the same I-35 road segments between Dallas and Waco. These figures suggest that the Waco to Austin segment of the trip has a different congestion regime than the Dallas to Waco section, because the Dallas to Austin trip also will experience the same congestion as the Dallas to Waco trip, at least up until Waco has been reached. Both origin/destination pairs have a modest number of very slow trips (where "very slow" is defined as more than 50 percent greater than the mean travel time). In some cases, these trips appear to have taken detours, based on the summary trip miles reported. In other cases, the travel distance was similar to that routinely followed for these city pairs. (For example, on March 28, a trip took 344 minutes instead of the mean of 203 minutes. But travel distance was the normal 193 miles. On April 9, this trip took 339 minutes, but the distance covered by the truck was 307 miles instead of 193). These trips have not yet been matched to I-35 trip conditions or TxDOT incident reports to determine if these re-routes are caused by specific disruptions.

Regional Carrier Data Set

Unlike the National Carrier, the trips operated by the Regional Carrier for which data were provided did not travel from one major terminal to another. Instead, the Regional Carrier data often included multiple stops for a single trip. While the data provided by the carrier described the time and place where specific events (stops) took place, four different types of stop locations are included in the dataset:

- Trip start.
- First stop.
- Last stop.
- Trip end.

It was thus necessary for the IA team to further process these data before they could be used.

The first of the data processing steps involved checking the validity of the individual data points. The validity of these designations was confirmed by comparing the latitude and longitude values for each location with the expected latitude and longitude for the customer or terminal which is located using the *stored lat* and *stored long* variables. When the current location values (*latitude*/*longitude*) did not correspond to the *stored lat* and *stored long* values, those stops were removed from further analysis.

To convert the remaining location records into the “trip” records which were used in the project’s before/after analysis, the following steps were undertaken:

1. Initial Sorting and Filtering.
2. Create and Filter Trip Records.
3. Extract Relevant Trips.

Each of these steps is described below. After the last of these steps was performed, an outlier analysis was then performed on individual trip records where those records were more than double the travel time of the mean value for similar trips.

Initial Sorting and Filtering

The initial file was sorted first by *dispatch number* (unique trip ID) and then by actual time of arrival. This stacks all points associated with a specific trip in time order. Data points where the actual latitude and longitude for that data record do not correspond to the stored (expected) latitude and longitude for that location were then removed.

Create and Filter Trip Records

“Trip” records were then computed by combining the data from consecutive records when those records were associated with the same *dispatch number*. Total travel time for the segment was computed as the difference in time between the two *e_datime_gmt* variables in the consecutive stop records. The resulting new trip records (which would more correctly be called “trip segment” records) were then filtered so that only those records that have their first *record type* variable set as “Trip Start” and their second *record type* variable set as “First Stop” were kept. This filtering was performed to remove trip segments that did not identify trip segments that go directly from the terminal to the first stop of a delivery sequence. This ensured that the travel times being computed are not impacted by non-transportation related delays at an intermediate terminal stop.

Extract Relevant Trips

The data from Step 2 were then processed with GIS software to determine the subset of trips that likely used I-35 within the construction zone. This was done as follows:

- Divide up the region into smaller geographic zones and assign each trip endpoint to a zone.
- For each combination of zone i to zone j, determine if a trip traveling between those zones would be likely to have used the section of I-35 in the construction zone or not.
- For each trip, give that record a true/false score based on whether it was one of the i-j zone combinations from the previous step.

The review of the resulting data set showed that there was a wide distribution of first delivery locations (destinations) in the Regional Carrier data, so an aggregation or clustering step was required. The key to this task was finding the appropriate balance between the sample size of trips going to a specific set of destinations and having those destinations be both similar in geographic location and have a similar "uncongested" travel time from the trip origin in Temple, which was the location of the primary terminal in the dataset. A reasonably similar travel time was needed to ensure that differences in travel time in the before/after comparison were due to differences in travel conditions experienced, and not due to differences in travel distance or "normal" path (i.e., the distance from points A to B and A to C are very similar, but the path from A to B is all freeway, and the path from A to C involves use of a number of small arterials, which contain many traffic signals from the origin to the destination).

Baseline Data Set Results

The baseline data processing for the baseline Regional Carrier data set resulted in the following:

- **Original data set:** 83,952 records (individual trip endpoints).
- **Removal of duplicates:** 83,663 net records (289 duplicates).
- Complete trip records from Trip Start to First Stop: 7,349 trips.
- **Complete trip records with O/D resulting in trips on I-35:** 5,634 net trips (1,715 trips were created that did not have origin/destination pairs that result in use of I-35 between Dallas and San Antonio).
- **Baseline trip records with O/D resulting in trips on I-35:** 4,974 net trips (660 trips in the data set were either during the break in data collection in response to Hurricane Harvey or are part of the After Period data set).

For the baseline regional data set, city limit boundaries were combined with the mapping of origin and destination clusters to develop the initial location cluster boundaries. Note that it was not sufficient to use a map of the origin or destination locations to visually detect potential cluster locations, because a cluster of closely spaced locations could mask the quantity or density of locations. For example, in the extreme case, a large number of destinations at exactly the same location might appear to be a single location on a map. In such a case, there is no indication of the significance of the location in terms of how often it is the destination of a trip. Therefore, the map was supplemented with a frequency distribution summary that indicates density. For example, a two-dimensional x-y matrix of the number of origins/destinations at regular x- or y-distance intervals can be constructed. In the case of the baseline data set, latitude/longitude increments were used as the distance intervals, to allow the resulting distribution matrix to be compared more directly to the map display. Figure 10 shows the density tables for Regional trip origins and destinations. The dimensions of each table were defined based on the extent of latitudes and longitudes for the origins and destinations of trips in the regional data set. Each element of a table is a count of the number of origins or destinations within a specified interval of latitude and longitude.

ORIGINS — Latitude

Longitude	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35
-100.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-99.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-99.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-98.5	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
-98.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-97.5	0	0	0	0	0	0	0	0	0	0	1	4	9556	19	3	0	1	0	0	0	0
-97.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-96.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1	0	0	0
-96.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-95.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-95.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DESTINATIONS — Latitude

Longitude	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35
-100.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-99.5	0	0	0	0	58	290	51	1	17	0	0	0	0	0	0	0	0	0	0	0	0
-99.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-98.5	0	0	0	0	0	0	0	0	541	883	0	0	0	0	0	0	0	0	0	0	0
-98.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-97.5	0	0	0	0	0	0	0	0	0	161	1171	251	165	332	142	1397	167	23	0	0	0
-97.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-96.5	0	0	0	0	0	0	0	0	0	0	0	0	0	6	205	1780	1167	6	0	0	0
-96.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-95.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	353	56	82	25	0	0	0
-95.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 10. Chart. Trip endpoint density tables.

The following cluster areas were used for the Regional data analysis:

- San Antonio.
- Austin.
- Temple (origin).
- Tyler.
- Waco.
- Fort Worth.
- Dallas.

Temple was the clear choice for origins after the data cleaning steps associated with the correct "type" of trip location were performed as described above. All but five of the usable Before Period trips for the Regional baseline data set originate from Temple.

The other locations (San Antonio, Tyler, Waco, Austin, Fort Worth, and Dallas) were used as destinations. They were chosen because they have the largest concentration of destinations (by density), which also aligns with our check of a trip from Temple using I-35.

For each location, an initial square geographic boundary was used. The boundary was based on the city limits plus a buffer, then adjusted as necessary to capture large numbers of nearby destination points that might exist (the destination density table was used to help design the cluster regions).

The Dallas-Fort Worth metro area was initially defined as a single section. It was then split into two sections for future use to test how travel time results might differ for the east versus west sides of the original larger metro area (square boundary clusters were used to enable the two regions to be adjacent to one another without a gap).

Finally, only the subset of trips that start at Temple and go to each of those destinations were used to produce statistics similar to those produced for the national data set.

The Regional Carrier baseline and post-implementation data contains trip data from February 14 to August 14, 2017 for the baseline period, and September 18, 2017 to March 18, 2018 for the post-implementation period. Table 6a displays descriptive trip statistics for the Regional travel time data collected during the baseline (Before) period. Table 6b displays descriptive trip statistics for the Regional travel time data collected during the post-implementation (After) period.

Table 6. Regional Carrier descriptive statistics.

Origin	Destination	Number of Trips	Mean travel time	Standard Deviation of travel times	80th Percentile travel time	80th Percentile travel time minus Mean	80th Percentile minus Mean (% of mean)
a) Baseline							
Temple	Fort Worth	544	2:42	0:32	3:02	0:20	12%
Temple	Dallas	1686	3:01	0:47	3:18	0:17	9%
Temple	Tyler	164	3:38	0:40	3:56	0:18	8%
Temple	Waco	214	1:12	1:05	1:20	0:08	11%
Temple	Austin	661	1:42	0:40	2:02	0:20	20%
Temple	San Antonio	645	3:03	0:39	3:27	0:23	13%
Temple	Laredo	161	5:44	0:53	6:02	0:19	6%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 6. Regional Carrier descriptive statistics (continuation).

Origin	Destination	Number of Trips	Mean travel time	Standard Deviation of travel times	80th Percentile travel time	80th Percentile travel time minus Mean	80th Percentile minus Mean (% of mean)
b) Post-Implementation							
Temple	Fort Worth	261	2:43	0:58	2:56	0:13	8%
Temple	Dallas	1615	2:59	1:02	3:20	0:21	12%
Temple	Tyler	143	3:38	1:04	3:56	0:17	8%
Temple	Waco	247	0:58	0:28	1:06	0:08	14%
Temple	Austin	605	1:43	0:50	2:00	0:17	17%
Temple	San Antonio	662	3:01	0:42	3:19	0:18	10%
Temple	Laredo	158	5:40	0:38	6:01	0:20	6%

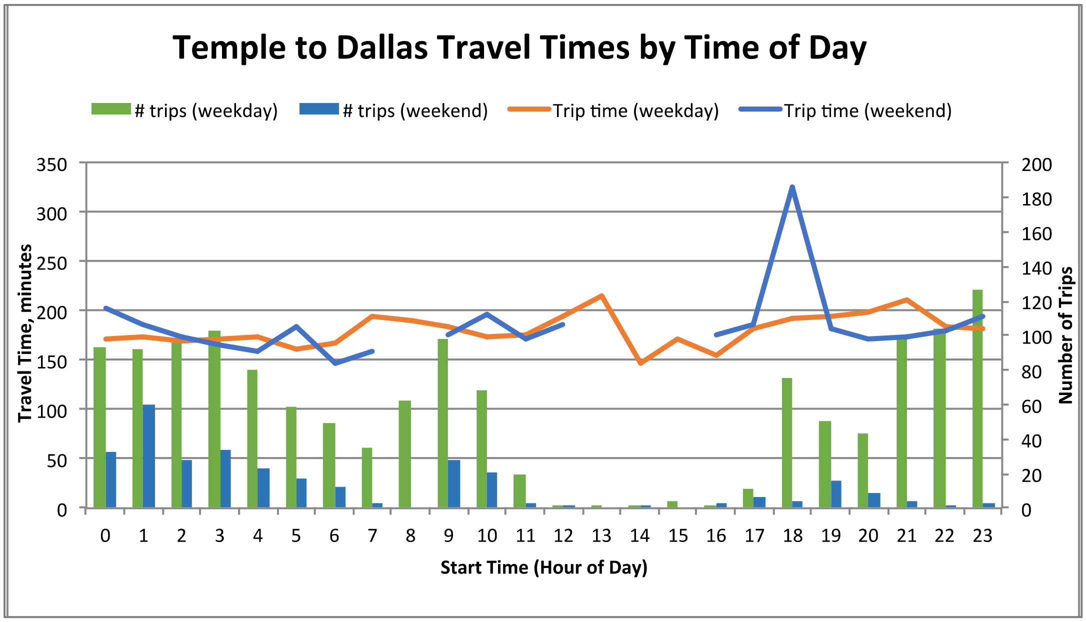
Source: I-35 FRATIS Impacts Assessment Team, 2018.

As expected, these results show more trip-to-trip travel time variations than the National Carrier results, as suggested by the percentage difference between the 80th percentile travel time and the mean travel time. For example, the baseline National Carrier intra-route variations ranged from 3 percent to 9 percent, while the Regional Carrier variations range from 6 percent to 20 percent. A portion of this added variability is due to the more diverse set of destinations included in the Regional Carrier data set. That is, simply because the Regional Carrier data includes a much larger number of destinations, we expect that a large fraction of the added travel time variability is due to differences in travel time to these different destinations within each of the metropolitan destinations.

Figure 11 to figure 14 illustrate how the travel times experienced by the Regional Carrier vary given the time of day when each trip starts. For the Regional Carrier, time-of-day variation is small relative to the day-to-day variation in travel times. Most “outlier” travel times apparent in the graphics below are the result of small sample sizes, which cause outlier “singleton trips” to become very visible. To help understand when singleton outliers are the cause of variation, the number of trips starting in each hour is shown on the right-hand axis. This helps the reader understand both when trucks are traveling during the day, and whether the mean travel times being reported for a given time period are from single trips or are the aggregate of many trips. The weekday travel time results show moderate variation by time of day. The weekend travel times show similar variations. Both weekday and weekend figures show a number of outlier travel times. Figure 11 to figure 14 only show data from the Before Period, but travel patterns in the After Period were very similar.

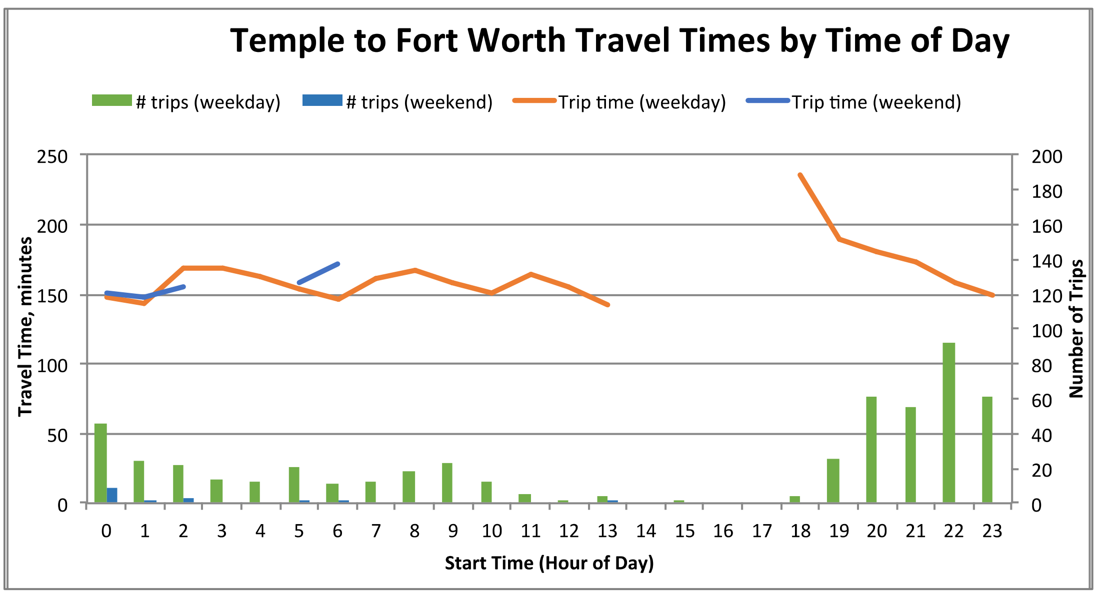
When examining these figures, note that the occasional gaps in the travel time curves reflect times of day when there are no trips. All four figures below have small sample sizes for trips starting in the late afternoon on both weekdays and weekends.

These results demonstrate that the before/after analysis needs to account for the disproportional impact that outliers have on the statistics of the before/after analyses. The presence of these outlier trips also emphasizes the need to balance the need to account for real outliers—typically caused by the delays the I-35 FRATIS system is meant to identify and help mitigate—with the need to identify and remove outliers that are the result of data collection and reporting errors.



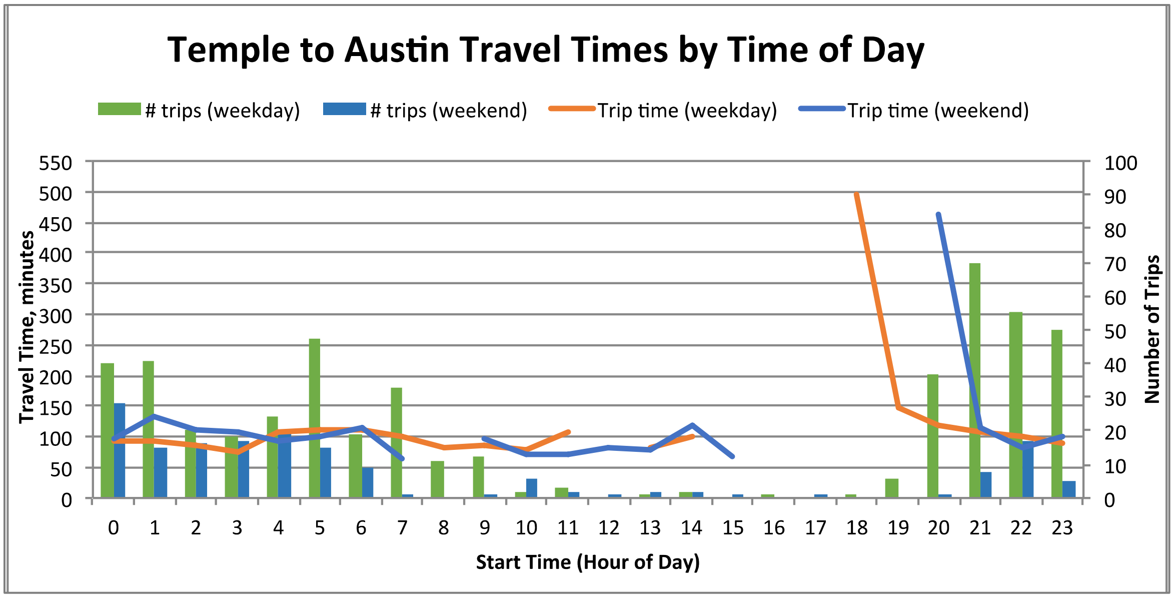
Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 11. Graph. Regional Carrier Temple to Dallas travel times.



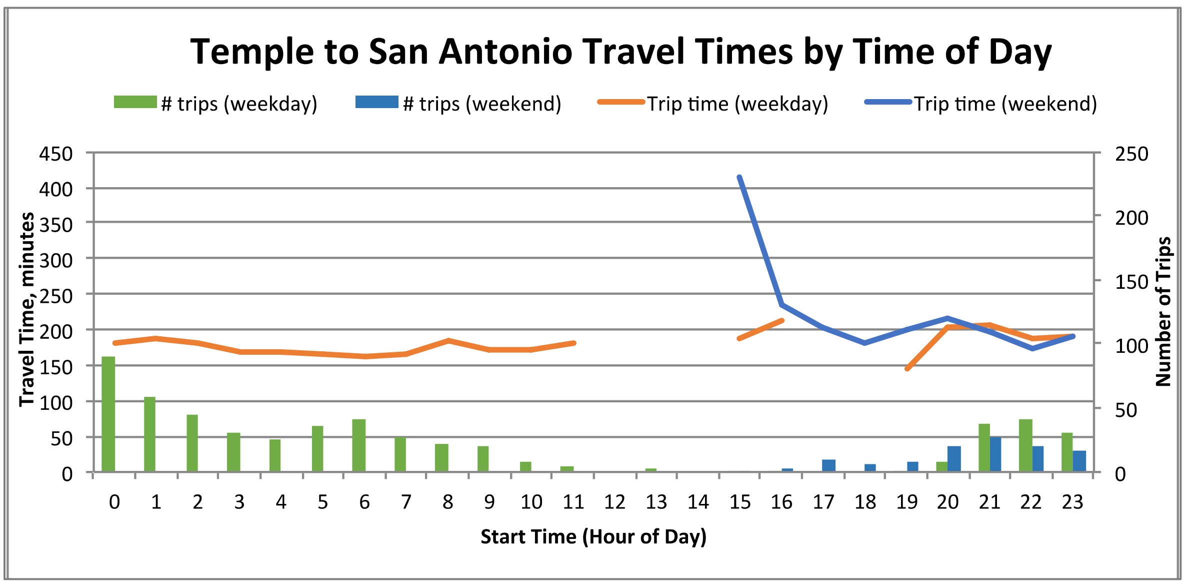
Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 12. Graph. Regional Carrier Temple to Fort Worth travel times.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

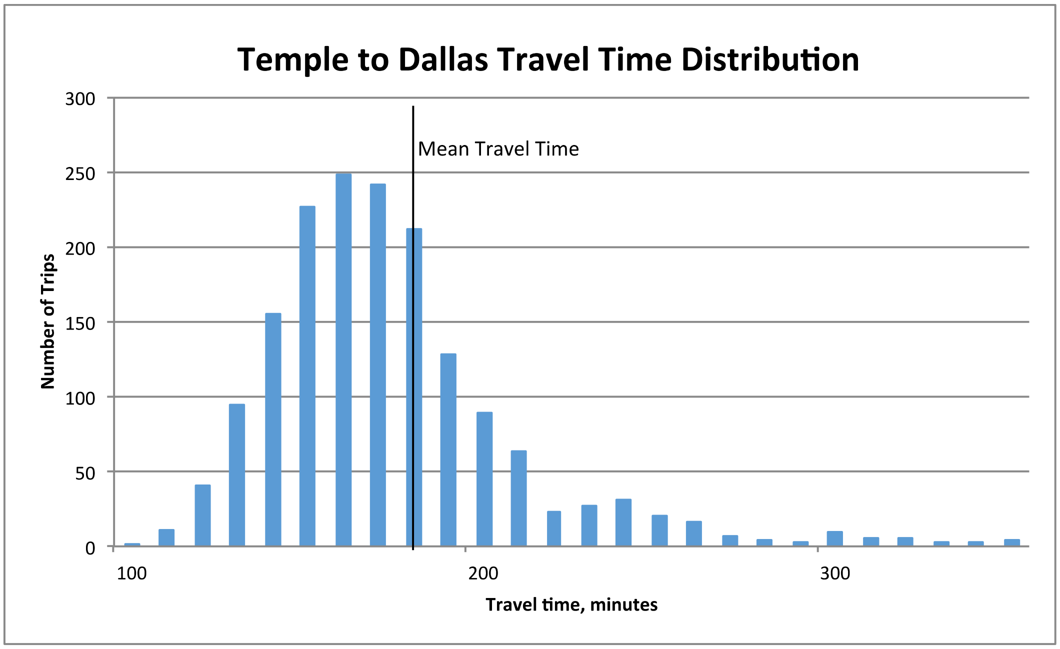
Figure 13. Graph. Regional Carrier Temple to Austin travel times.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

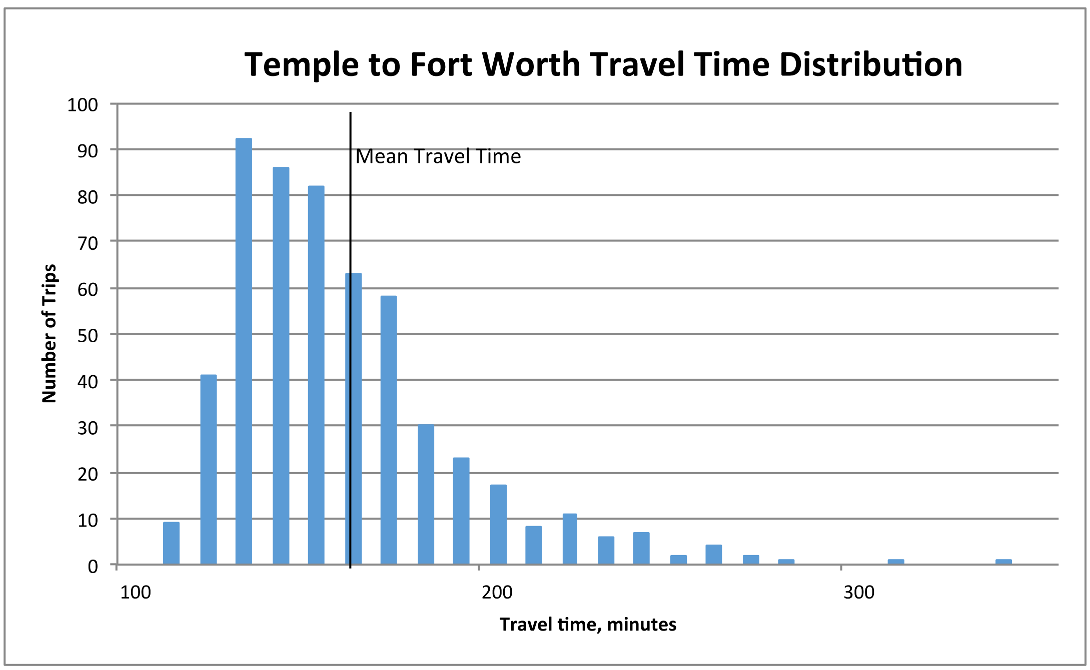
Figure 14. Graph. Regional Carrier Temple to San Antonio travel times.

