Evaluate Travel and Economic Impacts of Texas Freight Corridor Projects

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Final Report: Evaluating Travel and Economic Impacts of Texas Freight Corridor Projects

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Executive Summary

Texas has the second-largest economy in the U.S. and the tenth-largest in the world. The efficient and cost-effective movement of goods plays a critical role in the state's economy. With a drastic increase of population, Texas freight volume moved by highways is expected to almost double from 2.2 billion tons in 2016 to 4.0 billion tons in 2045[1]. This growing truck tonnage will lead to increased daily truck trips and truck miles traveled, which in turn will further exacerbate some of the challenges that Texas freight transportation is already facing, including congestion, safety, restrictive infrastructure conditions, insufficient rural and multimodal connections, and limited funding. The rapid pace of technological developments adds another layer of challenges.

To address these challenges and better prepare the Texas freight highway system for the growing freight volume, many projects have been proposed or are under consideration. Thus, while developing freight plan and programs, the Texas Department of Transportation (TxDOT) needs to answer some essential questions: How would these projects impact the local as well as statewide travel conditions? What benefits can these projects bring to the state economy? Finally, how can TxDOT prioritize these projects while considering available funding?

To help answer some of these questions and facilitate better decision-making, the Center for Transportation Research (CTR) at the University of Texas at Austin worked with the TxDOT Freight and International Trade Section to establish a consistent framework for evaluating the travel and economic impacts and performing benefit-cost analysis of freight corridor projects.

The framework is established based on the Statewide Analysis Model (SAM), which is a Texas statewide travel demand model, and the widely used economic analysis model Transportation Economic Development Impact System (TREDIS). SAM was used to evaluate the network-wide travel impact of the projects that are under study and provide the resulting travel condition information to TREDIS for economic impact assessment.

An automated data processing tool was developed by the CTR team to expedite and smooth the data flow between these two major components of the framework. The CTR team also developed methodologies to estimate the construction, maintenance, and operation costs when they are not available from existing planning documents. To better capture the safety benefits and improvements to vehicle operation stemming from upgraded infrastructure, the CTR team developed a detailed analysis procedure that breaks down travel not only by mode and purpose (as a normal economic analysis would), but also by roadway type. This approach enabled a more detailed analysis that can more accurately capture some of the economic benefits. The CTR team also developed a common base case by updating the roadway network in SAM to the 2018 conditions. This 2018 common base case not only reflects the current roadway network more accurately but also enables comparison across different scenarios, as all scenarios are analyzed against the same base (no build) case.

Using the framework, tools, and analysis procedures described above, the CTR team helped TxDOT analyze the travel and economic impact of various scenarios. These scenarios include upgrading important freight corridors to higher standards (e.g., to the standard of a four-lane divided highway or interstate highway), implementing all planned or proposed projects along an important freight corridor, and implementing projects that aim to relieve severe traffic congestion; also considered were some hypothetical scenarios exploring the potential of using truck-only lanes or truck platooning to improve freight efficiency. These scenarios have diverse effects on the network-wide travel conditions and yield

[1] Texas Freight Mobility Plan 2018. Accessed at https://www.dot.state.tx.us/move-texas-freight/studies/freight-plan.htm

positive or negative benefits in different benefits categories. Most of the scenarios analyzed are proved to be cost-effective with overall benefit-cost ratios higher than one.