The distribution of travel times for several city pairs served by the Regional Carrier are shown in figure 15 through figure 18. As with the National Carrier trip data, the distributions generally show a longer “tail” to the right of the mean travel time due to a combination of data errors and the impacts of exogenous factors.



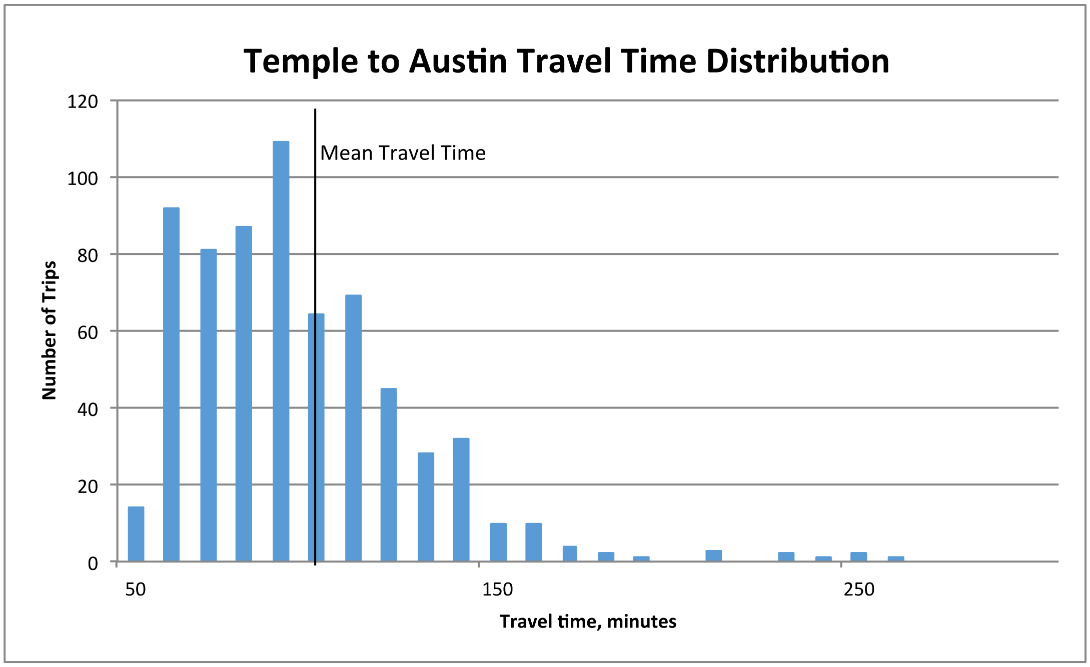
Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 15. Graph. Regional Carrier travel time distribution for trips between Temple and Dallas.



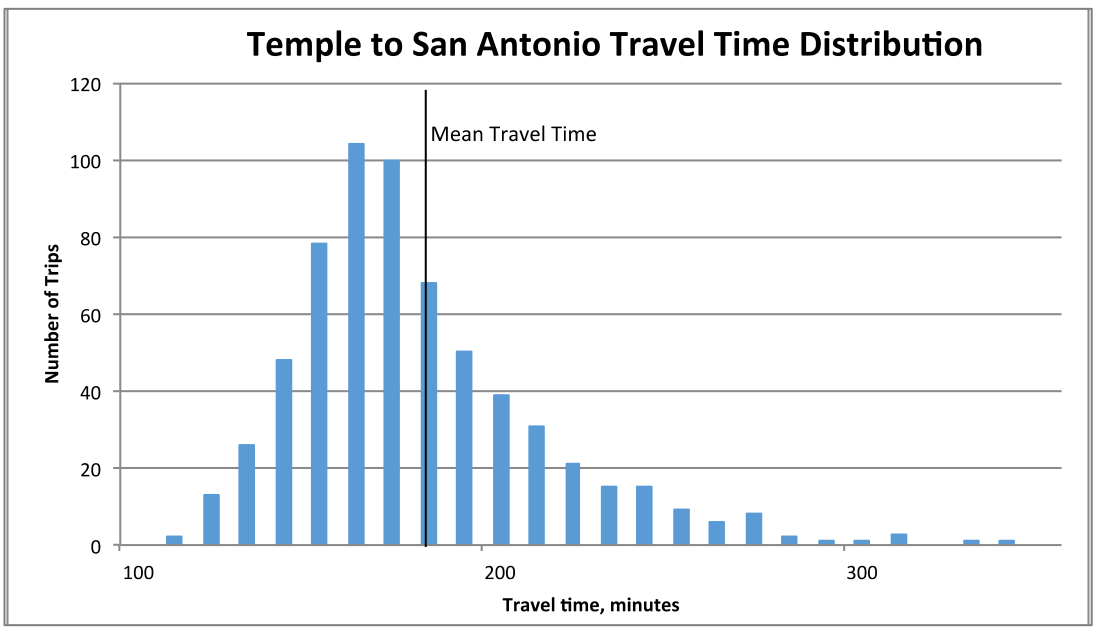
Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 16. Graph. Regional Carrier travel time distribution for trips between Temple and Fort Worth.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 17. Graph. Regional Carrier travel time distribution for trips between Temple and Austin.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 18. Graph. Regional Carrier travel time distribution for trips between Temple and San Antonio.

Data Descriptions: Exogenous Factors

Supplementary data were used to test whether before versus after differences in travel time characteristics were different when background construction activity was held relatively constant, as opposed to results based on all trips processed together regardless of possible differences in external factors. This was tested by stratifying (clustering) the overall before versus after data set of individual trips by the level of construction activity and delay affecting each trip (using closed lanes and detour recommendations as indicators). Those delay levels were defined for each trip as follows:

None: No construction lane closures occurred along the trip route.

Low: There was at least one construction event, with a total of a single closed lane, along the trip route; none of the construction events had an official detour recommendation.

Medium: There was at least one construction event, with a total of two or more closed lanes, along the trip route; none of the construction events had an official detour recommendation.

High: There was at least one construction event along the trip route, and at least one of those events had an official detour recommendation.

Overall, after collecting and reviewing the exogenous data, it was determined that in general, a significant majority of trips were not affected by either weather or incidents. In addition, the number of trips affected by construction delays was small enough in some cases to affect the ability to derive conclusive results about the effect of those factors on travel times. That is, the sample sizes were too small in either the before or after period (or both periods) to produce results with an acceptable level of statistical reliability.

Using the construction cluster definitions shown above, the original data set was grouped into subsets with similar construction activity and delay characteristics, in an effort to determine if the effects of construction information access on travel times were different for specific subsets. For the purposes of clustering, all trips were eligible for filtering by construction activity level, including those potentially affected by weather or incident events. The specific results are described in chapter 7.

Chapter 6. User Satisfaction Surveys

This chapter covers the feedback collected from the staff of the National and Regional Carriers that participated in the I-35 FRATIS IA project. The chapter discusses the opinions of those staff based upon their experiences using the forecast closure and delay notifications, along with near real-time construction delay information, based on the delivery of that information to their firms for six months as part of the I-35 FRATIS project.

Interview Questions

Interviews with the participating trucking firms started off with this set of questions. The questions delivered to each company differed slightly due to the different ways that construction delay information was provided to the two participating carriers. The National Carrier utilized the Web-based Freight Solver tool, while the Regional Carrier received the My I-35 traveler information emails. The questions asked of participants were as follows:

1. How do you disseminate the Freight Solver and/or email information in your company?
2. How do you manage your fleet (GPS, dispatchers, equipment in cab, etc.)?
3. Roughly how often did you use the Freight Solver and/or email information?
   - Can you provide any specific examples where you used the Freight Solver and/or emails?
4. Did the Freight Solver and/or email change the timing and/or routing of your trucks?
   - What type of Freight Solver and/or email information was used (lane closures, construction location, other?)
5. Describe the benefits of the Freight Solver and/or emails.
6. Describe the limitations of the Freight Solver and/or emails.
7. What format would you recommend we use for distributing or delivering the Freight Solver and/or emails in the future?
8. Did you pair the Freight Solver and/or email information with any other sources of real time roadway data?
9. Any general observations on how the Freight Solver and/or email impacted your overall operations?
10. If possible, would you continue to use the information from the Freight Solver and/or emails?
11. Any other comments?

Refer to appendix A. Interview Responses for detailed responses to each interview question.

Main Takeaways

Benefits

After six months of receiving this information via a Web-based Freight Solver tool or daily My I-35 traveler information emails, both the National and Regional Carriers found value in the system and wished to continue receiving **both** the lane closure and delay information, despite the fact that neither carrier could compute tangible benefits resulting from the use of that data. In general, dispatchers and truck drivers found value in knowing what to expect on the roads **ahead of time**. This allowed drivers to make stops earlier or later (to eat, take breaks, etc.) based on both the planned delays and near real-time delays. It also helped drivers prepare for slowdowns and vehicle queueing in places where those negative roadway performance outcomes are rare.

When asked for which roadway performance indicators their dispatchers valued the most, the responses included:

- Traffic camera access.
- Weather information.
- Updated alerts as to current accidents and the estimated time for those accident sites to be cleared.

Limitations

While the Freight Solver can be extremely valuable when other routes are available for the driver to take, the main limitation identified of this project is the limited number of alternate routes available along this segment of I-35. The minimal impacts of the system on route choice and time of departure can be attributed to this lack of alternate options. For example, if the construction zone was located inside the Austin city limits, there would be many more routes available for a driver to take to avoid the congestion, closures and delays. This would both encourage drivers and dispatchers to look at the traveler information more frequently, and result in more effectively measured benefits.

Another known limitation of navigation systems is that predictive travel time information currently cannot account for traffic diversion, which prohibits drivers from understanding what ***will*** happen if they chose the same alternate route as everyone else.

Improvements

Suggested improvements to the Freight Solver include minimizing the number of clicks needed in the Freight Solver to obtain the information requested, tailoring the Freight Solver data so that it can be directly ingested into the existing fleet management systems and tailoring the output information so that it is useful for individual trip making decisions.

One unanimous requested improvement to this system from both carriers is to provide truck drivers direct access to the information, pushed either through the drivers' smart phone applications or their in-cab communication devices. This allows drivers to both use the information more easily, and removes the need for dispatchers to identify which drivers need the information, understand when they need it, and arrange to get it to them.

Lastly, instead of targeting individual trucking companies, it was recommended that FHWA's Freight Office to go to freight software companies like ALK Technologies and Omnitracs and work directly with those companies to directly incorporate this information into their navigation packages. The National Carrier felt that getting this data into ALK Technologies' navigation packages alone would reach approximately 90 percent of the market.

Pilot Participation

The National Carrier has partnered with research teams on average two to three times a year. The lead for the National Carrier rated his expectations going into this pilot as a 7 or 8 out of 10, thinking that it had a 50/50 chance of succeeding depending on how well both entities (trucking firm and I-35 FRATIS team) communicated and connected at each layer, but many opportunities to develop valuable relationships. Based on the outcome of the project, his rating remains at a 7. He believes that the geographic area where we conducted the pilot lacked opportunities for improvement in freight deliveries, given the availability of the information being delivered. The National Carrier's staff thought that while the information may not be mature enough just yet (e.g., integration and delivery options), the project topic was definitely worth their time to explore and found that the application itself really exceeded their expectations in terms of the type of information that the Solver is able to display. National Carrier staff also appreciated the fact that TTI really listened to their needs and did not put the information into a complicated optimization system. The National Carrier team felt that we were not trying to push our own agenda, but really wanted to find a solution to a problem that everyone experiences—in the name of science. They also praised the good communication within the I-35 FRATIS teams.

Chapter 7. Impacts Assessment

This chapter presents the results of the before/after analysis. The chapter references some tables found in chapter 5.

National Carrier

The analysis of before and after travel time and travel time reliability shows that little has changed in terms of the National Carrier's operation as a result of the carrier's access to TIDC data. Table 7 summarizes the numerical changes in descriptive trip statistics (i.e., Before versus After) for the National Carrier. See table 5 for the Before and After data from which table 7 is constructed.

Table 7 shows that the central tendency of travel times, as measured by average (mean) travel time, did not change significantly during the After Period when compared to the Before Period. Overall, 8 of the 10 monitored National trip routes had absolute percentage changes in mean travel time of 1 percent or less, and 1 other trip route showed a change of 2 percent or less. Only the Laredo to Dallas trip showed an absolute percentage change in mean travel time that was larger than 2 percent (-5 percent); that trip also had a very small sample size, making the trip statistics susceptible to the effects of a few unusually long trips.

A review of the distribution of travel times for each trip route shows that the variability of travel times also did not change significantly during the After Period when compared to the Before Period. This can be seen in two different numerical indicators of travel time reliability. The first indicator of variability is a comparison of the difference between the 80th percentile travel time and the mean travel time for a given route. When that difference is computed for the After Period and compared to the corresponding difference during the baseline or Before condition, the percentage change of that difference (relative to the baseline) was between -3 percent and +1 percent for 9 of the 10 trips (see table 7). In other words, the variability of travel times did not change significantly from the Before to the After Period. (One trip, Dallas to Laredo, showed a change of -6 percent; however, that value was based on a sample size that was far smaller than the other trip routes).

A second indicator of variability is the standard deviation of all travel times for a given trip route. Table 7 shows the extent to which the standard deviation changed, with before versus after differences ranging from -13 minutes to +17 minutes, and the percentage change significantly higher than the corresponding percentage change for the 80th percentile indicator. In contrast to the 80th percentile travel time, though, the standard deviation is influenced by every trip time in the data set, and the resulting values can be sensitive to extreme outliers in a way that the 80th percentile value is not. A further exploration of the data shows that the influence of extreme outliers had a significant effect on the observed change in standard deviation. For example, the largest change in standard deviation, in both absolute and percentage terms, was the 17 minute change for the Waco to Dallas trip, which corresponds to a +106 percent change relative to the baseline. A review of the travel time data for this trip revealed that a single extreme trip value accounted for this large change, and that when that one trip was removed from the data set, the resulting change in standard deviation was 0 percent. This also consistent with the average and 80th percentile-based values for that trip, which show only a +2 minute and +1 minute change, respectively.

Table 7. National Carrier descriptive statistics (before versus after changes).

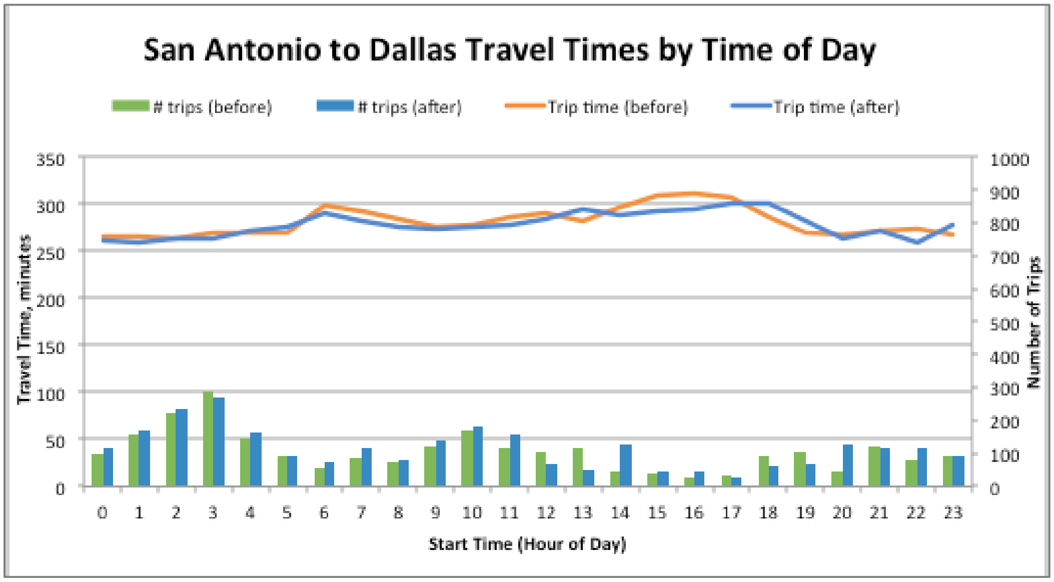
Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in (80th Percentile travel time minus Mean)	Change in (80th Percentile minus Mean) (% of mean)
Dallas	Waco	-0:01 (-1%)	0:07 (50%)	-0:04 (-4%)	-0:03	-3%
Dallas	San Antonio	-0:02 (-1%)	0:05 (23%)	-0:02 (-1%)	0:00	0%
Dallas	Austin	-0:03 (-1%)	-0:02 (-9%)	-0:08 (-4%)	-0:05	-2%
Dallas	Laredo	0:01 (0%)	0:05 (13%)	-0:26 (-5%)	-0:27	-6%
San Antonio	Laredo	-0:02 (-1%)	0:00 (0%)	-0:03 (-2%)	-0:01	-1%
Waco	Dallas	0:02 (2%)	0:17 (106%)	0:03 (3%)	0:01	1%
San Antonio	Dallas	-0:02 (-1%)	0:03 (12%)	-0:02 (-1%)	0:00	0%
Austin	Dallas	0:02 (1%)	0:02 (9%)	-0:02 (-1%)	-0:04	-2%
Laredo	Dallas	-0:24 (-5%)	-0:13 (-28%)	-0:20 (-4%)	0:03	1%
Laredo	San Antonio	0:01 (1%)	0:03 (23%)	0:03 (2%)	0:02	1%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

It is useful to consider both metrics of variability when determining the importance of the observed changes. The 80th percentile metric is resistant to extreme outliers, while the standard deviation metric includes all travel times in its computation. Note that in both cases, extreme low-value outliers (i.e., travel times that were significantly faster than estimated free flow speeds) were filtered out prior

to computing metrics, because they represented unrealistically fast trip times or could reasonably be interpreted as data entry errors. However, similar assumptions could not be made for high-value outliers (travel times that were significantly slower than average speeds) because extremely high travel times could legitimately occur because of factors such as trip re-routing to longer routes, congestion, or other external effects. Therefore, those values were left in the standard deviation computations shown in table 5. At the same time, in many cases the extreme high values do in fact represent erroneous data; therefore, it is useful to compare table 5's standard deviation results with filtered results (e.g., trip characteristics without the extreme data points) to better understand the true nature of the change in variability of travel times (such as the Waco to Dallas example noted above). Overall, the less sensitive 80th percentile-based values are a useful companion indicator of variability.

One of the potential effects of additional traveler information is that greater knowledge of construction-based delays could be used by trucking firms to reschedule trips to a different time of day to avoid those delays, or to determine the amount of flexibility for scheduling stops along the route. Therefore, each trip route was reviewed to estimate the distribution of trip start times, and how or whether that distribution changed following the start of the new traveler information service. This was done by computing how the individual trip travel times were distributed by time of day of the trip start, for the Before and After Periods, for each trip route. When those Before and After Periods are compared, they show the distribution of trips by time of day of the trip start (to the nearest hour) is not significantly different in the After Period versus the Before Period (Two routes, Dallas to/from Laredo, have inconclusive trip start results because of small sample sizes). They also show relatively little change in average travel times as a function of the trip start time. Figure 19 illustrates a typical time-of-day distribution, using the San Antonio to Dallas route. The figure shows that the number of trips that start at various times of the day follow a generally similar pattern for the before and after time periods; it also shows that the average travel times are similar by time of day. Other routes showed similar patterns. These results suggest that there is some latitude for the National Carrier to shift trip start times without large travel time differences, when delays are anticipated as a result of construction or other factors for which information is known in advance.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

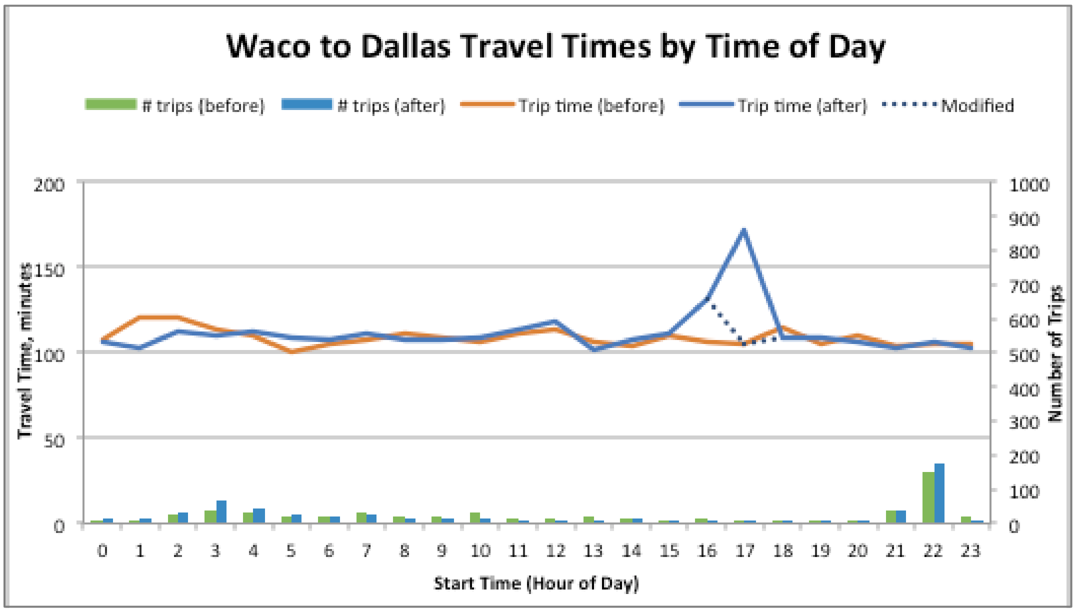
Figure 19. Graph. National Carrier San Antonio to Dallas travel times.

One apparent exception to the general time-of-day patterns is the route from Waco to Dallas, which showed a noticeable difference in trips that start around 5:00 p.m., with the average travel time during the After Period over 60 percent longer than average travel time during the Before Period. In that case, a review of the data shows that the large Before versus After difference is the result of a single extreme outlier in the After Period, combined with a small sample size that magnifies the effect of that outlier. While it is possible that the extreme value is a true value, the magnitude of the travel time (over 13 hours for a 115-mile trip) and the absence of any other values of a similar magnitude on the same day, suggest that it is more likely to be an erroneous data point, perhaps because of a delay in specifying the conclusion of the trip on the trip logging device. If that single outlier is removed from the computations, the resulting After average travel time is instead virtually the same as the Before average travel time. Figure 20 illustrates the original results, along with the modified After results after the extreme value is filtered.

Another way to characterize travel times is to estimate the frequency distribution of trip times. The general character of the distribution of travel times was similar across trip routes, with a small, compressed distribution of trips to the left of the mean travel time, and a greater number of trips over a longer distribution to the right of the mean travel time that reflect congestion and other delay factors. This was observed during both Before and

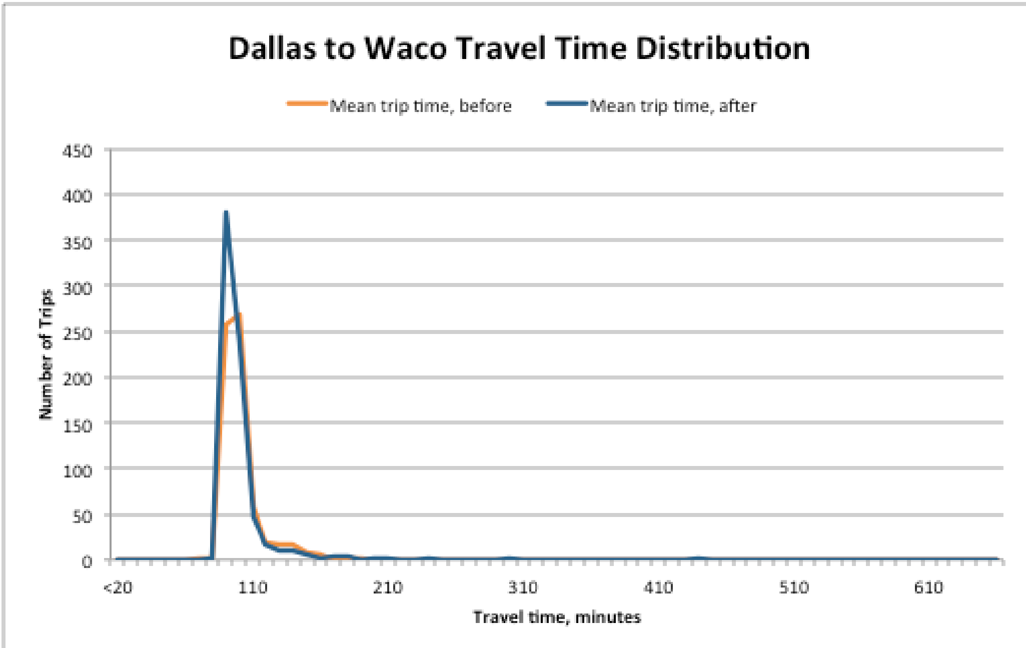
After Periods. While the compressed or distributed nature of the distribution did vary depending on the trip route, the overall nature of the distribution for a given route did not change significantly from the Before to the After Period.

Figure 20 illustrates a typical example of travel time distributions, using the Dallas to Waco route. The distribution of trip times did not change significantly from the Before to the After Period, with similar tails of the distribution and a similar mean time. The primary difference is the magnitude of the number of trips, which reflect differences in Before versus After sample size. Another method of representing the nature of travel times on a route is to display the N^{th} percentile travel times. The N^{th} percentile distributions showed similar results for Before versus After time periods, for each route. The primary difference observed was that the magnitude of extreme (N > 90 percent) outliers could vary considerably for the Before versus After Periods. However, the occurrence of extremely high outlier values of differing magnitudes for the Before versus After Periods would not be unexpected, even if the general nature of the travel times is very similar for Before and After Periods. Figure 22 illustrates this, showing how the N^{th} percentile travel times for the Dallas to Waco trip match closely until the extreme high outlier values are reached.



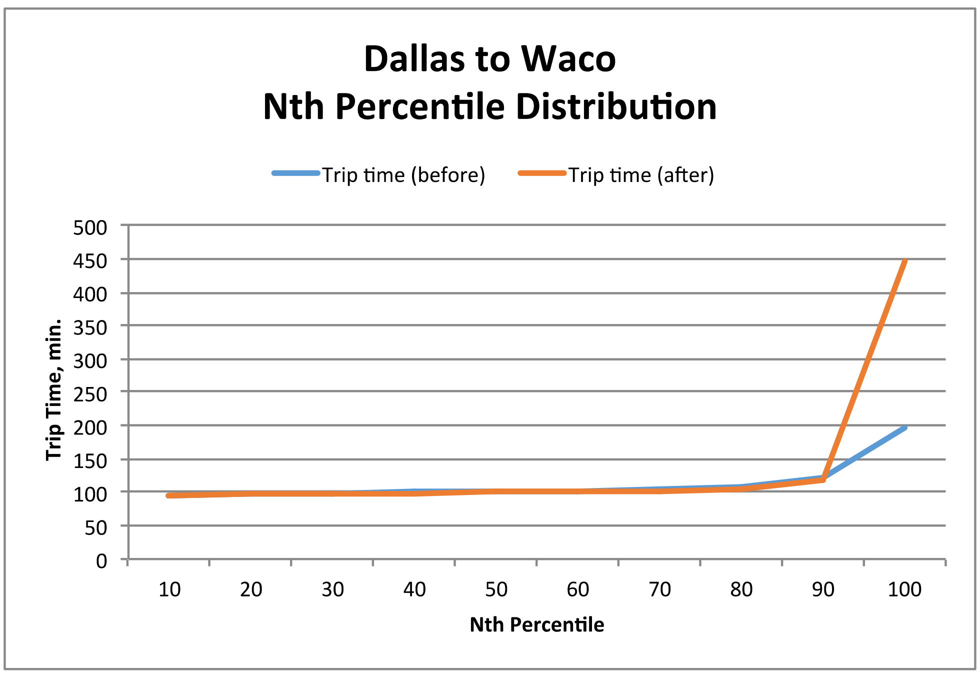
(Source: I-35 FRATIS Impacts Assessment Team, 2018.)

Figure 20. Graph. National Carrier Waco to Dallas travel times.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 21. Graph. National Carrier Dallas to Waco travel time distribution.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 22. Graph. National Carrier Dallas to Waco Nth percentile trip time distribution.

The researchers were advised that the National Carrier had noted greater attention being paid to construction delay information by its dispatchers during the early part of the After Period, compared to the latter months of the After Period. Therefore, a supplementary before versus after review was performed to evaluate whether results were noticeably different for different subsets of the After Period. The results showed that when comparing the before versus after conditions for the first month of the After Period (when dispatchers were more aware of delay information) versus the last three months of the After Period (when dispatchers did not use delay information as much), the differences were not significantly different for those two subsets, and those subset results also similar to those from the overall After Period. Table 8 shows the trip statistics for the first month of the After Period, the last three months of the After Period, and the overall After Period, respectively. The results show that the average trip time for either of the subset After Periods is between 98 percent and 102 percent of the overall After average trip time. The 80th percentile-based metric is within +/- 2 percentage points of the overall After metric for nearly every route. The exception is the Dallas to Waco route, which shows a variability of 6 percent for the first month, versus 1 percent overall. However, that value changes to 1 percent for the second half of the After Period, matching the overall After value (these subset results do not include the routes with very small sample sizes, i.e., fewer than 10 individual trips).

Regional Carrier

As with the National Carrier, the analysis of Regional Before and After travel times and travel time reliability shows that little has changed in terms of the Regional Carrier's operation as a result of the carrier's access to TIDC data. Table 9 summarizes the numerical changes in descriptive trip statistics (i.e., Before versus After) for the Regional Carrier. See table 6, presented earlier, for the Before and After data from which table 9 is constructed.

As with the National Carrier trip data, the central tendency of regional travel times, as measured by average travel time, did not change significantly during the After Period when compared to the Before Period. Overall, 6 of the 7 Regional trip routes had absolute percentage changes in mean travel time of 1 percent or less. One trip (Temple to Waco) showed an absolute percentage change in mean travel time that was larger than 1 percent (-19 percent). A review of the data suggested that the large change for that trip was the result of this trip's sensitivity to extreme outliers in the Before Period that might be based on erroneous data. The outliers for this trip showed very long trip lengths relative to the predominant trip length of other trips on this route, and/or very long trip durations relative to the overall distribution of travel times, either of which could be the result of erroneous logging of trip endpoints on the trip log device. For example, if the top four extreme outliers for that trip are removed (from a sample size of 214) this reduced the change in the mean travel time from -14 minutes (-19 percent) to -7 minutes (-11 percent).

A review of the variability of travel times for each regional trip route showed results similar to those of the National trip data: The variability of travel times did not change significantly during the After Period discussed for the National data set (i.e., comparison of the difference between the 80th percentile travel time and the mean travel time), the percentage change of that difference for the After Period versus the corresponding difference during the baseline or Before condition (relative to the baseline difference) was between -4 percent and +2 percent for all seven trips. In other words, across all trips for a given route, the variability of regional travel times did not change significantly from the Before to the After Period.

Table 8. National Carrier descriptive statistics for different After time periods.

Origin	Destination	Number of Trips	Mean travel time	Standard Deviation of travel times	80th Percentile travel time	80th Percentile travel time minus Mean	80th Percentile minus Mean (% of mean)
a) After (1st month)							
Dallas	Waco	71	1:44	0:10	1:50	0:06	6%
Dallas	San Antonio	316	4:42	0:28	5:00	0:18	6%
Dallas	Austin	84	3:23	0:18	3:34	0:11	5%
Dallas	Laredo	2	7:39	0:17	7:48	0:10	2%
San Antonio	Laredo	0	n/a	n/a	n/a	n/a	n/a
Waco	Dallas	78	1:51	0:17	1:54	0:03	3%
San Antonio	Dallas	270	4:36	0:26	4:48	0:12	4%
Austin	Dallas	79	3:25	0:18	3:37	0:12	6%
Laredo	Dallas	1	8:25	0:00	8:25	0:00	0%
Laredo	San Antonio	0	n/a	n/a	n/a	n/a	n/a
b) After (4th through 6th months)							
Dallas	Waco	381	1:45	0:25	1:46	0:01	1%
Dallas	San Antonio	1556	4:35	0:27	4:51	0:16	6%
Dallas	Austin	405	3:21	0:23	3:27	0:06	3%
Dallas	Laredo	4	7:41	0:16	7:53	0:12	3%
San Antonio	Laredo	833	2:32	0:17	2:38	0:06	4%
Waco	Dallas	324	1:51	0:43	1:55	0:04	4%
San Antonio	Dallas	1507	4:32	0:30	4:46	0:14	5%
Austin	Dallas	406	3:29	0:24	3:43	0:14	7%
Laredo	Dallas	6	7:35	0:28	8:11	0:36	8%
Laredo	San Antonio	823	2:37	0:17	2:44	0:07	4%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 8. National Carrier descriptive statistics for different After time periods (continuation).

Origin	Destination	Number of Trips	Mean travel time	Standard Deviation of travel times	80th Percentile travel time	80th Percentile travel time minus Mean	80th Percentile minus Mean (% of mean)
c) After (all months)							
Dallas	Waco	723	1:44	0:21	1:45	0:01	1%
Dallas	San Antonio	2859	4:36	0:27	4:53	0:17	6%
Dallas	Austin	756	3:20	0:21	3:27	0:07	4%
Dallas	Laredo	17	7:59	0:45	8:07	0:08	2%
San Antonio	Laredo	1291	2:32	0:17	2:37	0:05	3%
Waco	Dallas	614	1:50	0:33	1:54	0:04	4%
San Antonio	Dallas	2736	4:34	0:29	4:50	0:16	6%
Austin	Dallas	754	3:29	0:25	3:44	0:15	7%
Laredo	Dallas	21	7:33	0:33	8:10	0:37	8%
Laredo	San Antonio	1279	2:36	0:16	2:44	0:08	5%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 9. Regional Carrier descriptive statistics (before versus after changes).

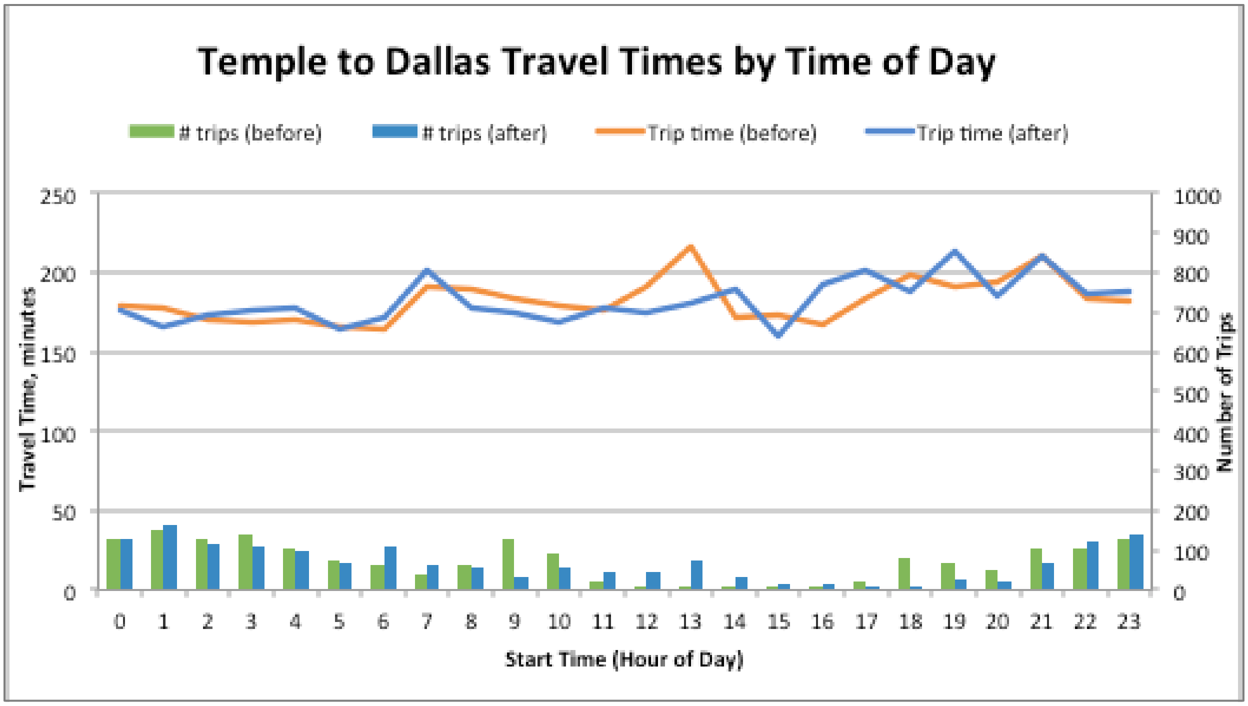
Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in (80th Percentile travel time minus Mean)	Change in (80th Percentile minus Mean) (% of mean)
Temple	Fort Worth	0:01 (1%)	0:26 (81%)	-0:06 (-3%)	-0:07	-4%
Temple	Dallas	-0:02 (-1%)	0:15 (32%)	0:02 (1%)	0:04	2%
Temple	Tyler	0:00 (0%)	0:24 (60%)	0:00 (0%)	-0:01	0%
Temple	Waco	-0:14 (-19%)	-0:37 (-57%)	-0:14 (-18%)	0:00	3%
Temple	Austin	0:01 (1%)	0:10 (25%)	-0:02 (-2%)	-0:03	-3%
Temple	San Antonio	-0:02 (-1%)	0:03 (8%)	-0:08 (-4%)	-0:05	-3%
Temple	Laredo	-0:04 (-1%)	-0:15 (-28%)	-0:01 (-0%)	0:01	0%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 9 also shows the results using the standard deviation of all travel times for a given trip route, as a second indicator of travel time variability. The table shows the extent to which the standard deviation changed, with before versus after differences ranging from -37 minutes to +26 minutes. As with the National results, the percentage change based on standard deviation for Regional trips is significantly higher than the corresponding percentage change for the 80th percentile indicator, reflecting the higher sensitivity of the standard deviation indicator to extreme outliers that was discussed previously for the National data.

As with the National data results, it was useful to compare both metrics of Regional trip time variability; the 80th percentile metric is resistant to extreme outliers, while the standard deviation metric includes all travel times including outliers. As with the National data set, extreme low-value (short travel time) outliers were filtered out prior to computing metrics, because they were considered unrealistic or likely data entry errors; high-value (long travel time) outliers were kept because they might represent delayed trips with the same factors that could occur with the National trips, e.g., trip re-routing to longer routes, congestion, or other external effects. Because extreme high values could represent erroneous data, a comparison of variability metrics with and without extreme outliers can be helpful to determine the true nature of the change in travel time variability. For the Regional data, the less sensitive 80th percentile-based values were generally in alignment with the Before versus After change in average travel times.

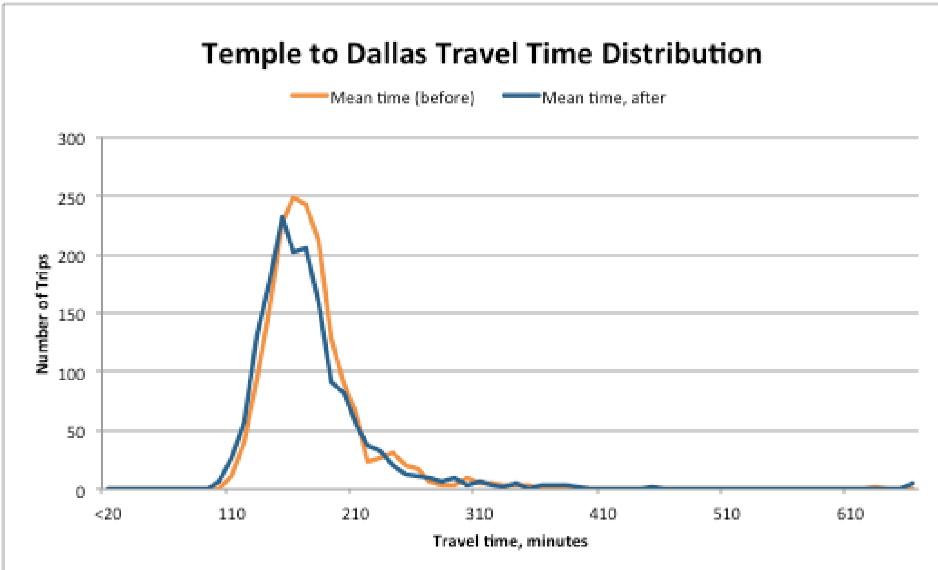
As with the National data, the distribution of Regional trip start times was evaluated to better understand whether that distribution had changed because of access to new traveler information about construction delays. The data for Regional trips were distributed by time of day of the trip start for each trip route, for the Before and After Periods. The results show relatively little change in average travel times as a function of the trip start time (to the nearest hour), for the Before versus the After Periods. Also, the distribution of trips by time of day was not significantly different in the After Period versus the Before Period. Figure 23 illustrates a typical example of time-of-day Regional distributions, using the Temple to Dallas route. The figure shows results similar to those of the National trips, namely that the number of trips that start at various times of the day follow a generally similar pattern for the Before and After time periods, and the average travel times also are similar by time of day. However, the results are not conclusive for some Regional routes because of relatively small sample sizes, combined with possible effects of outlier values. The Regional results do suggest that there might be latitude to shift trip start times to avoid construction delays, similar to the National results.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

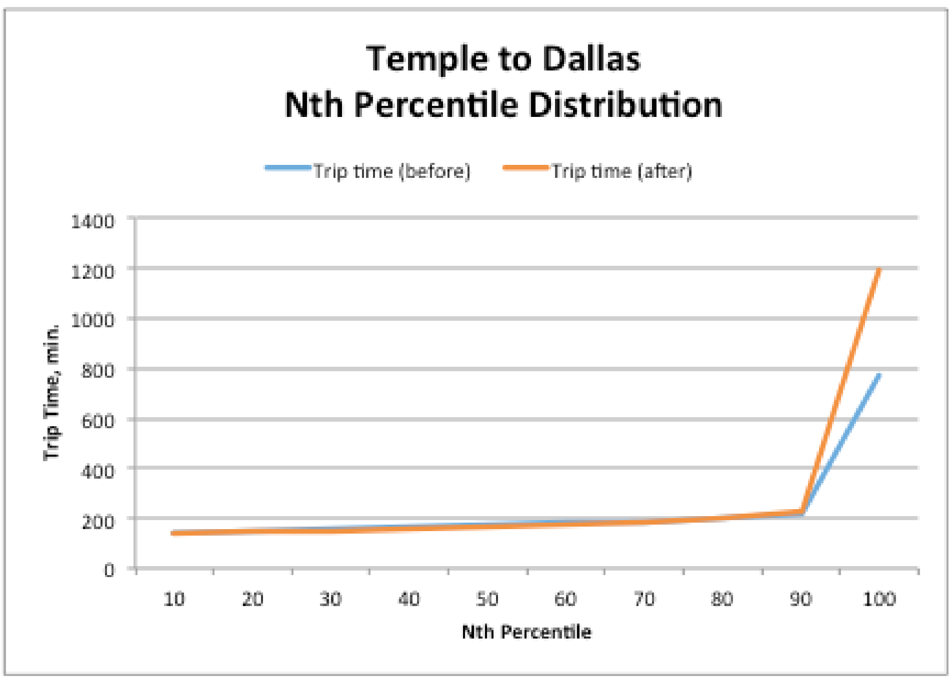
Figure 23. Graph. Regional Carrier Temple to Dallas travel times.

The general character of the frequency distribution of Regional travel times was similar across trip routes, with a small, compressed distribution of trips to the left of the mean travel time, and a greater number of trips over a longer distribution to the right of the mean travel time that reflect congestion and other delay factors. This was observed during both Before and After Periods. The nature of the distribution varied depending on the trip route. However, the nature of the distribution for a given route did not change significantly from the Before to the After Period. Figure 24 illustrates a typical Regional trip distribution, using data from the Temple to Dallas route; while the general character of the distribution is similar for the Before versus After Periods, there is a difference in sample size, as shown by the differing magnitudes of the Before versus After trip counts for a given travel time. As with the National results, the N^{th} percentile distributions also similar for Before versus After time periods, for each Regional route. Figure 25 illustrates how the N^{th} percentile distributions match closely, until the differing before versus after extreme high outlier values are shown.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 24. Graph. Regional Carrier Temple to Dallas travel time distribution.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 25. Graph. Regional Carrier temple to Dallas Nth percentile trip time distribution.

Impacts of Exogenous Factors

The results described above for the central tendency, variability, timing, and distribution of travel times suggest that there was not a significant difference in those characteristics following the introduction of new traveler information services for construction events and related delays.

However, the data collected by the National and Regional Carriers did not include information about external factors that might have a potential influence on travel times. In an effort to better understand whether those external factors might have some relationship to travel times, supplementary databases were accessed to provide a general description of the external factors that were associated with each trip in the data sets.

Those factors were then used to define subsets of the original data set, where the trips in each subset had similar construction delay characteristics; the same tests of central tendency, variability, timing, and distribution of travel times that were performed for the entire data set were then used for each subset.

The following are discussions of the nature of exogenous factors for the National and Regional data sets, and their possible relationship to trip characteristics.