- Among those scenarios that involve upgrading an interstate highway or US highway to a higher standard—upgrading the I-2, I-69 and I-27 corridor to the minimum standard of a four-lane divided interstate highway and upgrading segments on all four rural corridors (US 87, US 69, US 59, US 281) to the minimum standard of a four-lane divided highway—all generate positive net benefits and higher-than-one benefit-cost ratios. Among them, upgrading the entire I-2 corridor generates the highest benefit-cost ratio, followed by upgrading US 59 from Laredo to Houston and upgrading the I-69 full corridor.
- Among those scenarios intended to improve the corridor by implementing all the planned or proposed projects—I-10 within the Texas Triangle[2], I-35 full corridor, and I-35 within the Texas Triangle—all result in a benefit-cost ratio of almost two or above. However, the I-35 full corridor improvement combined with upgrading US 281 doesn't generate enough benefits; that scenario's benefit-cost ratio is close to zero.
- Among those scenarios aiming to reduce congestion at bottlenecks, implementing all projects planned or proposed at the 20 most congested locations results in the highest benefit-cost ratio, followed by implementing all projects at the top 25 trucking congested locations. The Clear Lanes projects generate positive benefits overall, but not enough to cover the costs.
- Among those exploratory scenarios, truck platooning is expected to bring significant benefits to the state. The truck-only lanes are proved to be beneficial as well. Expanding interstates to at least three lanes each direction proves to be effective only if we confine the scope to those interstates within the Texas Triangle.

The analyses of these scenarios demonstrate that the study framework, tools, and analysis procedures developed in this project can be extremely useful for evaluating and comparing the economic implications of different projects or programs and for facilitating better decision-making while developing plans, policies, and projects to improve travel and environmental conditions, safety, and freight movement efficiency.

[2] The Texas Triangle is formed by the state's four main cities—Houston, Dallas-Fort Worth, San Antonio, and Austin—connected by I-45, I-10, and I-35.

Chapter 1. Background and Study Objectives

Texas has the second-largest economy in the U.S. and the tenth-largest in the world. The efficient and cost-effective movement of goods plays a critical role in the state's economy. In 2016, freight transportation in Texas created 2.2 million full-time jobs, generated $145 billion in wage income, $215 billion in gross state product, and $49 billion in tax revenue, as more than 2.2 billion tons of goods moved through the state's multimodal transportation system. Of these 2.2 billion tons of freight, more than 50% of them are moved by trucks along Texas roadways[3].

The Texas population is expected to increase by 11 million from 2016 to 2045. This equals to an average of 1000 people moving to Texas daily. The population increase drives significant freight growth. Texas freight volumes moved by highways is expected to almost double from 2.2 billion in 2016 to 4.0 billion tons in 2045[3]. This growing truck tonnage will lead to increased daily truck trips and truck miles traveled, which in turn will further exacerbate some of the challenges that Texas freight transportation is already facing[3], including the following:

- *Congestion*
  Texas was home to 6 of the top 25 U.S. freight bottlenecks in 2016. Dallas-Fort Worth and Houston are in the top 10 cities in the U.S. for trucking congestion costs.
- *Safety*
  Over 23,000 truck-involved crashes happened in 2016.
- *Restricting Infrastructure Conditions*
  In the Texas Highway Freight Network, 76 bridges are in poor or worse condition, 13 bridges have weight restrictions, and 291 bridges have vertical clearance under 15 feet.
- *Insufficient Rural and Multimodal Connections*
  Many roadways connecting important rural energy and agriculture activity centers have an obsolete design. Many roadways connecting ports and other intermodal facilities are in highly congested urban areas or in poor condition.
- *Funding*
  Lack of sufficient funding to support freight projects.

To address these challenges and better prepare the Texas freight highway system for the growing freight volume, many projects have been proposed or are under consideration. For example, TxDOT identified four key corridors within the Texas Highway Trunk System and proposed an upgrade to these corridors, anticipating the improvement to these corridors can help relieve congestion on their parallel interstate systems, promote connectivity and economic development throughout Texas, strengthen international trade routes, and address safety concerns through the use of modern/enhanced designs[4].

The list of projects that can help address some of the challenges mentioned above can be unlimited, but the available funding is limited. Projects that are more cost-effective should have higher priority. Also, some projects might be proposed with the intent to improve a local condition but may end up adversely affecting the system-wide conditions due to the overlapping effects of multiple projects and the route- and mode-shifting nature of traffic.