National Carrier Data Set

The National routes had similar distributions of trips affected by weather and/or incidents. Depending on the route, about 70 percent to 81 percent of the trips (before) and 65 percent to 94 percent of the trips (after) on the route were not affected by either weather events or incidents. The project team was unable to establish a clear correlation between either incidents or weather and significant delays. The project team did correlate individual trips with reported incidents based on when the truck left its origin and when and where the incident occurred, but no statistically significant correlation was found between travel time and the occurrence of incidents or rainfall. The lack of a clear impact on performance of truck trip duration resulted in weather and incidents being discarded from further analysis.

Most National routes showed a shift in the occurrence of construction events affecting trips on each route in the After Period compared to the Before Period, with more construction activity observed during the After Period. During the Before Period, 6 of the 10 routes were affected by construction events; of those trip routes, individual trips on four routes were affected by no more than one event at some point during the trip, while individual trips on the other two routes were affected by at least one event during the trip. During the After Period, there was a greater amount of construction activity that affected more trips; 7 of 10 routes were affected by construction events, and while the level of activity varied considerably from route to route, at least some of the trips on 6 of those routes were affected by up to 4 or more events of some type at some time during the trip.

The National data set was clustered into subsets using the construction activity definitions in chapter 5. After stratifying the results by level of construction delay, it was determined that the sample sizes were small enough to be inconclusive in most cases. The following is an overview of results, by level of delay:

None: The trip routes with larger sample sizes showed only small changes in average and (80^{th}-mean) trip times.

Low: Inconclusive: All trip routes had zero sample size.

Med: Inconclusive: All trip routes had zero sample size.

High: The trip routes with larger sample size showed only small changes in average and (80^{th}-mean) trip times.

Table 10 shows the resulting Before versus After change in descriptive National trip statistics for each construction activity level, using the same metrics described previously for the entire data set. Blank rows indicate trip routes with zero sample size. Looking at the mean travel times and the 80^{th} percentile-based percentage metric for variability of travel times, most routes show small changes with magnitudes similar to those of the entire data set. At the “None” construction level, the results are very similar to those of the entire data set, for those trips with a non-zero sample size. The “High” level shows higher absolute differences, though the magnitudes are still similar to those of the entire data set. The change of standard deviation was usually higher than the 80^{th} percentile-based metric, as they were for the entire data set.

Overall, the results of stratifying travel time characteristics by level of construction activity suggested that when holding background conditions constant, the National trip data results for the subsets were still similar to those of the sample group as a whole, and did not suggest that construction information about significant expected construction delays resulted in a significant difference in travel time characteristics even when a subset of trips with similar characteristics were reviewed. However, the conclusiveness of the results was limited by the small sample sizes of some cluster categories.

Regional Carrier Data Set

Most Regional routes had similar distributions of trips affected by weather and/or incidents, compared with the National data. Depending on the route, about 64 percent to 79 percent of the trips (before) and 65 percent to 73 percent of the trips (after) on the route were not affected by either weather events or incidents. As with the National Carrier dataset, the project team was unable to establish a clear correlation between either incidents or weather and significant delays for the Regional Carrier trips. The lack of a clear impact on performance of truck trip duration resulted in weather and incidents being discarded from further analysis.

The occurrence of construction among the Regional trips showed a similar trend as that of the National trips; during the Before Period, four of the seven Regional routes were not affected by construction events, while individual trips on the other three routes were affected by no more than one such event at some point during the trip. During the After Period, there was more construction activity affecting Regional trips, just as there was with the National trips; while the activity varied considerably from route to route, at least some trips of every route were affected by up to 4 or more construction events at some point during the trip.

As with the National data set, the Regional data set was clustered into subsets using the construction activity definitions in chapter 5. The Regional results were determined to be limited by small sample sizes, much like the National results. Table 11 shows the resulting Before versus After change in descriptive Regional trip statistics for each construction activity level, using the same metrics described previously for the entire data set. Looking at the mean travel times and the 80^{th} percentile-based percentage metric for variability of travel times, most routes show small changes similar to those of the entire data set. The change in standard deviations was higher than the 80^{th} percentile-based metric, as they were for the National data set.

Table 10. National Carrier descriptive statistics, by construction level.

Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in 80th Percentile travel time minus Mean	Change in 80th Percentile minus Mean (% of mean)
Construction Level = None						
Dallas	Waco	0:00 (0%)	0:07 (50%)	-0:04 (-4%)	-0:03	-3%
Dallas	San Antonio	n/a	n/a	n/a	n/a	n/a
Dallas	Austin	n/a	n/a	n/a	n/a	n/a
Dallas	Laredo	0:01 (0%)	0:05 (13%)	-0:26 (-5%)	-0:27	-6%
San Antonio	Laredo	-0:02 (-1%)	0:00 (0%)	-0:03 (-2%)	-0:01	-1%
Waco	Dallas	0:02 (2%)	0:18 (113%)	0:03 (3%)	0:01	1%
San Antonio	Dallas	n/a	n/a	n/a	n/a	n/a
Austin	Dallas	n/a	n/a	n/a	n/a	n/a
Laredo	Dallas	n/a	n/a	n/a	n/a	n/a
Laredo	San Antonio	0:01 (1%)	0:03 (23%)	0:03 (2%)	0:02	1%
Construction Level = Low						
(All routes had zero sample size)						
Construction Level = Med						
(All routes had zero sample size)						

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 10. National Carrier descriptive statistics, by construction level (continuation).

Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in 80th Percentile travel time minus Mean	Change in 80th Percentile minus Mean (% of mean)
Construction Level = High						
Dallas	Waco	-0:06 (-6%)	-0:10 (-67%)	-0:07 (-6%)	-0:01	-1%
Dallas	San Antonio	-0:05 (-2%)	0:02 (9%)	-0:07 (-2%)	-0:02	-1%
Dallas	Austin	-0:04 (-2%)	0:00 (0%)	-0:11 (-5%)	-0:07	-3%
Dallas	Laredo	n/a	n/a	n/a	n/a	n/a
San Antonio	Laredo	n/a	n/a	n/a	n/a	n/a
Waco	Dallas	n/a	n/a	n/a	n/a	n/a
San Antonio	Dallas	n/a	n/a	n/a	n/a	n/a
Austin	Dallas	n/a	n/a	n/a	n/a	n/a
Laredo	Dallas	n/a	n/a	n/a	n/a	n/a
Laredo	San Antonio	n/a	n/a	n/a	n/a	n/a

Source: I-35 FRATIS Impacts Assessment Team, 2018.

The following is an overview of results, by level of delay:

None: Five of the seven trips showed only small changes in average trip times, and six of the trips showed small changes in (80th-mean) trip times; two of the trips showed larger changes in average trip time (-17 percent, +6 percent), though some of those routes were affected by extreme Before outliers, while others had significant differences in before versus after sample sizes. Overall, these results are not conclusive because of limited sample sizes for some routes.

Low: Inconclusive: All trip routes had zero sample size.

Med: Inconclusive: All trip routes had zero sample size.

High: Inconclusive: All trip routes had zero sample size.

Overall, the results of stratifying Regional travel time characteristics by level of construction activity were similar to those of the National data set: before versus after comparisons of trips with similar background conditions were similar to those of the sample group as a whole, and did not suggest that additional construction information about significant expected construction delays resulted in a significant difference in travel time characteristics even when a subset of trips with similar background delay factors were reviewed.

However, results of stratifying travel time characteristics by level of construction activity for Regional trips were limited by the small sample sizes for most stratification categories.

Table 11. Regional Carrier descriptive statistics, by construction level.

Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in 80th Percentile travel time minus Mean	Change in 80th Percentile minus Mean (% of mean)
Construction Level = None						
Temple	Fort Worth	0:00 (0%)	0:25 (78%)	-0:12 (-7%)	-0:12	-7%
Temple	Dallas	0:00 (0%)	0:21 (45%)	0:04 (2%)	0:04	2%
Temple	Tyler	0:01 (0%)	0:33 (83%)	0:01 (0%)	-0:01	0%
Temple	Waco	-0:12 (-17%)	-0:34 (-52%)	-0:12 (-15%)	0:00	2%
Temple	Austin	-0:02 (-2%)	-0:12 (-28%)	0:12 (12%)	0:14	16%
Temple	San Antonio	0:10 (6%)	0:04 (13%)	0:17 (9%)	0:08	4%
Temple	Laredo	0:07 (2%)	0:12 (36%)	0:13 (4%)	0:06	2%
Construction Level = Low						
(All routes had zero sample size)						
Construction Level = Med						
(All routes had zero sample size)						
Construction Level = High						
(All routes had zero sample size)						

Source: I-35 FRATIS Impacts Assessment Team, 2018.

The clustering approach was originally chosen to help the project team better understand the nature of before versus after changes in travel characteristics, by keeping the background conditions (i.e., construction delay level) within a cluster subset relatively constant. However, this approach was ultimately complicated by changes in the background conditions in the Before Period versus the After Period. In general, construction on the I-35 project is shifting southbound over time; these moving construction zones limited the ability to establish valid before versus after comparisons, because construction conditions for a given route were often not comparable between the Before and After Periods. The result was often a small or zero sample size for one or both time periods. For those cases where a comparison could be made, the above results suggest that there was little change in the before versus after conditions.

Environmental Impact Outcomes and Other Potential Benefits

One of the objectives of this study was to better understand the extent to which before versus after changes in travel characteristics, following the introduction of new traveler information services for construction events and related delays, would in turn produce environmental benefits. However, the results described above regarding changes to travel times suggest that there was not a significant difference in travel characteristics such as trip times, travel delay, and other metrics associated with the overall extent of travel, following access to new traveler information regarding construction. This in turn suggests that there were not significant changes in environmental factors such as fuel savings or air pollution emissions, or related monetary savings, as a result of access to new construction delay information.

These outcomes are further supported by characteristics of the construction activity and the nature of the project study area. First, individual construction delays were generally of a limited duration; this in turn limited the incentive for freight carriers to significantly change travel plans in response to advance knowledge about those delays. Travel time estimates collected by the Texas Transportation Institute using Bluetooth data show that only 3 percent of the more than 7,500 construction-related freeway closures on I-35 since 2013 resulted in a delay of more than 30 minutes, and 79 percent of the closure events resulted in delays of less than 10 minutes.

In addition, as noted in chapter 6, when participating freight carriers were interviewed about their experiences with the new information system, they noted that the I-35 study area was a facility that did not offer viable alternate routes that could have been considered as more efficient options if new information about travel and construction conditions warranted such actions. In the absence of alternative routes, carriers had limited alternative actions (or time-of-departure changes) that they could have considered in response to the new construction information to which they now had access.

In other words, the new construction information offered to freight carriers generally did not involve events that were significant enough to warrant consideration of alternatives, and even when they were significant, the viable alternatives were very limited. The net result was that freight carriers continued to plan their activities as they normally would, and travel characteristics did not change significantly even with the access to new information.

At the same time, the freight carriers did point out other benefits that emerged from use of the new system. The carriers believed that access to the new construction information enabled them to plan their trips more effectively, including scheduling of stops. Advance knowledge of upcoming delays and queues gave drivers a “heads-up” about expected conditions; that knowledge in turn enabled them to better prepare for upcoming conditions such as the onset of a queue, reduce the likelihood of encounters with unexpected events, and proceed in an even safer manner. While these benefits are not directly quantifiable in the same way that travel time benefits, fuel savings, and emissions could be estimated, they do represent real value to the carriers, based on their comments to the study team.

When the freight carriers in the study considered all the benefits and limitations of the new information system, they ultimately considered the information to be beneficial to their operations and their employees, and expressed a desire to continue receiving the information. They also noted that had there been alternative routing options, the system could have contributed to efficient operations even more.

Chapter 8. Work Zone Mitigation Tool

The design of the original impacts assessment required the construction of software which allowed the estimation of travel times between trucking origins and destinations given actual traffic conditions. **This chapter describes that software.** Originally, this software tool was to be constructed to facilitate a comparison between actual trip outcomes and the outcome of trips that would have been made if information on construction delays was not available to the trucking firms. However, because trucking firms were not interested in using the FHWA optimization software for planning their deliveries, it was necessary to change the project's analysis approach.

The project team still constructed the software tool as part of the project. Its intended use was no longer simply to perform evaluation work for this project, but to demonstrate how a tool like it could be used to increase the productivity of trucking operations when trucking firms are provided with advanced notice of expected construction delays.

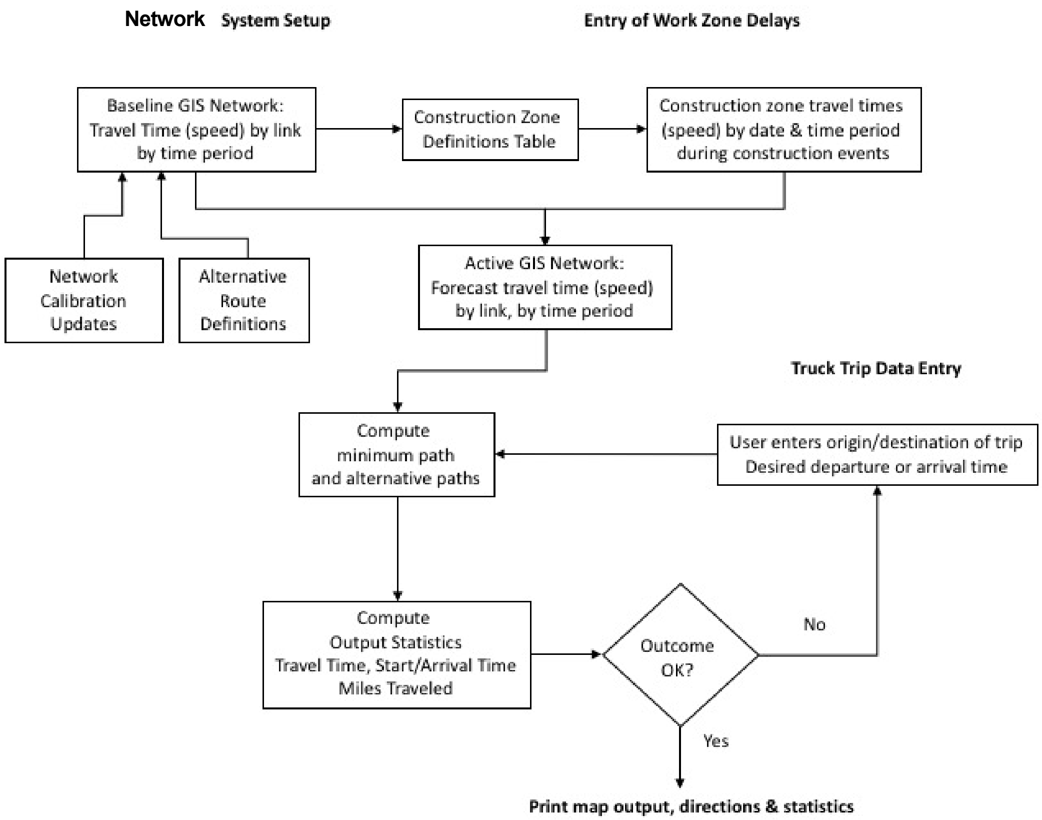
The software tool is a set of GIS programs that allow trucking firms to examine the predicted impacts of construction zones on their planned trip making activity and explore the benefits of alternative routes and start times on expected travel time, expected arrival time, and total miles traveled. A detailed report describing the tool was written for the project, and has the title "Task 4: Work Zone Mitigation Scenario Planning Tool and Outcome Predictor Report."

The Tool requires that a State highway agency or a metropolitan planning organization (operations level user) set up the transportation system network and maintain the software. The operating organizations also are responsible for entering the size and timing of expected construction delays. It is intended that individual users (envisioned to be trucking companies) would access the software via a Web browser and enter the trip details; e.g., trip origin/destination and desired departure or arrival times. The Tool then computes the estimated minimum travel time from origin to destination, along with the roadway routing used to achieve that minimum travel time. The tool also provides two alternatives to the "optimal" route, along with the travel times and routing paths associated with those alternative route options.

The Tool also provides an option which allows the end user to specify a desired arrival time, and the system estimates the required trip departure time and route in order to arrive at the desired time. For this option, the user also can obtain alternative travel times for different departure times, in case one of those alternative start times saves considerable time, and the arrival time is flexible for that freight shipment.

System Architecture and Data Flow

Figure 26 illustrates the basic architecture and data flow associated with the Work Zone Mitigation Scenario Planning Tool.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 26. Flow chart. Work Zone Mitigation Scenario Planning Tool architecture.

The system has several places where data needs to be supplied by the operating agency. At this time, these interfaces are reasonably crude, as the Tool was designed to support the evaluation of a construction work zone information delivery test, and resources were not available to make the interfaces user friendly. However, the tasks being performed are reasonably simple. The individual performs the following tasks:

1. **Network Setup:** The operating agency must set up the base transportation network. This is the functionality needed to allow the system to be used anywhere in the country, provided data are available. It must be performed by individuals with GIS skills and an understanding of basic traffic and roadway networks (Baseline GIS Network step in figure 26).
2. **Network Verification and Calibration:** This step includes any calibration adjustments needed to route trucks correctly if the available network does not effectively account for truck restrictions or company routing preferences (Network Calibration Updates and Alternative Route Definitions steps in figure 26).
3. **Work Zone Delay Data Entry:** This process is used to enter the estimates of construction zone delays. Note that the Tool does not predict construction zone delays. The estimated delays to be entered must be provided by the highway agency and manually entered into the Tool. The manual entry is required because no standard exists for automatically reporting the location, size, or extent of

construction delays, thus no automated input function was built for the Tool. The delay estimate data are entered via two separate data tables. One table describes which network links are impacted by each construction zone (the construction zone definitions table in figure 26), and a second table which describes the size of the estimated delays and the time periods when those delays will occur for each of those construction zones (the Construction zone travel times (speed) by date and time period during construction events step in figure 26).

4. **Truck Trip Data Entry:** Once the network is ready for use, an individual (e.g., trucking company dispatcher) examining the impacts of construction delays on truck trip planning can enter the specific trips they wish to operate. The individual enters the specifics of a truck trip (e.g., origin, destination, departure time or desired arrival time, etc.) and obtains feedback on the travel time required and the routes that should be used (User enters origin/destination of trip step in figure 26).

The system also contains several functional processes, which also shown in figure 26:

Updated GIS Network. This process is where the base transportation network is updated to reflect the travel conditions on links in the modeled highway network as a result of the estimated construction zone conditions (Active GIS Network step in figure 26).

Compute Minimum and Alternative Paths. This process computes truck travel paths based on updated network data and desired start or arrival times.

Compute Output Statistics. This process summarizes and outputs travel outcomes and statistics along the selected paths (travel time, miles traveled, paths taken).

When the end user specifies a desired arrival time, the system iterates through possible departure times to determine the optimal path and departure time to reach the specified destination at the desired time. The results of these computations are presented to the end user. The end user may then either print those results, or select another departure or arrival time, in order to explore additional travel options.

The above functionality is described in more detail in the following subsections, however, detailed task descriptions should be obtained from the "Work Zone Mitigation Scenario Planning Tool and Outcome Predictor Report."

Network Setup

The Tool is written primarily in PostgresSQL. It requires a GIS transportation network file that works with the pgrouting analytical software. This file structure also works with most general routing libraries available for GIS software. The file structure used for the Tool is NOT directly compatible with ESRI products.

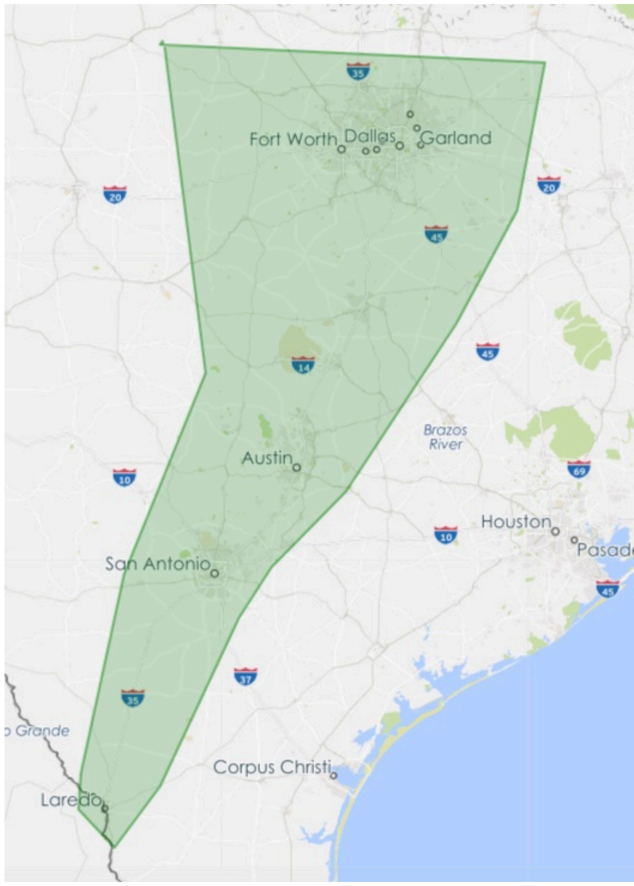
The selected highway network for the Tool was built using the highway network used for the NPMRDS database. NPMRDS was selected based on: 1) the availability of data; 2) the ease of use of the NPMRDS data; 3) the ease of adoption of the technique elsewhere in the U.S., as each new implementation of this tool will require its own GIS highway network and detailed travel time data; 4) NPMRDS network data are free to State DOTs and MPOs; and 5) the network covers the entire National Highway System (NHS), which includes the vast majority of the lane miles trucks operate on. Thus, the use of NPMRDS significantly lowers the cost of obtaining and deploying travel time data that vary over time which is a requirement for this time-of-day varying routing tool.

The primary limitations of using the NPMRDS include: 1) the dataset available for free is not a routable network; 2) the free network lacks ramp data; and 3) the free network does not include roads off of the NHS.

However, the NPMRDS network can be easily replicated nationally—at no purchase price to State DOTs or MPOs—and has the advantage of being able to directly access data needed to populate the required link-specific travel times. This allows States and MPOs to routinely update the base network travel times over time as new data becomes available through the NPMRDS, this continuously updating the software. These attributes were determined to be more important for the current development of this tool than alternative networks which provided more complete roadway coverage, but was more costly for States to deploy.

The data for the NPMRDS can be downloaded by any State DOT or MPO from the NPMRDS resource Web site. Credentials are required to perform the download, but those credentials are freely available to State DOTs and MPOs. To gain access to these data, contact the group within your agency responsible for reporting roadway performance to FHWA. The NPMRDS site allows downloads of both GIS shapefiles of roadway links and detailed travel time data on those links. This means that time-varying travel data for each link can be easily obtained, and those data are directly linked to the roadway network links that will then be used for routing and travel time computations.

A specific subset of the NPMRDS network was selected for use in this project. The geographic boundaries of the network were identified from the location of origins and destinations of the Regional and National Carrier trips that had previously been determined to travel on I-35 through the construction zones. An analysis of these origins and destinations allowed the project team to draw a geographic boundary around I-35 that gave the project team confidence that all practical routes between origins and destinations would be found within the network. This basic geographic boundary is illustrated in figure 27 below.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 27. Map. Highway network geographic boundary for the Work Zone Mitigation Tool.

For this test, data were selected for one month (April 2017) in order to create a travel time database with different travel times for each link for each day of the week and hour of the day. Data were downloaded as summary 1-hour travel times for each day in April. These were then summarized in SQL to create a single travel time for each hour for the seven different days of the week (*Note that even smaller time increments could be incorporated into the Tool if desired*. *In addition, more than one month of data could be used to create the base layer of network performance. The base layer also could be periodically updated using these same procedures).*

The NPMRDS data archive allows downloading of truck only, car only, or “all vehicles” travel time datasets. For this project, tests were performed with both the “all vehicles” travel time dataset and the “truck only” dataset in order to determine if the “truck only” dataset would produce modeled travel time predictions that were closer to the travel times reported by the participating trucking firms. The results of testing these alternative travel time datasets showed that the “truck only” dataset produced travel times that were only marginally slower than the travel times produced using the all vehicles dataset. While the “truck only” dataset is more closely aligned with the intent of the Tool, the truck-only dataset has more missing time periods than the all-vehicles dataset. As a result, the IA team believes that the use of the all-vehicle dataset is acceptable where trucks have the same speed limits as cars.

The use of the NPMRDS NHS network does create three significant problems:

1. The network shape files, as downloaded from the national repository, are not initially routable.
2. The NPMRDS network files do not contain ramp links (see figure 28).
3. While the NPMRDS contains all links in the National Highway System—and those routes are the primary truck routes, many truck deliveries are made via local roads that are not part of the NHS, and therefore are not included in the model network.

As a result of the first two limitations, several additional set-up tasks were performed to convert the available data into a routable network. These steps were:

1. Using the PostGIS topology extension, the project team forced the creation of nodes at all interchanges.
2. Perform a search for consecutive links in the network that should be connected but are not, and make those connections (this occurs where the end points of consecutive shapes do not share the same end point).
3. Using the PostGIS pgRouting extension, the project team generated a routable network from the result of (2). This automatically updates “source” and “target” columns and generates a table of “vertices” (which are commonly known as “nodes”). This set of tables enables the use of the Dijkstra family of routing functions in PostGIS/pgRouting.

The third limitation creates minor errors in the travel time estimates. The size of these errors was examined as part of the calibration process, and determined to be minor relative to the variation in travel time inherent between trucking origins and destinations caused by daily variations in travel conditions.

The lack of ramp links and ramp data in the NPMRDS creates error in the network routing and travel time computations because links between roads must in some cases be “forced” when shapefile links cross. In most cases, these errors should result in modestly faster overall travel times because ramp delays are not incorporated in the routing function. Turn delays also missing from the network database. Given the other potential errors in the travel time computations for this tool, the errors associated with these network limitations were determined to be acceptably small for this routing application.

Using topology extension, any time road segment arcs crossed, an interchange was created. Thus, over- and underpasses become junctions. Although these junctions allow turns where they may not actually exist, a visual inspection of the network suggests that the number and size of errors introduced in this process is small for the network being used for this project. In general, these artificial ramp interchanges create roadway-to-roadway connections which are similar to what actually occurs in the physical networks being modeled. The differences between the “real world” and the simplified model (e.g., the actual path along a cloverleaf interchange versus a simple node connection) can generate a modest error, particularly when ramp delays are significant relative to the mainline delays, but they typically do not alter the fundamental paths being followed, nor create errors in model-based travel time computations that are larger than the variation already inherent in the travel times experienced by trucks, given different driver behavior, the slower acceleration of trucks, and the fact that heavily loaded trucks tend to drive more slowly than lightly loaded trucks simply due to performance issues on grades and during acceleration/deceleration.

Of larger concern was the fact that the routing paths created by the addition of these “intersection nodes” needed to be carefully checked to ensure that movements that were not allowed (for example, there may be no northbound to eastbound movement at a given freeway-to-freeway interchange) were not mistakenly included in the routable network as a result of the process of making the NPMRDS shapefiles routable. The fact that the NPMRDS shapefiles are directional helped in this process. Removing these false nodes must be performed manually.

The more limited network used in the model (i.e., the lack of many smaller roads) also adds some error in the travel time computations. Like the lack of ramp delays and turning movement delays, the lack of links for smaller roads in the model when compared to the actual highway network will typically shorten the distance—and associated travel time—a truck must travel to reach its destination in the model relative to the actual distance a truck must travel. The model treats the origin or destination of the trip as the closest network node to the actual latitude/longitude coordinate of the origin/destination. The actual starting/stopping point may be off a smaller road connected to that node. These errors were assumed to be modest, and calibration tests showed the errors to be on the order of several minutes, based on detailed distance measurements from selected Regional Carrier locations along minor roads to network nodes, assumed travel speeds on those links, and assumed signal delays on those roads.

As illustrated in figure 27, the modeled network contains major roads in Texas from the Dallas/Fort Worth metropolitan area in the north to the San Antonio metropolitan area in the south, centered on I-35. This network size was selected to meet the needs of the evaluation project, but also limit the time and cost of the network set-up and testing. The only constraint on the network size is the computational ability of the computer being used and the availability of data related to transportation link performance (i.e., travel times on each link). Given the relatively sparse network provided by the NPMRDS, computational constraints are unlikely with this tool. The bigger issue is the initial setup, testing, and refinement of the base highway network.

The next step in the network setup is to look for disconnected links. This was performed by running an SQL query that looked for nodes attached to only one link. Roughly 1,000 of these points existed in the NPMRDS based network file. The majority of these points are “edge points.” That is, they represent a legitimate end point of the network and beyond this point the network connects to roads that are not on the NHS or are outside the geographic boundary shown in figure 28. However, several hundred of these links represent limitations in the NPMRDS segment definitions found in the national network files, and/or they represent limitations in how well the National Highway System road network can be used for modeling freight deliveries.

Two major types of errors (not counting edge points) were found in the review of disconnected points. These were:

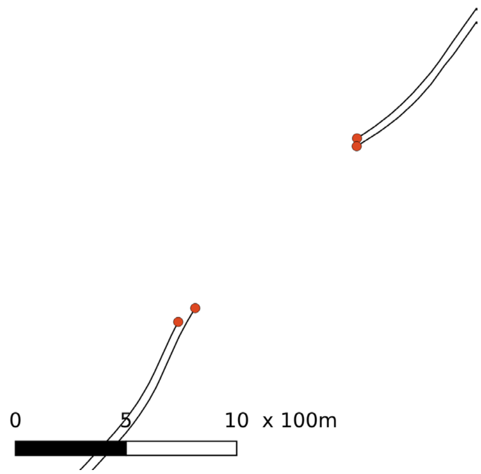
1. Missing links or segments.
2. Disconnected segments.

One example of a missing link is illustrated in figure 28. In figure 28, the missing link is actually a ramp that connects one major road to another. In this case, the connection from U.S. 281 to westbound U.S. 290 exists, but the connection from eastbound U.S. 290 to U.S. 281 does not exist. When this occurs, it is necessary to manually adjust these links by adding the appropriate links to the GIS file, or extend an existing link to make the required connections. When doing this, it also is necessary to manually identify which movements need to be inserted. For example, the curve of the link that does exist for the eastbound movement in figure 28 suggests that only a connection to southbound U.S. 281 exists. However, a careful review of the satellite imagery shows that eastbound U.S. 290 connects to both north- and southbound U.S. 281. Thus, two missing connections need to be added here. To fix these missing connections, the end point of the existing link is extended manually to connect to the closest north- and southbound nodes. The travel time on the extended link is computed as being at the same speed as the link being extended. Thus, travel time grows in proportion to the change in length for the road segment being extended.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 28. Illustration. Missing link in the National Performance Management Research Data Set database.

The second type of missing link is illustrated in figure 29. In this case, both directions of a roadway segment were missing from the NPMRDS dataset. These links must be added by hand, with travel times again being changed in proportion to the speed on the link being lengthened to close the gap.

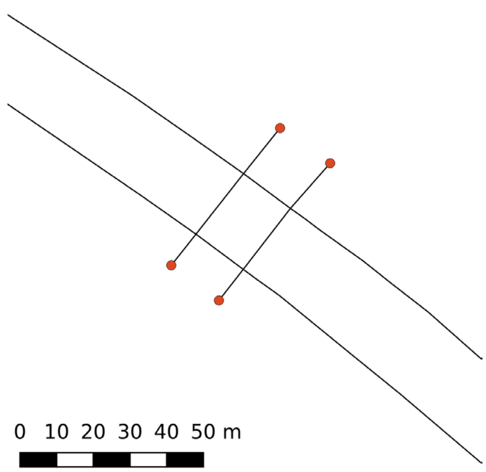


Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 29. Illustration. Missing network segment in the National Performance Management Research Data Set database.

In both the cases shown in figure 28 and figure 29, the distances involved in these missing links were short, less than ¼ mile. It also is interesting that a review of the NPMRDS data site suggests that these links should exist in the NPMRDS shape file, but they were not included in the file the project team obtained via the automated download process. It is unclear why this would be the case, but individuals creating routable networks from the non-routable NPMRDS links should expect to find similar issues.

The last type of unlinked road segment is shown in figure 30. In this last case, a short segment of roadway is likely defined as an NHS segment, and is thus included in the NPMRDS dataset, but that road segment is not directly linked to any other road segments. These segments were simply deleted from the dataset.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 30. Illustration. Disconnected National Highway System segment.

Once the network file was created, it was necessary to populate each link in that file with a travel time for each hour and day of the week. These data were simply extracted from the summary NPMRDS file and joined to the GIS network file using the Traffic Message Channel (TMC) code as the joining variable between the two data tables. Where the network file road segment is a different length than the NPMRDS data file road segment, the speed on that link stored in the NPMRDS data record for each hour is used along with the new road segment length to compute the travel time on that revised road segment. The result was a simple SQL compatible file with the information shown in table 12.

Table 12. Travel time data included in the network file.

tmc_code	length_mi	travel_time	Dow	time_start_of_segment	the_geom_32614
TMC Code Number	Distance (miles)	fraction of an hour	Day-of-week (1 = Sunday, 7 = Saturday)	Hour-of-day (0 = 12:00 a.m.—12:59 a.m.)	Binary encoded linestring in UTM Zone 14 N

Source: I-35 FRATIS Impacts Assessment Team, 2018.

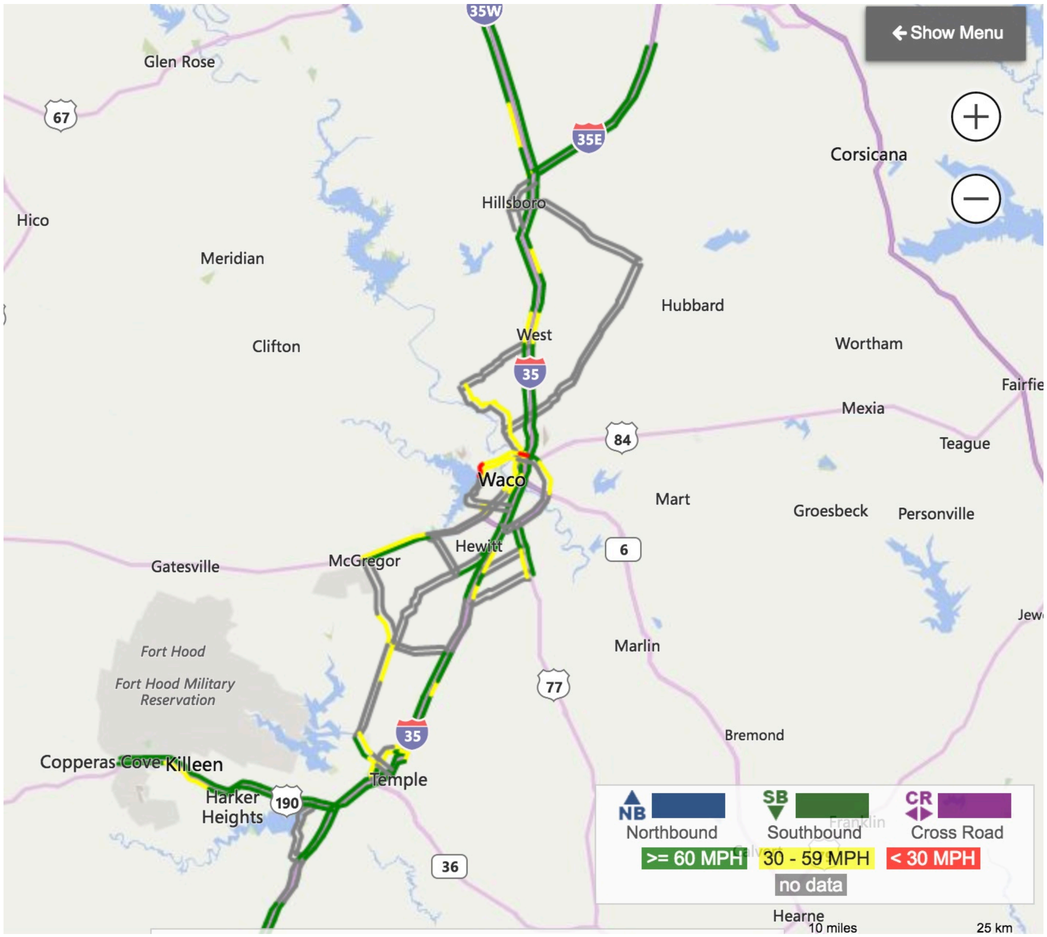
Each roadway segment (link) in the network has 168 rows in the database (24 hourly travel time values, for each of the 7 days of the week).

Once segment travel times were connected to the network links, it was possible to run tests of the routing algorithm and use the outputs to show the resulting minimum paths (test results are presented later in this report). By selecting a robust set of origins and destinations for testing, it was possible to use the path outputs to determine whether any obvious errors exist in the network's connectivity. Errors found in the network were then fixed by making manual changes to the network. These changes consisted of adding missing network connections or removing inappropriate network connections. In other circumstances, although manual fixes might be appropriate (e.g., errors in roadway length or travel time might exist, and could be found and fixed in this step).

The last step in the network set up function was to define possible alternative routes. Ideally, the routing software would automatically select possible re-routes, but limitations in currently available software algorithms made this a difficult task. To the available routing algorithms "any" difference in two routes constitutes a "different" route. Thus, when testing the routing algorithms, the project team found that routes selected for the "minimum time path" and "second fastest path" tended to have very marginal differences. For example, they only differed by which ramp was used to get on or off I-35. Where frontage roads were present in the network file, trips would simply get off onto a frontage road and re-enter on the next slip ramp. In these cases, the two routes were essentially identical.

To resolve this problem, the project team obtained from the TxDOT traveler information Web site, a map of recommended alternative routes. These alternative routes were provided by TxDOT for consideration by travelers when delays are high on I-35. An image of these alternative routes, taken from that Web site, is shown in figure 31. The project team then selected a single TMC segment in each direction in the middle of each of these major alternative routes and created a table of those segments.

When computing the "alternative route" paths, each alternative path considered must pass through at least one of these segments. This forces the path finding algorithm to use roads that deviate by at least a substantial amount from I-35 for at least a portion of the trip from origin to destination. The use of these "alternative route segments" is explained in more detail in the section "Compute Minimum and Alternative Paths" later in this document. The network set up process simply requires a list of these points.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 31. Map. Texas Department of Transportation recommended I-35 alternatives routes.

Network Verification and Calibration

When testing the network, it may become obvious for one reason or another that trucks being routed should not use specific links or should be encouraged to use some links rather than others. For example, the National Carrier indicated that some roads that might otherwise serve as re-routes around I-35 construction were not available to the carrier when the truck being routed was carrying hazardous materials. Alternatively, a carrier may wish for their trucks to take a specific road because its geometrics provide a safer trip, even if a parallel road offers a slight time advantage.

Because the system uses a simple SQL compatible file structure for holding the "baseline" roadway segment travel time, the Tool was designed so that users have the ability to make link-specific adjustments to link speeds and travel times by simply making changes to the records associated with the link in question. This functionality was built into the Tool so that users could artificially code travel tines on links as being very slow, so that vehicles would not be routed across that link. This feature it was not needed for this test.

Work Zone Delay Data Entry

This same basic network update function is used to update the network link travel times so that they reflect expected delays due to construction. This is done by creating a "Construction Zone Definitions Table," then entering construction delays using a spreadsheet form. Construction delay values are applied to a copy of the baseline network travel time data and are not stored in the baseline network itself. This means that they are not permanent and must be re-applied each time routing is to be performed.

To facilitate applying the desired construction delays, a two-step data entry process has been designed.

The first step in this is process is to create and maintain a "Construction Zone Definitions Table." This table allows the operations-level user to create a name for each construction work zone, and define, up front, which roadway links (TMC code segments) are to be impacted by delays occurring in this work zone. The name for each construction zone should be obvious to future users, so that they can easily identify and select a construction zone of interest in the future. Once constructed, this table allows a user to simply select the construction zone for which delays are estimated, without having to understand which TMC road segments are associated with that construction zone.

Table 13 illustrates what the Construction Zone Definitions Table looks like. Work zones can include more than one direction of traffic; however, the name of the work zone should make it clear as to which direction—or directions—of traffic that work zone impacts. The TMC codes included in the table define the links to which work zone delays will be applied.

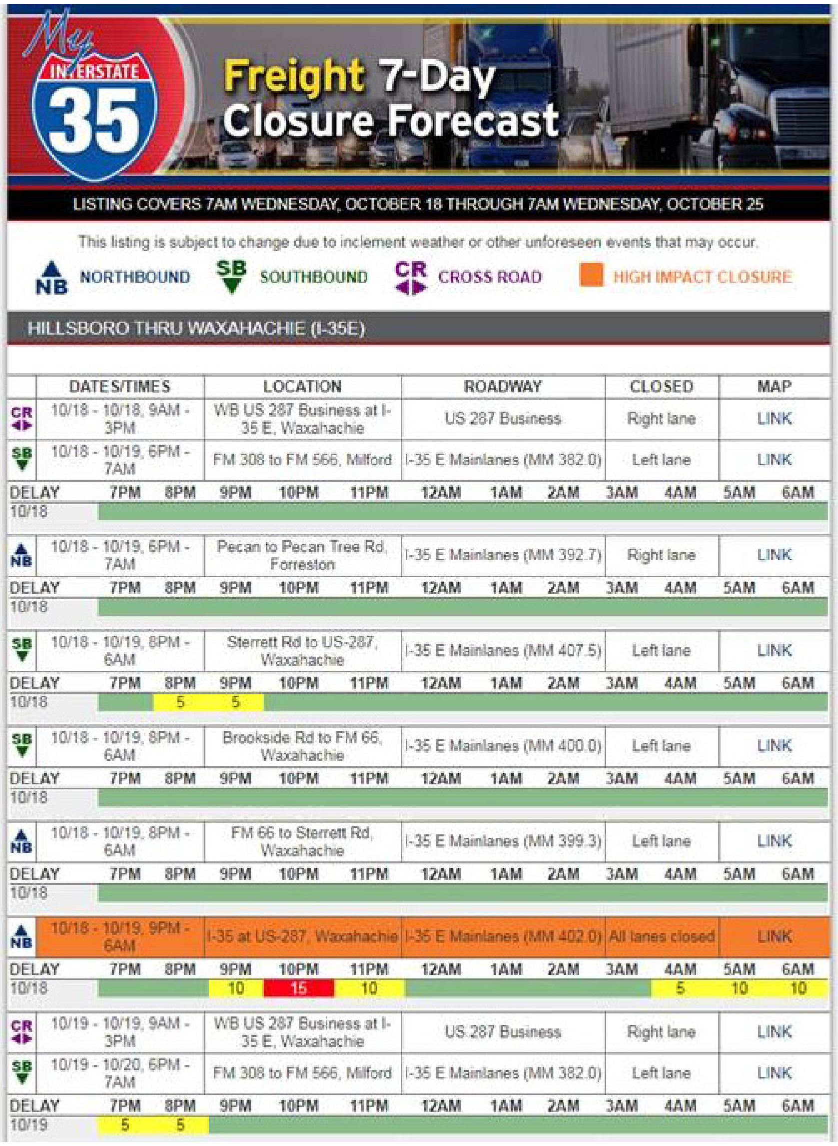
Table 13. Example of the Construction Zone Definitions table.

Work Zone Name	TMC Codes
I-35: Sterrett Rd to U.S.-287	111-05273 111N05273 111-05272 111N05272 111-05271 111N05271
I-35: Brookside Rd to FM 66	111N05268 111-05267 111N05267

Source: I-35 FRATIS Impacts Assessment Team, 2018.

The second step for entering construction delays is to use the Work Zone Delay Entry spreadsheet form to enter the actual delays (increases in travel time above normal travel times) that are being estimated for specific work zones. The user should only select from work zones identified in the Construction Zone Definitions Table. Thus, if a new construction project begins, the definitions table must be updated to include that new work zone and the TMC codes of the road segments it impacts.

The estimated delay entry spreadsheet expects delays to be entered in minutes of <u>extra</u> travel time expected for each work zone. It is expected that the operations-level user entering these delays will have information such as the freight 7-day closure forecast sent out by Texas DOT and shown in figure 32.



My INTERSTATE 35 Freight 7-Day Closure Forecast

LISTING COVERS 7AM WEDNESDAY, OCTOBER 18 THROUGH 7AM WEDNESDAY, OCTOBER 25

This listing is subject to change due to inclement weather or other unforeseen events that may occur.

NB NORTHBOUND SB SOUTHBOUND CR CROSS ROAD HIGH IMPACT CLOSURE

HILLSBORO THRU WAXAHACHIE (I-35E)

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
CR	10/18 - 10/18, 9AM - 3PM	WB US 287 Business at I-35 E, Waxahachie	US 287 Business	Right lane	LINK
SB	10/18 - 10/19, 6PM - 7AM	FM 308 to FM 566, Milford	I-35 E Mainlanes (MM 382.0)	Left lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18												

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
NB	10/18 - 10/19, 6PM - 7AM	Pecan to Pecan Tree Rd, Forreston	I-35 E Mainlanes (MM 392.7)	Right lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18												

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
SB	10/18 - 10/19, 8PM - 6AM	Sterrett Rd to US-287, Waxahachie	I-35 E Mainlanes (MM 407.5)	Left lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18		5	5									

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
SB	10/18 - 10/19, 8PM - 6AM	Brookside Rd to FM 66, Waxahachie	I-35 E Mainlanes (MM 400.0)	Left lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18												

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
NB	10/18 - 10/19, 8PM - 6AM	FM 66 to Sterrett Rd, Waxahachie	I-35 E Mainlanes (MM 399.3)	Left lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18												

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
NB	10/18 - 10/19, 9PM - 6AM	I-35 at US-287, Waxahachie	I-35 E Mainlanes (MM 402.0)	All lanes closed	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/18			10	15	10					5	10	10

	DATES/TIMES	LOCATION	ROADWAY	CLOSED	MAP
CR	10/19 - 10/19, 9AM - 3PM	WB US 287 Business at I-35 E, Waxahachie	US 287 Business	Right lane	LINK
SB	10/19 - 10/20, 6PM - 7AM	FM 308 to FM 566, Milford	I-35 E Mainlanes (MM 382.0)	Left lane	LINK

DELAY	7PM	8PM	9PM	10PM	11PM	12AM	1AM	2AM	3AM	4AM	5AM	6AM
10/19	5	5										

Source: Texas A&M Transportation Institute, 2018.

Figure 32. Chart. Example of Texas Transportation Institute/Texas Department of Transportation 7-day freight delay email.

An example of the Work Zone Delay Estimate Data Entry spreadsheet is shown in figure 33. This figure illustrates how one specific set of construction delays would be entered. It uses a work zone delay estimate shown in orange (or the last northbound row) towards the bottom of figure 32. In this case, delays are expected to occur on northbound I-35E on October 18, 2017 (10/18/17). Five different delay conditions exist in that work zone. Each of those conditions requires a different entry into the spreadsheet. Each entry can refer to one or more consecutive hours of delay, during which similar delay conditions can be expected.