Based on these considerations, the TxDOT Freight and International Trade Section worked with CTR to establish a consistent framework for evaluating the travel and economic impacts of freight corridor projects. The main objective of this project is to support TxDOT's decision-making by predicting the

[3] Texas Freight Mobility Plan 2018. Accessed at https://www.dot.state.tx.us/move-texas-freight/studies/freight-plan.htm

[4] Texas Transportation Commission January Workshop Presentation: Statewide Connectivity. Accessed at: http://ftp.dot.state.tx.us/pub/txdot/commission/2019/0130/2-presentation.pdf

network-wide travel impacts of proposed or considered freight corridor projects and estimating their costs and economic benefits to the state.

Chapter 2 of this report provides an overview of the framework created under this study and the modeling tools used to conduct the analysis. Following this overview, Chapter 3 describes in detail each scenario analyzed using the framework and tools presented in Chapter 2, with their predicted travel impact to the statewide roadway network and estimated economic benefits. Based on these analyses, some recommendations that could assist TxDOT in selecting or comparing alternative projects/policies are developed and presented in Chapter 4.

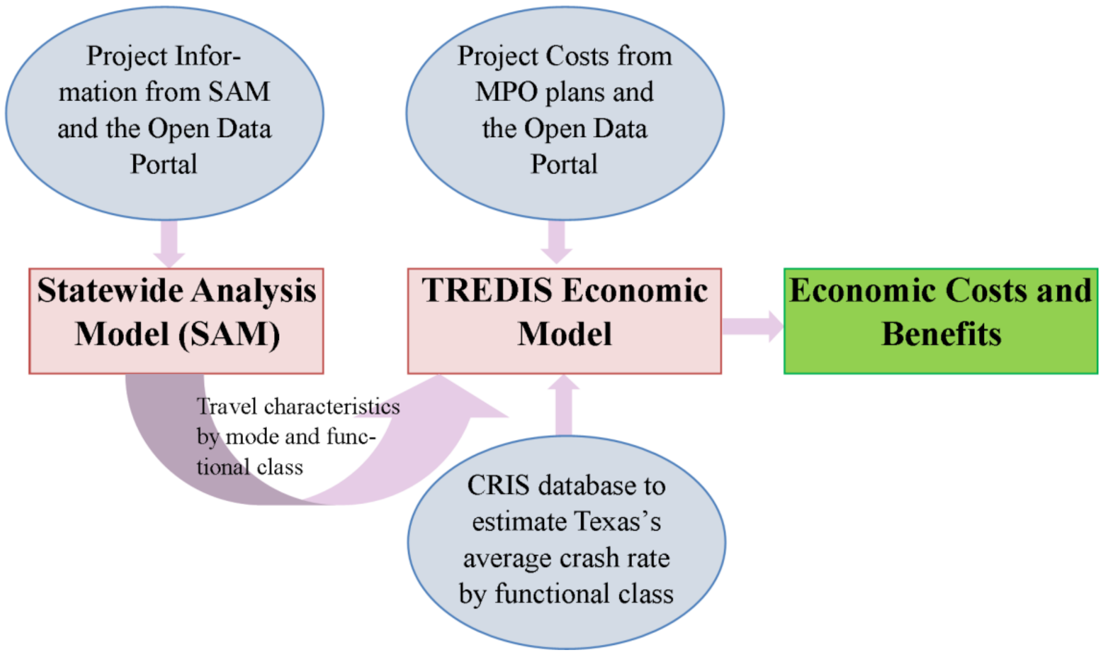
Chapter 2. Study Methodology and Modeling Tools

Having a consistent framework for evaluating the network-wide travel and economic impacts of planned or proposed freight corridor projects can facilitate better decision-making. The CTR team created an analysis framework based on modeling tools TxDOT is currently using and developed an automated data processing procedure to connect different components of the framework seamlessly.

2.1 Overall Analysis Framework

The overall analysis framework is illustrated in Figure 2.1.