Workzone Selection	Delay (minutes)	Start Hour	End Hour	Date
NB I-35E near US-287 Waxahachie	10	21	22	10/18/17
NB I-35E near US-287 Waxahachie	15	22	23	10/18/17
NB I-35E near US-287 Waxahachie	10	23	0	10/18/17
NB I-35E near US-287 Waxahachie	5	4	5	10/19/17
NB I-35E near US-287 Waxahachie	10	5	7	10/19/17
Select Workzone				

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 33. Chart. Example of the Work Zone Delay Estimate Data Entry spreadsheet.

In figure 33, the first four entries reflect expected delay conditions that last one hour. The last entry reflects a delay condition that lasts two hours.

The delay reported in each line of the spreadsheet is then associated with all of the impacted TMC segments included in the Construction Work Zone Definitions table for the selected work zone. To compute the link-specific delay, the total delay entered in each row of the table is spread across each of those TMC segments in proportion to their length (that is, if there are 10 minutes of construction delay, and that delay is being applied across three road segments of lengths 1 mile, ¾ of a mile and ¼ mile, the 10 minutes of delay results in 5 minutes of delay per mile or added delay of 5 minutes, 3.75 minutes, and 1.25 minutes, respectively for the three road segments).

The Work Zone Delay Estimate Data Entry spreadsheet can be saved, re-used, and modified at a later date. This keeps an operations-level user from having to reenter large amounts of data as different delays are added or subtracted from examinations being performed.

Updated GIS Network

The link-specific delays discussed above, are only computed when the spreadsheet shown in figure 33 is selected in the start-up screen of the Tool. When that occurs, the Tool software:

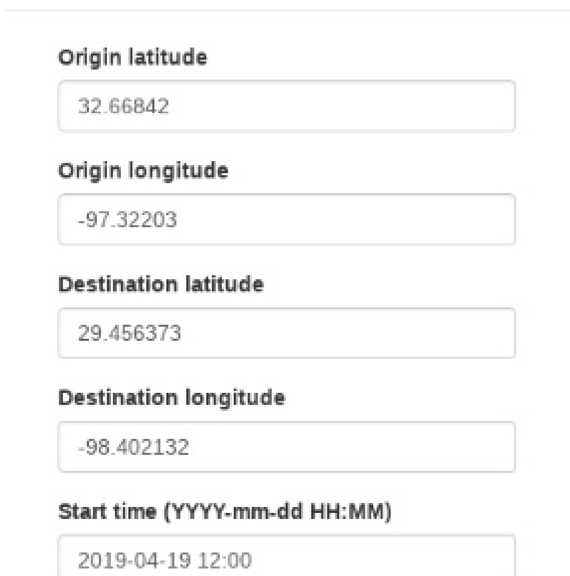
1. Creates a copy of the Baseline Network Travel Time database called the Active Network Travel Time database.
2. Computes the link-specific construction delays.
3. Adds those delays to the travel time found on each of those segments in the Active Network database.

This updated travel time database is used for all computational tasks (routing and performance reporting) that occur within the Tool. Note that “previously used” construction zone delays are discarded whenever the Tool is run. Only the construction delays from the active Work Zone Delay Estimate Data Entry spreadsheet exist in the Active Network. If previously used work zone delays are desired along with new delays, the user should create a duplicate of the first Work Zone Delay Estimate Data Entry file, and then make additions or subtractions as desired, saving it under a new name (or discarding the previous version). These combined delays are then applied against the Baseline Network to create a new Active Network. The Active Network is never saved. It is discarded each time the user exits the Tool.

Truck Trip Data Entry

Once the Active Network database has been created, it is possible for the end user to enter as many truck trips as desired in order to obtain routing information. Truck trips are entered one trip at a time.

The Truck Trip Entry process also is a simple data entry form that is part of the start-up screen. In the screen, the user enters the data that describe the trip for which travel routing and timing information is desired (see figure 34). Below the text shown in figure 34 is an option which allows the user to indicate whether the time being entered is the desired departure time or is the arrival time by which the trip must reach its destination.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 34. Illustration. Example of the Truck Trip Data Entry Screen.

At this stage in the software's development, the Trip Origin and Trip Destination must be entered as latitude/longitude coordinates. Future versions of this software could allow street address data entry or perhaps clicking on a map, but that function is outside of the scope of this project.

If the user selects a departure time, the Tool identifies the shortest travel time path to the destination starting at that time. The tool also computes two alternative paths for each trip for which a start time is specified, providing the user with multiple options. The user is presented with the start time, travel time, arrival time, and a map image of the three computed paths. They can then select the specific path they wish to use.

If the end user selects a desired arrival time, the Tool software computes the time at which that trip needs to start in order to arrive by that time. Trip starts are examined in 15 minutes increments. The "earliest" departure time selected for this analysis is the arrival time minus the time required to travel that distance at a speed of 80 mph, plus one hour. Shortest time paths are then identified for start times for the four hours prior to that initial start time, in 15-minute time increments. The system then provides as output the latest trip departure time that arrives prior to the required arrival time, as well as the fastest trip time during that four-hour departure window. The routing for both of these trips also outputted.

Compute Minimum and Alternative Paths

The Tool uses a number of steps to compute the minimum travel time and alternative paths reported to the user. The specific steps performed by the software vary depending on whether the software is determining the shortest time path for a given origin and destination pair, alternative paths for that same trip, or determining the required start time for a desired arrival time.

The first task is to determine where the origin and destination are connected to the highway network. The next step is a function of whether the software is looking for the best path for a given departure time, or whether the software is looking for the best start time for a given arrival time.

If the user has selected a departure time in the Truck Trip Data Entry Screen, the Tool computes a shortest time path from the origin to the destination. The Tool then computes a number of alternative paths for that trip. It does this by forcing the shortest path algorithm to include specific alternative routes in the path. These paths must contain at least one of the "Alternative Truck Routes" segments defined in the network set up process, and that point cannot be included in the minimum time path. This prevents the path finding algorithm from defining an "alternative path" as choosing a minor diversion (e.g., using a frontage road), instead of the mainline, and considering that a "different path." A separate fastest path is identified from origin to destination for each of the Alternative Truck route points (one path is produced for each point and must pass through that point). The actual trajectory-based travel time is then computed for each of those paths, with a starting time at the origin that is the desired departure time. The fastest two alternative paths are then selected as the "best" alternative routes. The user is then presented with the start time, arrival time, travel time, and a map image of the three "best" paths. They can then select the specific path they wish to use. This provides the user with an understanding of their options and allows them to use professional knowledge to select from among those options, as dispatchers often have insight into various route choices that are not captured in simple network models.

If the end user selects a desired arrival time in the Truck Trip Data Entry Screen, the Tool software performs a series of iterations of the path finding and travel time computation task. The system determines the latest trip departure time that arrives prior to the required arrival time, given the expected travel conditions, as well as the fastest trip time found during that four-hour departure window. The routing for both of these trips also outputted.

Using this method, several of these trips (especially the "initial start time" trip) will arrive late to the destination. These "late" trips were specifically included in the analysis output to show a dispatcher whether delaying a shipment's arrival could save travel time, provided the required arrival time can be made more flexible. For example, the "initial" start time might cause a driver to arrive in the construction zone just before the construction event ended, when delays are at their highest. In this case, waiting an hour to allow the anticipated queue to dissipate may end up saving that driver considerable time. Providing these additional trip options gives the dispatcher the ability to determine if saving that time is worth delaying the shipment's arrival.

Compute Output Statistics

Regardless of whether the user enters a desired departure or arrival time, the system produces output statistics which can be printed at the user's discretion. The following outputs are available for each trip path and start time:

- Trip origin.
- Trip start time.
- Trip destination.
- Trip arrival time.
- Trip duration.
- Trip path (route by route directions).
- Total miles driven from origin to destination.

A map of the trip path also is provided in order to ensure that the path selected makes sense to the end user. If the path does not make sense, an operations-level user can artificially "slow" a segment on that path using the Network Base Calibration function described earlier, in order to force the Tool to select a different route. This is a simple method that can be used to ensure that errors in the network speeds do not route trucks onto roads which are not suited to those trucks, so that dispatchers can apply their own knowledge of desirable or undesirable road segments.

Calibration and Validation of the Work Zone Mitigation Scenario Planning Tool

Calibration Tests

The primary calibration of the Tool was performed by comparing the travel times computed by the Tool against the travel times experienced by the National Carrier. The intent here was not to duplicate those times, but to make sure that the times produced by the model were "reasonable" replications of the times experienced by truckers. This is for several reasons:

1. Travel times reported, even from NPMRDS, are based on average measured times of all vehicles in the NPMRDS sample—either all vehicles or all trucks in the NPMRDS data sample—these travel times will differ from individual trip times—even if the NPMRDS is an unbiased sample—simply

because the individual trips are essentially randomly selected points from within that travel time distribution. Thus, the odds of those times actually matching are very small.

2. The limitations in the network comprehensiveness near the origins and destinations should result in slightly faster travel times being reported in the model than in the observed trip times, simply because the trips computed in the model do not experience some of the signal control delay actual trucks experience during the first and last miles of their trips. That is, the missing roads are small, are likely have lower speeds compared to the larger roads typically included in the NPMRDS network and are more likely to be impacted by signal delay. This means even if the distances are similar due to the selection of “closest points” to the latitude/longitude of the origin or destination, the model will not include some of the slower speed road segments used by the actual trucks.

The National Carrier was used for primary calibration because of the large number of trips made between specific origins and destinations. This provides a large sample of similar trips that can be compared against the model outputs. It is expected that the mean travel times from the National Carrier trips will be close in travel time to the mean travel times produced using the model. The Regional Carrier serves a much larger number of destinations, and thus, does not have as many trips between specific origin/destination pairs. This decreases the sample size for any given origin/destination pair. If multiple Regional Carrier destinations are grouped by geometric proximity into one “destination,” then at least a portion of the variation in travel times from those reported Regional Carrier trips are due to actual differences in routing, and thus added error to the comparison against model outputs. Thus, the National Carrier is the primary source of data for the calibration tests.

The first calibration test compared the distance reported as being traveled in the National Carrier database and the trip distances in the model. Table 14 shows this comparison. This table shows that the travel distances in the model slightly exceed the typical mileage driven by the National Carrier trucks. These differences are small, generally between 1 and 4 percent. This suggests that error due to the modeled trips not containing the road segments at very beginning and end of the truck trips is very small, due to the fact that additional time is included in the modeled trips due to the added length of those trips when compared to the actual National Carrier trip distances. The errors also are within the initially selected calibration goal of being within 5 percent of the actual mileage.

The next step in the calibration effort was to compare the differences in travel times between the model and the National Carrier. Table 15 shows this comparison. The National Carrier times reported in table 14 are simple averages of all valid trip times reported. This means that the mean National Carrier travel time statistic is weighted based on the volume of trips by time of day. That is, the fact that more trips start late at night (2:00 a.m., 3:00 a.m., and 11:00 p.m. are the most popular start times, as shown in figure 35 below) means that the mean National Carrier travel times are more heavily weighted towards late night time starts than the modeled trips.

For the model data, travel times were computed for start times for all 24 hours of the day, for each of the seven days of the week. These 168 values were then averaged to produce a simple mean travel time. No specific time of day weighting was applied.

Table 14. Comparison of National Carrier mileage from origin to destination.

Origin	Destination	Model Mileage	Mean National Carrier Mileage	Expected Mileage National Carrier[1]	Difference Absolute/ Percent (Model—Mean Carrier
Austin	Dallas	198.8	194.9	193	3.9 / 2%
Dallas	Austin	198.8	195.4	193	3.4 / 1.7%
Dallas	San Antonio	272.0	268.1	265	3.9 / 1.5%
Dallas	Waco	104.4	100.8	100	3.6 / 3.6%
San Antonio	Dallas	272.1	269.7	266	2.4 / 0.9%
Waco	Dallas	105.8	100.4	100	5.4 / 5.4%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

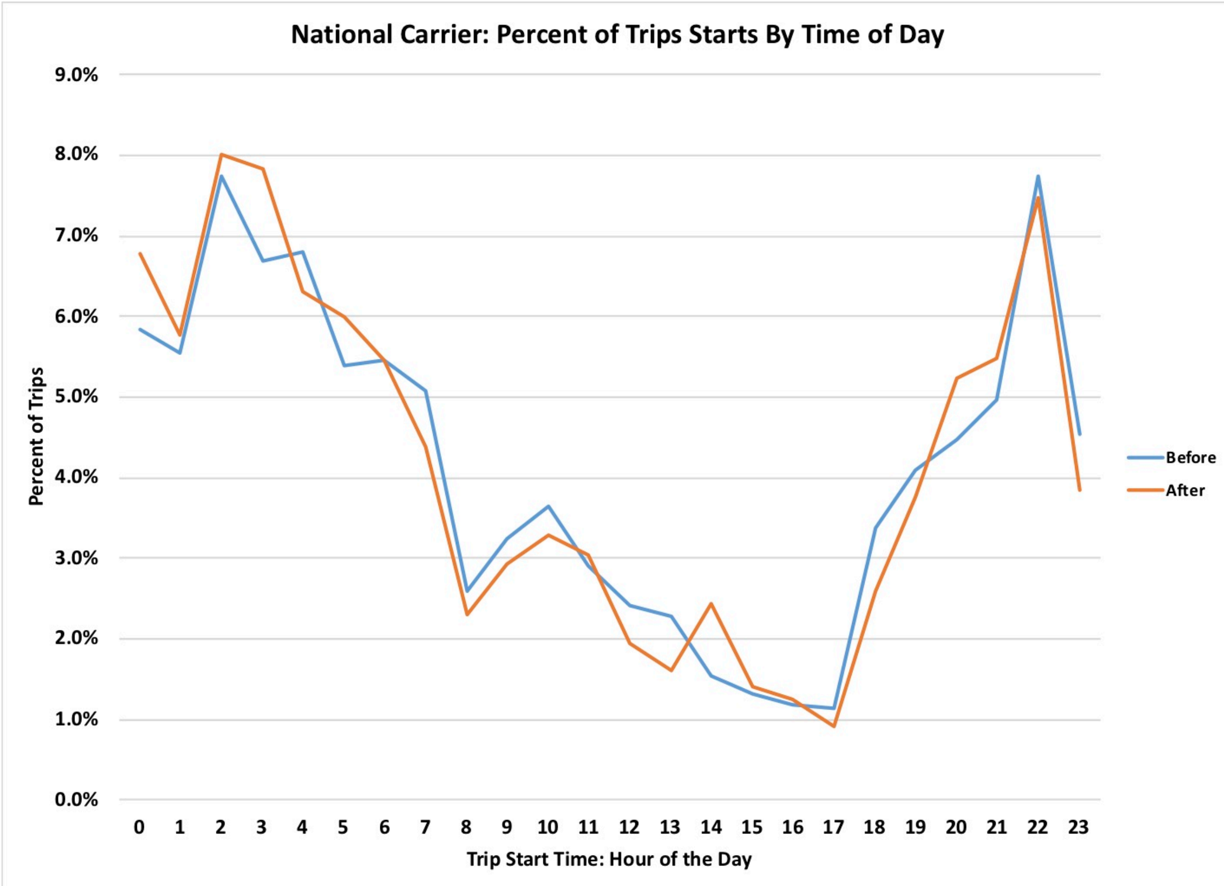
[1] Expected Mileage is the number of miles the National Carrier dispatch system expects the truck to drive from a given origin to a given destination. Actual mileage can vary for several reasons, for example, the driver making a stop for food, fuel, or other purposes can add mileage, as can minor differences in routing chosen by the driver versus that predicted/selected by the carriers routing algorithm.

Table 15 shows that the mean travel times for the National Carrier do not change significantly between the Before and After time periods. Minor decreases in travel time were measured for some O/D pairs, but these changes in travel time are marginal. Figure 35 shows that the time-of-day distribution of these trips did not change significantly. Table 15 also shows, as expected, that using the Truck Only NPMRDS data instead of the all vehicles NPMRDS data increases the modeled travel times, however, these changes in the data used for the model's travel times only slightly modify the modeled travel times. That is, the use of the Truck Only dataset travel times, does not fundamentally improve the relationship between the reported National Carrier travel times, and the modeled travel times. Finally, and most importantly, table 15 shows that the modeled travel times are consistently faster (shorter travel times) than those observed in the actual truck data. These faster travel times are observed despite the fact that the model causes trucks to drive slightly further than they do in real life. Even using the "truck only" travel times does not resolve these differences. The mean error of the model is greater than the 5 percent error bound desired for calibration stated in the Tool design report. However, the mean absolute error is less than the desired 15 percent error selected in that report. This also suggests that there is a modest bias to the model's travel times.

Table 15. Comparison of mean National Carrier travel times from origin to destination.

Origin	Destination	National Carrier Mean Before* Travel Times	National Carrier Mean After* Travel Times	Model Travel Time Using All Vehicle NPMRDS Data	Model Using Only NPMRDS Truck Data	Difference (Before National Carrier—Truck Only NPMRDS) Percent	Mean Absolute Difference (After National Carrier—Truck Only NPMRDS) Minutes
Austin	Dallas	209	209	185	189	10%	20
Dallas	Austin	204	200	187	190	7%	10
Dallas	San Antonio	280	275	262	265	5%	10
Dallas	Waco	107	105	96	98	8%	7
San Antonio	Dallas	276	273	261	265	4%	8
Waco	Dallas	110	108	95	96	13%	12

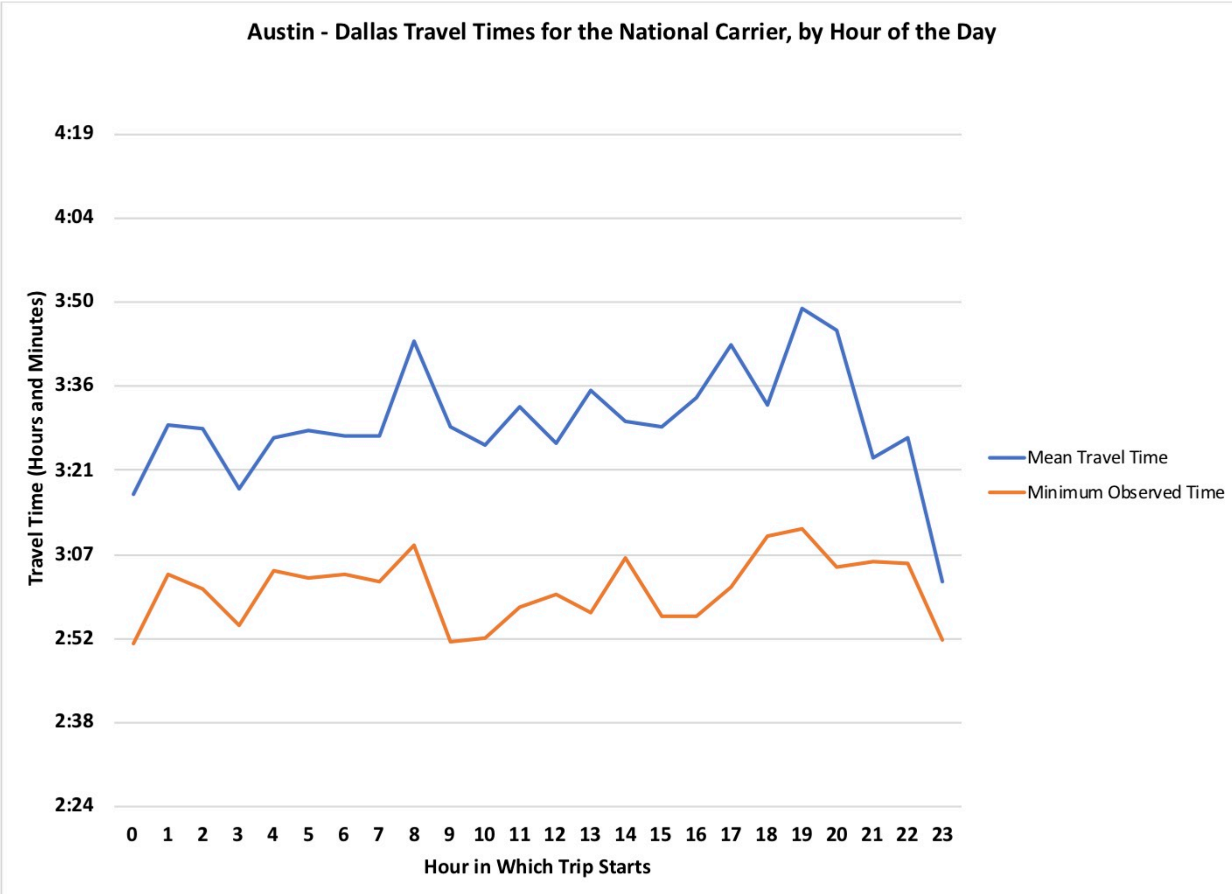
Source: I-35 FRATIS Impacts Assessment Team, 2018.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 35. Graph. The time of day when National Carrier trips start.

To examine the impacts of time of day on expected travel time, figure 36 shows the mean travel time for National Carrier trips from Austin to Dallas, given the hour of the day when the trip starts.

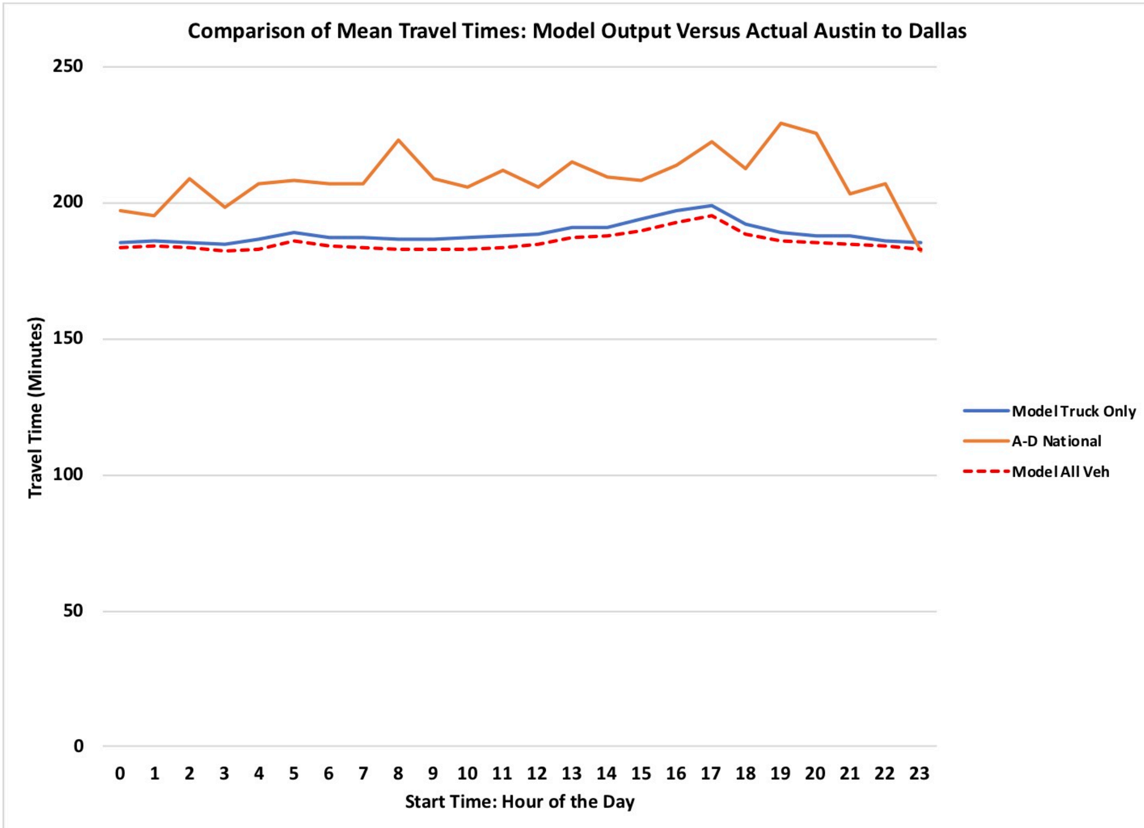


Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 36. Graph. National Carrier travel times by start time of day from Austin to Dallas.