Figure 2.1: Freight Corridor Projects Travel and Economic Impact Analysis Framework



The analysis process can be summarized in the following five steps:

1. *Collect projects' information*
   Projects understudy need to be implemented in the travel demand model to evaluate their potential network-wide impact on travel conditions. To model these projects, various types of information—including project location, year, extent (including project length and limits), type, and costs—need to be collected. Two major sources of the project information used in this study are SAM project database and TxDOT's Open Data Portal[5] (ODP). The study team also tested some speculative scenarios in which entire corridors were modified. In those cases, there are no specific projects to model, but rather minimum standards to which the corridor is adjusted in the SAM.

2. *Estimate network-wide travel impacts of studied projects using SAM*
   With project information collected in the previous step, the study team then models these projects by modifying the roadway network in SAM. For example, if a project proposes to widen a section of roadway from four lanes each direction to six lanes, the study team would update the roadway network in SAM to change the number of lanes for that section of roadway. For scenarios in which entire corridors are upgraded, the study team adjusts the network by finding all of the

[5] TxDOT Projects. Accessed at: http://gis-txdot.opendata.arcgis.com/datasets/txdot-projects

locations where the corridor is below the new minimum standards in the base case. Once all the projects under study are reflected in the network, the study team runs the SAM with the updated roadway network to estimate the statewide travel impacts of those projects.

3. *Extract travel characteristics data from SAM and process them to be input into TREDIS*
   Once SAM is done running, it generates a set of travel characteristics data. These data are extracted from SAM and processed to take the form of input data required by the economic analysis model. This includes, for example, grouping them by mode and trip purpose. Travel along centroid connectors has to be excluded for the analysis, and travel outside Texas has to be separated to generate local results. The CTR team created an automated data processing tool that can complete this procedure in minutes. For detailed safety and vehicle operating costs, the travel is further disaggregated by roadway functional class (FC).

4. *Estimate project costs and run the TREDIS model*
   Another important input data for running TREDIS are project costs. When project costs are available from the SAM project database or the ODP project list, they are used directly. Otherwise, the CTR team uses either the TxDOT Sketch Planning Tool[6] or project-specific information to estimate the project costs. This will be discussed in more detail in Section 2.4. With travel characteristics of the base case (i.e., without implementing those projects under study) and the scenario (i.e., with all the projects under study implemented to the roadway network), project costs, project duration, and analysis timeframe determined, the CTR team runs TREDIS to perform economic analysis. The CTR team also developed a procedure to conduct detailed safety and vehicle operation analysis in TREDIS, which can improve the accuracy of the analysis and better reflect Texas conditions. This procedure will be discussed in more details in Section 2.6.

5. *Examine and report analysis results*
   The last step is to examine the economic analysis results generated by TREDIS to see if they make sense and check for any anomalies. Finally, the analysis results, including the travel, environmental, social, and wider economic benefits, as well as the benefit-cost ratio of the set of projects under study, can be reported.

Productivity gains from improved access and connectivity are not modeled. The SAM does not perform calculations for the latent demand, meaning that trips are only shifted between modes or paths. Additionally, determining market access changes for a large state with multiple metropolitan areas receiving different changes to overall access in each scenario is not a situation TREDIS was designed to handle smoothly.

For all the scenarios presented in this report, the study team assumed the design and construction spending range from 2018 to 2040 and the changes in travel or operations and maintenance spending from 2018 to 2050. For scenarios without specific projects, such as scenarios that examine the upgrade of entire corridors, the costs are generally distributed over a ten-year construction period between 2020 and 2030. At the sacrifice of significant computation costs, it would be possible to create simulations with more complex timing rather than utilizing interpolation, such that the benefits of each project only accrue after that project is constructed. Attaining the maximum amount of detail with this method would require thirty-two separate SAM runs for each scenario, and thus this was not attempted.