Figure 36 shows, as suggested by the overall bias detected in table 15, that there are differences in mean travel times by time of day. In general, trips that start in the late evening from Austin can be expected to have travel times that are 20 to 30 minutes longer than trips that start in the middle of the day. These higher congestion periods explain the reason why a large fraction of the National Carrier trips start during time periods when the faster travel times can be expected. This would suggest that the evenly weighted model travel times should increase the mean of the modeled travel times relative to the actual travel times. This suggests that the model is even more optimistic about actual travel times than shown in table 15.

Figure 37 presents an examination of mean travel time by time of day for the National Carrier's Before data versus the mean travel time observed by hour of the day for the model using both the Truck Only version of NPMRDS and the "All Vehicles" version of the NPMRDS dataset. It can be seen that the bias noted in the summary table 15 is present throughout the day. Figure 37 also shows that while some variation in modeled travel times occurs with different start times, the NPMRDS data do not show the same level of travel time variability found in the actual data. In addition, while the model shows some increase in travel time for trips starting in the evening commute period, the NPMRDS data does not capture the increase in travel time found in the trips starting late in the day. The project team has not been able to discover a reason for these differences.

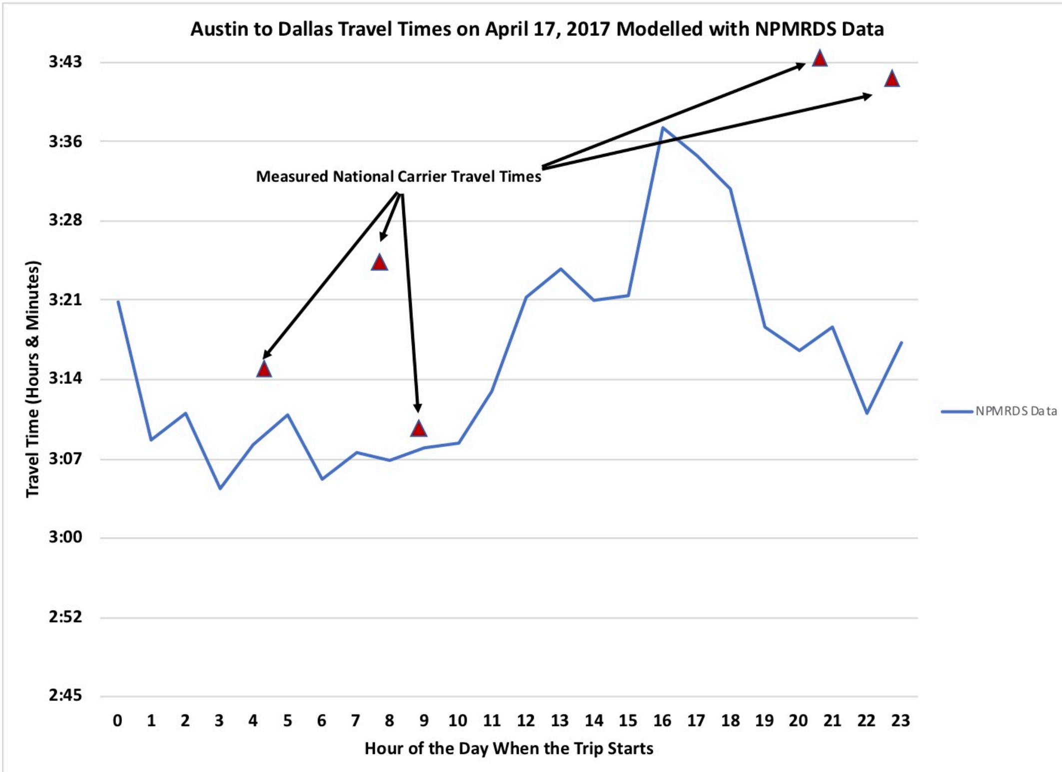


Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 37. Graph. Comparison of National Carrier Before data against model estimates by hour of day.

To determine if these outcomes are the result of using one specific month (April 2017) of NPMRDS data, while the “actual” data came from multiple months of travel conditions, specific National Carrier trips were compared against the modeled trips for those specific days and time periods. That is, for these comparisons, a specific day in April 2017 was selected, and the NPMRDS data for that day was used to provide network link travel times in the model. Travel times were then estimated by the model for trip start times that matched actual National Carrier trip records. Figure 38 illustrates the outcome of these comparisons for April 17 for the trip from Austin to Dallas. For this comparison, the modeled travel times use the All Vehicle NPMRDS data.

It can be seen in figure 37 that the differences in the specific trip travel times follow the same basic pattern observed in the summary time of day data. In some cases, the actual travel times are only a few minutes slower than the modeled travel times. In other cases, especially for the trips starting late in the day, the actual trip travel times are between 20 and 30 minutes slower than the estimate provided by the model.



Source: I-35 FRATIS Impacts Assessment Team, 2018.

Figure 38. Graph. Comparison of modeled trip travel times for April 17, 2017 versus actual National Carrier travel time reports.

From this comparison, it is unclear whether specific truck behavior (stops for fuel or bathroom breaks) are the cause of these differences, whether it is the lack of network detail near the terminals, or whether the NPMRDS data simply under estimates travel time compared to the observed National Carrier speeds.

The project team then investigated the location of the various National Carrier terminals and examined the distances that trucks would need to travel on smaller arterials to reach the major roads included in the NPMRDS to determine if the lack of these smaller roads are likely source of the bias in the estimated travel times. This examination found that two of the terminals are very close to nodes in the NPMRDS dataset, meaning that little travel time is required “off network” to reach the modeled network. For the other two terminals, distances of 0.75 to 1.25 miles must be traveled from the terminals to reach nodes on the NPMRDS network. This suggests that the “off system” mileage is not the source of the differences in travel times.

This analysis also suggests that the limited scope of the NPMRDS-based network may itself not represent a major source of error in the estimation of truck trip travel time for most likely freight origins and destinations.

Validation Tests

Given the performance of the model against the National Carrier’s revealed travel time performance, the model was then compared against Regional Carrier data. This comparison was not as readily performed simply because the Regional Carrier delivers to a much larger set of destinations than the National Carrier—at least in terms of the data shared with the independent evaluation team. This makes the direct comparison of travel times much more arduous, simply because of the data entry process required. In addition, the Regional Carrier trucks typically make more than one delivery, so the travel time test was restricted to the first delivery, to avoid having delays in deliveries at an early destination impacting the travel time associated with later delivery points. The National Carrier truck trips were terminal to terminal trips, with no additional stops. Thus, the National Carrier trips were much “cleaner” in terms of data collection and reporting than the Regional Carrier trips.

As a consequence, the validation effort consisted of using specific regional trips in April and comparing the reported trip travel times against the model results for those specific days and starting times.

A specific set of 11 trips was used to test the model. Each of those 11 trips went to a different destination. All started at the same terminal in Temple, Texas. The results of those initial 11 tests suggest that further trip comparisons would not greatly benefit the project. The Regional Carrier trips showed the same set of outcomes that were observed in the National Carrier data, but the Regional Carrier data included far more variation than found in the National Carrier data.

Once again, the mileage reported as being driven by the Regional Carrier was reasonably close to that estimated by the model. Table 16 shows these differences. (The actual origin and destination of these trips is not reported in this report so as to protect the proprietary business information of the carrier). As with the National Carrier, the model’s performance falls within the desired accuracy for the Tool as defined in the Tool’s design report.

Table 16. Comparison of Regional Carrier mileage versus model estimated mileage.

Origin	Model Mileage	Regional Carrier Reported Trip Mileage	Percent Difference
Trip 1	118.6	121.7	2.5%
Trip 2	133.8	138.0	3.0%
Trip 3	147.9	149.4	1.0%
Trip 4	122.6	123.4	0.7%
Trip 5	148.8	146.8	-1.3%
Trip 6	141.9	145.9	2.7%
Trip 7	154.0	169.1	8.9%
Trip 8	148.8	147.4	-0.9%
Trip 9	147.9	157.7	6.2%
Trip 10	122.6	125.2	2.1%
Trip 11	86.5	89.9	3.8%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

However, as with the National Carrier data, the travel times reported by the Regional Carrier were considerably slower than those reported by the model when using the NPMRDS data for the same date and start time (all comparisons are made for the dates of April 10, 2017 and April 17, 2017). These time comparisons are shown in table 17.

Table 17. Comparison of Regional Carrier travel times versus model estimated travel times.

Origin	Model Estimated Travel Times (NPMRDS Truck Data Only)	Regional Carrier Reported Travel Time (Minutes)	Travel Time Difference (minutes)	Percent Difference	Average Speed (Carrier Data)
Trip 1	108	128	20	15.6%	57
Trip 2	129	144	15	10.4%	57
Trip 3	142	159	17	10.7%	56
Trip 4	118	135	17	12.6%	54
Trip 5	140	179	39	21.8%	49
Trip 6	132	167	35	21.0%	52
Trip 7	148	182	34	18.7%	56
Trip 8	146	206	60	29.1%	43
Trip 9	146	204	58	28.4%	46
Trip 10	117	144	27	18.8%	52
Trip 11	84	147	63	42.9%	37

Source: I-35 FRATIS Impacts Assessment Team, 2018.

As can be seen in table 17, the “actual” travel times reported by the Regional Carrier consistently exceed the travel times estimated by the model by 10 to 20 percent, with several trip times being considerably longer than this.

In response to this, the project team explored these trips in far more detail. For example, since the Regional Carrier trips delivered freight to multiple destinations, one thought was that the destinations for these trips were further from the NPMRDS roadways, and those “last mile” segments were adding considerable time to the actual trips. This turned out to be a false assumption. The Regional Carrier destinations were no further from the NPMRDS network than the National Carrier’s. The Regional Carrier’s main terminal was just over 1 mile from NPMRDS road section vertices. Of the 11 destinations, several were within several hundred yards of freeway ramps, and none were more than 1.5 miles from the NPMRDS network. Thus, the distance to the pick-up or delivery point was not an issue in the differences in travel time examined.

One benefit of using the Regional Carrier data for calibration and validation, was that early in the project, the Regional Carrier provided a small GPS data set that could be used to examine the traces of truck movements and to examine how trips were recorded. A data point by data point examination of this data set suggests that the major difference between the Regional Carrier travel time estimate and the model estimate is not a result of errors or limitations in the model or in differences in NPMRDS speed estimates and actual carrier truck speeds, but in when a trip is reported to leave and/or arrive at a terminal by the carrier's fleet management system.

The GPS data stream provided by the Regional Carrier includes multiple records that occur within each terminal parking lot. These records show that the GPS data stream starts and stops periodically within that parking area. Rarely does the GPS data stream start as the truck leaves the terminal area. Instead, the data stream typically starts several minutes before the truck departs, and often (but not always) shows the truck spending several minutes maneuvering around the parking area prior to leaving ("truck maneuvering" is the conclusion because the GPS headings change with the different location reports, not just the exact latitude/longitude of the report). In other instances (when heading does not change), trucks can be seen at rest in the terminal parking area, but not moving.

In one of the example trips examined, the "start time" for the trip being reported for which detailed GPS data are available occurs 29 minutes prior to the truck actually leaving the location associated with the origin point for the trip. At the destination end of the trip, the vehicle physically enters the parking lot of the destination six minutes before the trip is reported as having "arrived" at the destination. These same patterns of early reporting of departure time and late reporting of arrival time exist in the majority of all trips for which detailed GPS data were examined.

Thus, it is clear from these data that the travel time data being reported by the Regional Carrier include at least some "in terminal" time. That "in terminal" time appears to be on the order of several minutes, to more than 20 minutes. An analysis of all trips submitted in the Regional Carriers detail GPS data sample shows that mean travel time decreases by 6 minutes if an estimate of terminal time is computed, where "terminal time" is the time spent within a small geographic buffer around the origin and/or destination after the GPS reporting for the trip begins or as a trip is ending. The standard deviation of the estimated terminal time is 4.9 minutes for each trip.

In this dataset, many of the "stops" for which terminal times are being computed are 2nd or 3rd deliveries for a given truck. For these trips, the truck is not starting a day's work, and thus, the "terminal time" spent by the driver (i.e., the time the driver spends getting their electronics set up correctly, making sure that their paperwork is correctly organized, etc. after they turn on the truck engine and GPS) should be much shorter—per destination. The expectation is that the terminal times at a major terminal—and especially the first departure and last stops of the day will have longer terminal times.

If these time reporting issues are considered when examining the travel times reported in table 17, the differences between the travel times reported by the fleet management systems and the model outputs become somewhat closer, especially when considering that the trips modeled in the Tool calibration all include starting at a terminal, and the National Carrier trips also include finishing a delivery at a major terminal. Adding terminal times to the travel times also helps explain the slow average speeds reported by the carriers for many of the reported trips. All of these trips take place primarily on I-35, although some additional Dallas area freeways are used for some portions of some of these trips. It is therefore unlikely that travel speeds for the entire trip average less than 50 mph. However, if terminal time is included, along with delays experienced in the actual trips, these slow speeds are not unreasonable.

These results, however, do suggest that the Regional Carrier data are less effective in reporting the differences in modeled versus actual travel time between various freight activities. As a result, the larger differences in travel time between the model and actual results should not be used to discredit the model's performance. The previous conclusion, that the modeled travel times are reasonable but somewhat faster than "actual" travel times, appears to be correct.

When taken together with the findings of the comparison of National Carrier modeled and actual travel times, we find that the Tool produces slightly biased travel time estimates, but that those estimates are within bounds found acceptable for use of the Tool. This conclusion is based on the mean absolute error in travel time falling within the initially adopted criteria. The fact that the mean error for travel time exceeds the proposed calibration criteria is attributed to the inclusion of terminal times of varying size within the fleet management travel time reports.

These results do suggest that future versions of the model should include, at the discretion of the user, terminal times that would be added to the on-road travel times predicted by the model. While these added times are not descriptive of the on-road travel times being examined in this study, they are important factors in when deliveries are made, and trucking firms may wish to include them in the estimates they wish to see from the model.

Summary of Calibration Test Results

The NPMRDS-based network model developed for use by trucking firms that wish to incorporate information on predicted construction delays into their routing and time of departure decisions appears to present an optimistic version of expected travel time. However, evidence suggests that much of the observed bias is caused by differences in how the participating trucking firms compute and report "travel time" versus how the model is computing and reporting travel time. The model reports only over-the-road travel time, with that time starting when the vehicle leaves its origin and ending when the vehicle reaches its destination. The Regional Carrier GPS data appears to include at least some "in terminal" time. That is, in the fleet management system data, the trip "starts" prior to the truck leaving the parking lot, and "ends" at least several minutes after arriving at the destination parking area. This creates some bias in the travel time being reported. While the IA team does not have detailed GPS data from the National Carrier, the size of the difference between modeled and actual travel times suggest that this same bias exists in the National Carrier data as well.

For trip planning purposes, the model appears to work as intended and produces travel times that are reasonable. Thus, the project team concludes that the model is sufficient for use in estimating the impacts of construction work zone delays and could be a beneficial tool in the hands of trucking firms as they work to optimize their daily work. However, while this tool is suitable for operations-level trip planning, one key limitation to note is that the alternate routing algorithm currently cannot change where trips enter and/or exit the network.

The findings from the model calibration and validation effort do suggest a number of improvements to the model that should be considered as part of any effort to activity deploy this tool. These improvements are included in chapter 9. Summary and Conclusions.

Summary of the Work Zone Tool Development Effort

This subsection states the conclusions drawn from the design, testing and use of the Work Zone Mitigation Tool. It also describes the potential uses and benefits of the system, the improvements which need to be made to the system to allow those benefits to be achieved, and the next steps needed to move the system forward towards deployment.

The Tool is a by-product of the independent evaluation contract for the I-35 FRATIS project. It was not the result of a software development project. As a result, the budget for this project was not sufficient to make the software fully ready for full deployment. While the software works as desired, a number of interface improvements need to be made before the system is ready for widespread deployment and use. These improvements are discussed below in the subsection titled Improvements Desired Prior to Deployment.

Expected Benefits

The primary reason this project's independent evaluation scope of work had to be revised was because the trucking companies were not interested in adopting the optimization software FHWA had developed for drayage applications for use in their general freight delivery business. It was discovered that companies of moderate or larger size already had their own optimization software, and that their optimization software involved the use of considerable business information stored inside their other management systems. Thus, the firms were not interested in testing the FHWA system, even though it could provide insight into how to optimize movements around expected construction delays.

However, the firms were interested in knowing more about expected construction delays and were interested in experimenting with ways to account for those delays when planning their delivery activities. The Work Zone Mitigation Tool allows trucking firms to gain considerable insight into available options for reacting to expected construction delays.

The Tool was designed to mimic the process available from many commercially available navigation applications. However, unlike those applications, it was specifically designed to account for construction delays provided by State DOTs and other highway agencies. It was designed to help trucking firms understand:

- When alternative routes are required.
- Which alternative routes result in the best delivery options.
- When changes in planned departure times are needed to ensure on-time delivery of freight.
- When the arrangement of alternative arrival times with customers can save large amounts of travel time, thus lowering the cost of freight delivery.

The Tool also designed to allow both the roadway agencies and the trucking companies a level of control over which roads are selected for alternative paths when such paths are needed.

System Design

The Tool was built using open source software and data that is readily and freely available to state DOTs and MPOs. These choices were made to lower the cost of system deployment and upkeep. The code itself is open source and can be modified as desired by U.S. DOT or any knowledgeable software user.

The Tool uses the following software packages:

- PostgreSQL (including the Post GIS and pgRouting extensions).
- The R statistical package (including R suite and RStudio).
- Shiny.
- QGIS (for cleaning the network data).

A basic knowledge of these tools is needed by the individual responsible for setting up the Tool for use within a specific State or region.

To set up the system, the State DOT or MPO must first download the NPMRDS network (shape) files and travel time data. These are available to State DOTs and MPOs through U.S. DOT free of charge. The NPMRDS includes all road segments on the NHS. It is possible to download only a portion of the NPMRDS network file, so that a State DOT or MPO can create a model network that is only as large as desired for their construction activity. The fact that only NHS road segments are in the database does create a limitation in the current version of the Tool in that roads that are not part of the NHS are not included within the tool unless the implementer purchases additional road segment data from the private-sector vendor supplying data to for the NPMRDS.

The next step in the Tool implementation is to convert the NPMRDS shape files into a routable network. Software is provided as part of the Tool to help with this process, but it does require agency staff time to perform quality assurance checking and to fix errors identified by that quality assurance (QA) process in the NPMRDS network. As the NPMRDS network matures over time, the amount of quality assurance work required will decline.

The Tool then requires that the highway agency operating the system identify work zones for which delay information will be provided. Each work zone must be named, and the NPMRDS road segments associated with that work zone must be identified.

The agency then must identify roads that are recommended for use as alternative truck routes when construction delays are occurring. One goal of this last step is to ensure that trucks avoiding work zone delays are routed only onto roads that can safely accommodate large vehicles.

Finally, the highway agency needs to be able to estimate the construction delays. The Tool does not estimate work zone delays. These must be produced independently by the highway agency. The road segment-specific travel delays are allowed to vary by time of day as well as from one day to the next. In the current version of the Tool, each change in expected delay—whether the location of that delay or the amount of delay expected—must be entered by hand.

The Tool is accessible via a Web interface. Trucking companies can then enter specific trips into an interface. The use enters their origin, destination, and either a desired departure time or required arrival time. The Tool then constructs a series of alternative trips. If the user picks a selected departure time, the Tool identifies the fastest route to the destination, as well as the best two alternative routes that use at least one of the agency selected alternative route road segments. The reported travel times and paths reported by the Tool include consideration of both “normal congestion” (by time of day) and the construction delays entered by the agency.

If the user selects a required arrival time, the Tool determines the required time of departure to arrive at that time, given expected normal conditions and the expected construction delays. The three best alternative paths and departure times are present to the user, again using the alternative routing choices of the agency.

In all cases, the user also is presented with basic statistics about their trip alternatives, including time of departure, expected time of arrival, total travel time, and mileage driven.

Tests of the model indicate that the estimated travel times are similar to—but slightly faster than—the travel times experienced by the participating trucking firms. At least part of the differences between the model's estimated travel time and the actual travel time of trucks appears to be due to the fact that participating trucking firms appear to include additional in terminal times in their reported origin-to-destination travel time reports.

Improvements Desired Prior to Deployment

While the system described above works as described, the user interface is still very rough. The system in its current state is a tool built to support an evaluation project. It is not a polished software suite ready for routine use by individuals who are not familiar with GIS software, the R-studio suite of programs, or NPMRDS. In addition, several other improvements were identified as part of this project which would greatly benefit both the deployment of this project and the delivery of construction delay information in general.

The first two improvements in the software are recommended actions for FHWA, regardless of whether they pursue further development of the software Tool, as these improvements have multiple benefits outside of the deployment of the Tool. A second list of Tool-specific improvements is presented later in this subsection.

The two most important improvements for FHWA to pursue are:

- Develop a data format standard that describes the location, severity (delay), and time of application for construction delays.
- Make available a routable, national NPMRDS network.

While this Tool was built with specific emphasis on trucking industry needs, all roadway users can benefit from advanced knowledge of construction delays. Many private firms currently provide both near real-time and forecast travel time estimates and navigation directions for customers. However, these firms do not have access to expected construction delay information. Many of these information providers provide the location of expected construction activity, but they are typically able to incorporate specific construction delays until congestion forms, at which time they attempt to provide near real-time notices about those changing conditions.

Creating and adopting a standardized format for delivery of <u>expected</u> construction delay information would allow these major firms to deliver that information to all travelers. In addition, the major suppliers of fleet management software also would be able to ingest these data. This would allow major trucking fleets to directly incorporate the construction delay predictions into their own freight delivery optimization software. The Tool would still provide excellent benefits to firms that did not have such capabilities, but the optimization benefits to trucking fleets will not be realized until these data are routinely ingested into the company-specific optimization software systems, and that will only occur when a standardized data format exists for ingesting that data from all highway agencies.

For the Tool, that same standardization would allow removal of the manual entry of construction delay information. This would decrease the cost of operating the system. It also would undoubtedly reduce the cost to the highway agency of producing the input data, as that process could be fully automated.

While the current NPMRDS is not available as a routable network to the State DOTs, private companies routinely purchase routable versions of NPMRDS. Creating a single, national routable network would make it far easier and less costly for agencies to adopt the Tool. That same routable network also be used for a wide variety of other agency-specific analyses, including multi-route travel time performance reporting. For the Tool, this improvement significantly reduces the cost, and lowers the time required to implement the Tool.