[6] TxDOT Sketch Planning Tool. Accessed at: https://www.txdot.gov/apps/statewide_mapping/StatewidePlanningMap.html

2.2 Modeling Tools

As mentioned above, the two major modeling tools used in this study are SAM and TREDIS. The following sections will provide a brief description of these two models. Part I of this Freight IAC studied different modeling tools and decided that these two would be the most appropriate for this type of study. Interested readers should refer to that report[7] or to Samuel F. Higgins' Master's thesis[8] for more information about these tools and why they were chosen.

2.2.1 SAM

SAM is a travel demand model that incorporates the passenger and freight modes across the whole state. It was developed to serve as a statewide planning tool in addition to providing the more detailed models of the urban areas. It contains the basic four-step modeling process common to travel demand models, but it covers the entire state of Texas as well as Canada, Mexico, and the rest of the continental US in varying levels of detail as part of an integrated freight demand model.

The SAM was first developed in 2003 by Alliance Transportation Group (ATG). ATG has continued to develop this travel demand model with increasing sophistication and in 2013 released SAM-V3, the third main version of the model, which is the version used for this study. SAM-V3, herein referred to as SAM, contains a full statewide passenger car travel demand model that includes commuting, business trips, and a variety of personal trip modes. It also estimates intercity travel by car, bus, air, or rail. Also included is an integrated freight model that handles all modes: light/medium truck, heavy truck, rail, air, and water (although air and water freight trips are not assigned to a network after mode choice). Several minor changes have been made since SAM-V3's release—this report uses version 1.1.1 of SAM-V3.

2.2.2 TREDIS

TREDIS is a web-based economic impact and benefit-cost analysis tool for transportation projects and programs, with a module specifically designed for alternatives assessment. The system combines a highly detailed economic database with economic simulation and forecasting capabilities. It incorporates various databases and analytic modules by agreement with IMPLAN and Moody's Analytics and provides results via a flexible visualization module.

TREDIS is the only system that spans all modes of passenger and freight transportation, including highway, rail, marine and air travel, and all types of intermodal terminals and facilities. It is also highly detailed in its representation of both freight and passenger costs and benefits, including the value of improving transportation reliability, access, and system connectivity. In this study, the CTR team included the travel modes and purposes shown in Table 2.1.

[7] Both the part I and part II final reports of this IAC are available upon request from the TxDOT Freight and International Trade Section

[8] Estimating Economic Impacts from Transportation Investments Using the Texas Statewide Analysis Model and TREDIS. Accessed at: https://repositories.lib.utexas.edu/handle/2152/22297

Table 2.1 Travel Modes and Purposes Considered in This Study

Mode	Purpose
Passenger Car	Business
Passenger Car	Commute
Passenger Car	Personal
Light/Medium-Duty Truck	Freight
Tractor Trailer Truck	Freight
Freight Rail	Freight
Passenger Rail	Commute
All Aircraft	All

For readers that are interested in knowing more about how TREDIS conducts the benefit-cost analysis and how to interpret the benefit-cost analysis results presented in this report, Appendix A of this report provides a more detailed overview of TREDIS Benefit-Cost Analysis and Appendix B present the eighty-seven default parameters used for the analysis in TREDIS, highlighting the parameters relevant to trucking.

2.3 Automated Data Processing Tool

The study team created an automated data processing procedure that can take travel characteristics from SAM outputs and generate the input data required by TREDIS to perform an economic analysis. This procedure provides a range of outputs that can also be used for other types of analysis, and the automation shortens the time to process a scenario by an order of magnitude: the time required to process scenarios at the end of Part II of this Freight IAC was roughly six to eight hours, and those results can now be obtained in five to ten minutes.

This automated data processing tool was developed based on Microsoft Excel macros, Python code, and TransCAD GISDK code. Appendix C of this report provides step-by-step guidance on how to run this tool to obtain the input data required by TREDIS after running a scenario in the SAM.