Tool-specific improvements that should be made in order to improve the user experience and decrease the time required to adopt the Tool are as follows:

- Currently the Tool does not allow map-based data entry. For example, origins and destinations must be entered by typing in the latitude and longitude of those destinations. The Tool would be much easier to use if trucking firms had the option to simply point at a spot on a map and have the X/Y coordinate values of that location automatically entered as an origin or destination.
- Similarly, the definition of a Construction Zone would best be entered in a similar manner. In this case, the agency user should be able to use a map interface to identify the beginning and ending of a work zone and have the GIS application automatically identify the NPMRDS road segments associated with that work zone. These would then be stored for later use within the Tool.
- The NPMRDS is limited to the NHS. While this project showed that—for this evaluation—that was not a significant detriment to the use of the tool, in other situations it could be. Thus, a better approach needs to be developed for routing truck traffic from the origins and destinations to the NPMRDS network. This project did not have the resources to allow the determination of the best way to accomplish this task. Identifying and testing alternative methods for performing this task and then implementing the best alternative would significantly benefit the use of this tool
- Discussions with the trucking firms indicate that while they are interested in using this type of tool, the firms were not actively involved in testing its use. Trucking firms should be engaged in user trials of the software, with the expectation that changes in the interface and system operation may be needed to make the tool more user-friendly to this audience. For example, a good question the firms need to weigh-in on is, “do the trucking firms wish to include additional in-terminal time in their travel time estimates, and if so, how flexible would they wish the entry of those times?”
- User feedback also should be obtained for the Tool’s outputs, with the expectation that changes in the design of those outputs—if not the technical details of those outputs—will be required.
- Finally, the system administrator’s interface currently a standard R-Studio screen. This is good for a technical user that may need to debug the software, but a more user- friendly interface should be designed which allows individuals not familiar with R or various GIS tools to install, tune and operate the Tool.

All of these improvements are intended to make the Tool easier to use and to make users more comfortable with the Tool’s outputs. These activities are necessary if the Tool is to be widely adopted. At this stage in the Tool’s development, it is a useful technical tool, but it is not ready for public use. The above improvements would go a long way towards making it ready for public deployment.

Next Steps for Continued Model Development

The Tool's develop currently slated to end with this IA project. The software will be posted on GitHub along with an Open Source license for its use. The next steps towards its deployment are as follows:

- FHWA must decide if this Tool, or a variation of the Tool's functionality is of sufficient benefit to be funded within the agency.
- Funding must then be allocated.
- Steps should continue to be taken to develop standards for the distribution of expected construction delay information.
- A stakeholder group of navigation service providers should be created to provide input to that process.
- If possible, the provision of routable NPMRDS networks should be incorporated in the next round of NPMRDS procurements.
- A software contract should then be let that provides for the development, implementation, testing, and refinement of a more user-friendly version of the Tool.

Implementation of the Tool would then follow from those steps.

Chapter 9. Summary and Conclusions

The I-35 FRATIS pilot test utilizing the enhanced TIDC information delivery program is intended to:

- Empower dispatchers with historical and near real-time information to enable faster and better decisions.
- Allow trucking firms to determine optimized truck routing if they so desired.
- Determine the best dispatch time for each truck trip to avoid congestion.
- Help trucks avoid or efficiently accommodate construction delays and lane closures on the I-35 corridor.
- Deliver near real-time traffic information such as lane closures, incidents, and expected delays.
- Provide dynamic routing for drivers to avoid congestion and deliver advance notifications to customers.

The evaluation described in this report examined whether the TIDC's information delivery resulted in measurable benefits to the trucking firms using the system. It is based on a year-long before/after analysis of two major trucking firms, with six months of data collected before the firms started using TIDC information, and six months of after data collection after TIDC information started being ingested into the truck firms' business processes.

In terms of the general conduct of the FRATIS project being evaluated, a significant amount of project time and effort would have been saved if more effective stakeholder engagement had been performed prior to project scope finalization. Such an effort would have quickly identified the lack of interest from trucking firms in the optimization software due to the existence of well-established commercial products.

Summary of Evaluation Results

The provision of data from the TIDC had little measurable impact on the travel times or travel time reliability experienced by the participating trucking firms. The evaluation was able to measure no significant changes in:

- Mean travel times between similar origins and destinations.
- Travel times by time of day.
- The fraction of trips operating during specific times of the day.
- The 80^{th} percentile travel times for individual origin/destination pairs.
- The standard deviation of travel times between those origin/destination pairs.

Consequently, no significant changes in fuel use, delay, labor hours, or other benefits occurred. As an example of the limited changes observed, table 18 presents the descriptive statistics for the National Carrier.

Table 18. Change in National Carrier travel time descriptive statistics.

Origin	Destination	Change in Mean travel time (min., % of baseline)	Change in Standard Deviation of travel times (min., % of baseline)	Change in 80th Percentile travel time (min., % of baseline)	Change in 80th Percentile travel time minus Mean	Change in 80th Percentile minus Mean (% of mean)
Dallas	Waco	-0:01 (-1%)	0:07 (50%)	-0:04 (-4%)	-0:03	-3%
Dallas	San Antonio	-0:02 (-1%)	0:05 (23%)	-0:02 (-1%)	0:00	0%
Dallas	Austin	-0:03 (-1%)	-0:02 (-9%)	-0:08 (-4%)	-0:05	-2%
Dallas	Laredo	0:01 (0%)	0:05 (13%)	-0:26 (-5%)	-0:27	-6%
San Antonio	Laredo	-0:02 (-1%)	0:00 (0%)	-0:03 (-2%)	-0:01	-1%
Waco	Dallas	0:02 (2%)	0:17 (106%)	0:03 (3%)	0:01	1%
San Antonio	Dallas	-0:02 (-1%)	0:03 (12%)	-0:02 (-1%)	0:00	0%
Austin	Dallas	0:02 (1%)	0:02 (9%)	-0:02 (-1%)	-0:04	-2%
Laredo	Dallas	-0:24 (-5%)	-0:13 (-28%)	-0:20 (-4%)	0:03	1%
Laredo	San Antonio	0:01 (1%)	0:03 (23%)	0:03 (2%)	0:02	1%

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Despite the lack of quantifiable benefits, both participating trucking firms remain enthusiastic supporters of the TIDC. Both see sufficient value in construction delay information that they are actively seeking internal company resources for improving the ability of their companies to ingest TIDC data to their existing business processes.

The direct benefits the trucking firm participants cited included those typically cited by the public when expressing support for improved traveler information. That is, TIDC information was readily passed to drivers to help them understand expected conditions along their routes. Drivers used this information to:

- Prepare for unusual queues during their trips, thereby lowering their crash risk.
- Pre-select when and where to stop for breaks during those trips.

These outcomes result in happy, satisfied information system customers, who appreciate and typically access the information being delivered routinely. Unfortunately the benefits from these outcomes are difficult to directly measure.

Conclusions

The lack of more quantifiable change in travel behavior is not due to any failure in the design or implementation of the TIDC. Instead, it is due to the geography of the location in which the TIDC was operating during the project evaluation. I-35 between Dallas and Austin lacks alternative routes whose use makes business sense for the vast majority of the construction delays that occurred during the evaluation. This resulted in the firms having limited interest in changing the start or arrival times of their trips or the routes used during those trips.

Both participating trucking firms reported that they expect to obtain more quantifiable benefits from work zone delay information:

- If construction delay information such as that provided by the TIDC was available in geographic locations where alternative routes existed, and
- If the TIDC information could be automatically fed into their existing business systems.

The first of these issues is simply a function of the location of I-35 construction activity that was present for this study. As I-35 construction moves to the Austin metropolitan area in the near future, the trucking firms will have considerably more opportunity to make changes in their travel plans, and the resulting benefits should be more quantifiable.

The second requirement points out specific areas of future work that should be supported by U.S. DOT that were identified in this evaluation. Most moderate to large trucking companies already use sophisticated scheduling and routing software to optimize their deliveries. These systems are directly integrated into their fleet management systems and their other business systems. To effectively take advantage of construction delay prediction and near real-time information, that information needs to be integrated into these existing systems. The TIDC information currently arrives as a separate data feed. As a result, the information contained in the TIDC data feed must be considered outside of each company's regular business process. This limits how effectively that information can be used by the firms, as staff must perform additional work to consider the impact of that information and then manually adjust the plans provided by their business systems.

If TIDC information was directly included in the data being used by those business systems, it would be more effectively considered in those business system optimization routines. This would increase the number of decisions that it effects. Having the data inside the fleet management data stream also greatly simplifies the delivery of that information to drivers and dispatchers, as it places that data in the information stream that companies want their staff to pay attention to, rather than requiring them to pay attention to multiple information sources.

This same finding also applies to the Work Zone Mitigation Tool developed as part of this project. The Work Zone Mitigation Tool was built to allow the evaluation team and others to directly analyze the benefits of alternative routes or departure times. In many ways, the Work Zone Mitigation Tool works like a more sophisticated version of the TIDC's Freight Solver tool. The functionality of both of these Tools was well received. However, for trucking companies, that functionality will be more effectively used if it is imbedded in their existing schedule optimization, navigation and fleet management systems.

The same routing and trip planning activity incorporated in the Freight Solver and the Work Zone Mitigation Tool would also be of significant benefit for individual travelers, and like freight travel, the best way to get that information to the public is to help bring the TIDC information into the navigation and trip planning tools the public already using. These findings lead directly to the recommendations in the section below.

Finally, it must be noted that while both participating trucking firms used and appreciated the TIDC information, they used the information differently. The National Carrier preferred using the Freight Solver. The Freight

Solver is a near real-time Web site updated once per minute to reflect the latest closures and delay estimates and presents the optimum departure time to the National Carrier based on the origin and destination pair selected by the site's user. The Regional Carrier used the TIDC email notifications. Both companies also valued near real-time notifications of changing travel conditions, but need the ability to adjust the frequency of the notifications they receive. They also expressed an interest in obtaining better information on the expected duration of unexpected events and delays.

Project Recommendations

The recommendations from this evaluation are split into long-term and short-term actions.

Long Term Actions

The U.S. DOT should actively pursue the development of standard data feeds that could be consumed by private companies. In addition, it is recommended that the companies providing scheduling, routing, and fleet management to trucking companies be directly engaged in this discussion—along with providers of general navigation software—to ensure that these data streams can be directly absorbed into the software that drive the vast majority of trucking company routing and scheduling business decisions. The experience TTI and TxDOT have gained in working with the National and Regional Carriers on what data are needed and how it needs to be presented offer considerable insight into the types of data and data structures that need to be accommodated in these formats.

U.S. DOT should actively work with highway agencies to collect data on construction delays, estimate expected delays for future construction activity, and publish those data using the standards to be developed above. Findings from earlier ITS America research on Traveler Information System deployment found that the private sector needs broad, national availability of information in order to develop sustainable, marketable products. Thus, while the TIDC system provides a superb example of how construction work zone information can be gathered and distributed, that same type of information is needed not just across the rest of Texas, but in all 50 States. As the availability of data expands, the private sector's business opportunities also will expand, which will bring additional resources to the table that support the delivery and use of this information. U.S. DOT support is needed to expand the availability of data which creates this market.

U.S. DOT needs to perform detailed market studies prior to finalizing the design of future technology development and deployment studies. This includes both determining whether stakeholders are willing to adopt those technologies, and whether commercial products already exist in that market. Stakeholder input obtained as part of those market studies should be carefully considered and used to shape the final design of those technology studies.

Short Term Actions

Until the uniform and more universal availability of work zone delay information is available, the TIDC is an excellent resource for the trucking community. Minor improvements to the TIDC were requested by the trucking firms, and the IA team supports those requests. They include:

- In the Freight Solver, minimize the number of clicks needed to obtain the information requested.
- Allow companies to more easily tailor the information they receive from the TIDC. This can include:

- Restricting information delivery to specific or individual trips.
- Providing more control over how many or how often alerts are received.
- Provide more direct ways to deliver TIDC information directly to the truck drivers (e.g., pushing information directly to smart phones or in-cab communication devices).

Lastly, both trucking companies participating in this project expressed significant appreciation to the entire project team for the team's high level of communication, willingness to listen, and willingness to incorporate their needs into a user-friendly solution. For both the short-term and long-term actions, it is highly recommended that U.S. DOT continue that approach to working with trucking companies and the businesses that support them. The businesses are very interested in working together to find solutions to problems that we all experience, but are leery of public agencies pushing their own agendas.

Appendix A. Interview Responses

The responses below were collected through a series of teleconference calls and emails with the National and Regional Carriers.

National Carrier

The primary participants in the user acceptance/satisfaction surveys for the National Carrier included three individuals. Their job roles and survey dates are listed below.

Job roles of National Carrier interview participants:

- Regional Supervisor—Operations Systems.
- Operations Systems Analyst.
- Director of Operations Systems.

Survey dates:

- March 29, 2018—teleconference call.
- April 24, 2018—email feedback.
- April 30, 2018—email feedback and teleconference call.

Table 19. Interview responses from the National Carrier.

Interview Question	Response
How do you disseminate the Freight Solver information in your company?	The dispatchers have direct access to the Freight Solver on their computer screens. The Freight Solver runs in a separate window from their normal dispatch and other work screens. Dispatchers typically look at the Freight Solver's predictions when they first start their day's work. The Freight Solver window then typically runs in the background and is referenced when the dispatcher desires a reminder or update. Dispatchers then often provided pre-trip information from the Freight Solver to the drivers either face-to-face at the dispatch window, or via phone calls.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 19. Interview responses from the National Carrier (continuation).

Interview Question	Response
How do you manage your fleet (GPS, dispatchers, equipment in cab, etc.)?	The National Carrier used PeopleNet to develop a “command center” at its headquarters, where five dispatchers have access to a wall of TVs that provide a birds-eye view of the entire delivery network, including information about any weather delays, accidents, breakdowns, or reported hard braking/stop incidents. The data flows into the system from PeopleNet units on the vehicle, as well as external information such as weather data. In addition to near real-time data displayed on the screen, the carrier uses the data that comes in to analyze and improve a variety of operational tasks.
Roughly how often did you use Freight Solver information?	The tool had a Hawthorne effect on the dispatchers—when the tool was new, it was used a lot, but over time, they tended to forget to check the screen, in part because it was typically hidden from view while they are working due to its need to run in a separate computer window. Dispatchers have many other screens that they access on a regular basis, and since the Freight Solver does not pop up automatically, it was easy to forget to use it.
Did the Freight Solver change the timing or routing of your trucks?	Not really. Due to the location of the delays on I-35, there was minimal impact on National Carrier decision-making because of the lack of alternate route options. Typically, being an hour or two late on a delivery is not an issue, unless it is a hot load. The National Carrier often uses the same route because the re-routes do not save enough time, or the re-routes do not specify whether doubles or hazardous material (HAZMAT) cargo are permitted.
What type of Freight Solver information was used (lane closures, construction location, other?)	The National Carrier used construction delay information from the Freight Solver. The incident information and construction information are equally important to them.
How much do you want to know about the nature of the incident or the nature of the delay?	The National Carrier wants information on both the nature of any incidents—including construction activity—and the size and scope of delays to be expected at those construction locations. In their opinion, the more information the better.
Did you pair Freight Solver information with any other sources of real time roadway data?	The National Carrier did compare Freight Solver estimated delays to delay times via other sources (Waze, etc.) and the information was found to be comparable.
Describe the benefits of the Freight Solver.	The value of the Freight Solver information was having the information ahead of time so that dispatchers could let the drivers know what to expect on the roads. Drivers may make stops earlier or later (to eat, etc.) than they would have otherwise based on both the expected delays and near real-time delays.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 19. Interview responses from the National Carrier (continuation).

Interview Question	Response
Describe the limitations of the Freight Solver.	The Freight Solver would be utilized more frequently if the information was presented differently. The National Carrier recommends fewer clicks to get to the critical information. Dispatchers struggled to deal with all of the other events that cause them to change routes/start times. This is due in part to having the Freight Solver information presented on computer windows that were not part of their existing dispatch/operations screens, and that results in the Freight Solver screen being routinely hidden by the other work screens.
What format would you recommend we use for distributing or delivering the Freight Solver in the future?	The National Carrier recommends providing Freight Solver information directly to the drivers so that they are not dependent on dispatchers and planners for the information. This can be done by integrating the Freight Solver into the National Carrier's freight software, as well as the carrier's messaging system that drivers currently use, which reads messages to the driver (and eliminates distracted driver issues), or even via drivers' smart phones. • The National Carrier also would like to see near real-time Freight Solver alerts whenever the predicted Freight Solver outcomes are changing significantly. • The National Carrier also would like the information to be tailored to each individual driver's trip (this could be done if the Freight Solver worked inside of the National Carrier's other fleet management systems).
If possible would you continue to use the information from Freight Solver?	Yes, if the coverage area had sufficient alternate route options.
Any additional comments?	• The National Carrier does not need public rest area availability information (*this was asked by TxDOT in one of the phone calls*), instead they need information about the various locations where they can swap trailers. • Hours of service restrictions are generally not a concern of the National Carrier (*this also was in response to a question asked by TxDOT*), because they have planned trips in a way that prevents that from becoming an issue in the first place. • The National Carrier would like to see whether this I-35 Connected Work Zone system performs better in an area with better supporting interstates (i.e., where alternative high speed roadways exist), like the northeast where there are so many more alternate routes for a truck to take to really see benefits. In Texas, drivers are generally stuck in their ways and they are going to stay on a certain path if there are only certain options available to them.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 19. Interview responses from the National Carrier (continuation).

Interview Question	Response
How do we make the traveler information easy for you to integrate into your system (dispatcher working screen)? The biggest drawback stated from you to using it is that it is on a different screen.	If it was part of the National Carrier's ALK Technologies navigation package and fed the information through in real-time, that would be ideal.
Maybe the next step is to talk to companies that already have this information. Which companies have this information already?	ALK Technologies has had it the longest. The National Carrier believes that if you get ALK on board, then you will probably reach 90 percent of the market. The National Carrier has offered to introduce the I-35 FRATIS project team to people at ALK. Omnitracs also has a truck routing service that they integrate with the electronic logging device (ELD) service.
If we can provide this kind of information to ALK or Omnitracs, then does that put the information directly to the dispatchers and drivers in a way that is safe and works within your system?	That is definitely a way to do it. The first thing a driver will ask for with the GPS navigation is <u>accurate, live traffic updates and construction work zone information</u>.
Would that navigation improvement help you with the day ahead load scheduling?	The way the National Carrier's models work today, the planners enter a drivers' projected travel time, based on previous projected travel times. Unintended consequences include picking up a driver because his vehicle broke down, or incident delays. Navigation would be less helpful for the National Carrier's on-demand drivers that go where the demand is.
When you are looking at travel times, are you looking to use a relatively static travel time?	The National Carrier's system provides static travel times, and it comes with variability. They have a database that analyzes all of the travel times. After 25 runs, it can tell you the average travel time with the variance. When you talk about network planning, when you get too far away from averages, then you can get in trouble, by including nodes that you do not want to include. And if you provide a network layer that is too detailed, you can end up rerouting trucks where they should not be going.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Regional Carrier

The primary participants in the user acceptance/satisfaction surveys for the Regional Carrier included two individuals. Their job roles and survey dates are listed below.

Job roles of Regional Carrier interview participants:

- Director of Transportation Support.
- Transportation Manager.

Survey dates:

- May 10, 2018—teleconference call.
- May 30, 2018—email feedback.

Table 20. Interview responses from the Regional Carrier.

Interview Question	Response
How do you disseminate the email information in your company?	The Regional Carrier passes it down to the dispatchers who put it out to the drivers via electronic communication in the trucks.
How do you manage your fleet (GPS, dispatchers, equipment in cab, etc.)?	The Regional Carrier uses several tools which include the ones you mentioned (GPS, in-cab equipment, communications with dispatchers).
Roughly how often did you use the email information?	Almost daily.
Did the email change the timing and/or routing of your trucks?	The Regional Carrier suspects that the emails did impact the timing and/or routing of their trucks, but since the truckers themselves have to determine what to do with the information, the Regional Carrier is not clear on the actual impacts. The Regional Carrier does not dictate the alternate routes for their truckers.
What type of email information was used (lane closures, construction location, other?)	Lane closures and construction location and timing, as well as expected construction delay information.
Describe the benefits of the emails.	They come in a timely fashion and are easy to read. Giving truck drivers the information to get there on time is valuable to the Regional Carrier. Anything that interrupts this process takes a hit on their business.
Describe the limitations of the email.	None.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 20. Interview responses from the Regional Carrier (continuation).

Interview Question	Response
What format would you recommend we use for distributing or delivering the email in the future?	Same.
Did you pair the email information with any other sources of real time roadway data?	No.
Any general observations on how the emails impacted your overall operations?	The Regional Carrier has been unable to determine specific dollar savings. This is in part because of the location of the current I-35 construction activity.
If possible would you continue to use the information from the emails?	Yes.
Right now you get this information via email. Is there a better way to get this information? Would it be better if it came in an automated message set?	Right now, getting this information through email is the most universal method because it can be used on any system. This works well on the route and delivery planning side. Ideally the information would be available through the in-cab devices (majority use Android operating systems, some use iOS). It might be nice to have a department of transportation or I–35 mobile app that pops up warnings regarding accidents along the highway system and whether there are any alternative routes.
Who is your navigation vendor?	ALK CoPilot.
Another suggestion that we have heard is to talk to ALK and provide them with standardized message sets. What are your thoughts on that?	The Regional Carrier thinks that would be great. That would ultimately help the driver get where they need to go. Having a 400-pound gorilla like the Regional Carrier telling the vendor that they want a feature like this would help it gain traction and compete for development funding with other improvements the vendor is considering.
Do dispatchers also use CoPilot?	Dispatchers use software that is internal to the Regional Carrier, not CoPilot. In this scenario, email-based notifications would be helpful. Dispatchers can then manually make any changes necessary, such as changing routes. However, the process is so cumbersome that it is unlikely that they would do it.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

Table 20. Interview responses from the Regional Carrier (continuation).

Interview Question	Response
If there was a Web-based tool that you could enter origin, destination, and departure time, like Google Maps but for trucks, would that be a useful tool? A tool that incorporates delays into travel times. Another option would be to talk to Google and give them the information.	It would be cumbersome to check Google traffic for all individual routes and potential departure and arrival times, instead of just being presented with a list of planned construction events along I-35, which dispatchers can keep in mind when routing or rerouting trucks. This list would only have to be checked once per day, instead of once per route. The Regional Carrier does like the idea of a routing system that could be incorporated into their existing system. Such a routing system could be Web-based or an API, with a way to import it into their system to assess road speeds on the corridor.

Source: I-35 FRATIS Impacts Assessment Team, 2018.

List of Abbreviations and Symbols

COfF	Texas Corridor Optimization for Freight
CSV	Comma Separated Values
DMA	Dynamic Mobility Applications
DOT	Department of Transportation
ELD	Electronic Logging Device
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information System
GIS	Geographic Information Systems
GPS	Global Positioning System
HAZMAT	Hazardous Material
IA	Impacts Assessment
ITS-JPO	Intelligent Transportation Systems Joint Program Office
MPO	Metropolitan Planning Organization
NASCO	North American Strategy for Competitiveness
NHS	National Highway System
NOAA	National Oceanic and Atmospheric Administration
NPMRDS	National Performance Management Research Data Set
O/D	Origin-Destination
PAI	Productivity Apex
QA/QC	Quality Assurance/Quality Control
SQL	Structured Query Language
TIDC	Traveler Information During Construction
TMC	Traffic Message Channel
TRAC	Washington State Transportation Center
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
U.S. DOT	U.S. Department of Transportation

U.S. Department of Transportation
ITS Joint Program Office—HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free “Help Line” 866-367-7487

www.its.dot.gov

FHWA-JPO-18-694

U.S. Department of Transportation