2.4 Cost Estimation

Most of the projects found in the ODP have project construction costs. Cost estimates for many of the projects in the SAM project database were obtained in Part II of this Freight IAC. If no project cost estimates were available, the CTR study team used several approaches to estimate the construction costs:

- *Finding project construction cost information from MPO planning documents*
  For projects that are already planned, the CTR study team looked for relevant planning documents from that area's planning agency (e.g., metropolitan planning organization [MPO] or council of governments) to see if construction costs are available. This was the primary method used in Part II of this IAC and provides a consistent basis to obtain costs for projects added to the newer version of the SAM.

- *Estimating project construction costs using TxDOT's Sketch Planning Tool*
  When project costs were not available in any planning documents or projects were not planned yet, the CTR team used TxDOT's Sketch Planning Tool to estimate the construction costs. This tool calculates construction costs based on Project Type (New Roadway vs. Reconstruction), Area Type (Urban vs. Rural), Route Type (Freeway, Arterial or Collector), Configuration (Divided vs. Undivided), whether the roadway is frontage road, and the number of main lanes. If the

roadway is frontage, the tool automatically assumes two lanes per direction. As noted by TxDOT, this tool is for planning purposes only. It cannot model some of the specific projects that we need to analyze in this study. For example, building an entirely new divided roadway segment with two lanes in each direction will have different costs than converting an existing two-lane highway into a divided highway with two lanes in each direction. In those cases, the CTR team made some adjustments to the estimated costs based on the specific project description; such adjustments are described in the following bullet points.

- *Estimating project construction costs based on other existing similar projects*
  In cases where the construction costs of similar projects to those under study were available, the CTR team used the information of those existing projects to arrive at the estimate. For example, when estimating the construction costs of upgrading several rural corridors (i.e., US 87, US 69, US 59, and US 281) to the standard of a four-lane divided highway, data about construction costs of doing similar upgrades along US 59 provided by TxDOT were used to estimate the construction costs for the other three corridors. The study team made this process systematic by developing a unit cost matrix base on different project types as shown in Table 2.2.

Table 2.2 Roadway Upgrade Cost Estimation

Upgrade Type	Unit Cost (million/mile)
Upgrade from Rural Minor Arterial to Rural Interstate (FC 6 to 1)	$6.745
Upgrade from Rural Principal Arterial to Rural Interstate (FC 2 to 1)	$1.777
Upgrade from Urban Freeway & Expressway to Urban Interstate (FC 12 to 11)	$1.939
Upgrade from Other Urban Principal Arterial to Urban Interstate (FC 14 to 11)	$4.542

Developing accurate construction cost estimates can be difficult in some scenarios, but the estimation directly and significantly affects the scenario's final benefit-cost ratio. Therefore, when the study team looked at the benefit-cost analysis results, it double-checked that the benefits and the costs both reflect the modeling of the same projects. For example, if a project's cost estimates obtained from an MPO include some project aspects that can be modelled in the SAM (such as to improving capacity) and additional project aspects that cannot be modelled (such as geometric safety improvements or signal system changes), the costs in the economic model would include parts of the project that the benefits do not capture, and might be too high. This issue was addressed by estimating the cost of the part of the project that could be modeled (using the same cost estimation techniques used for projects with no prior cost estimates). Because of the separate sources of uncertainty for the benefits and the costs, the magnitude of the benefits generated by improvement projects, and not just the final benefit-cost ratio, is an important metric in evaluating scenarios.

When conducting economic analyses, the estimated construction costs were distributed evenly from 2018 to 2040. The operations and maintenance costs were calculated as 0.2215% of the cumulative construction cost. This rate was determined in part II of this IAC based on data from Florida DOT. Interested readers are referred to this IAC's Part II final report for how this rate was determined.

2.5 Project Simulation Modeling

SAM has internal methods to activate or deactivate projects contained within its own project database, making those projects the easiest to model. The simplest method to do this, and the one the CTR team employed, is to change the project's build year in the SAM Project Access Table. If a project's build year is within the simulation's timeframe (before 2040 for the part of the simulation run within the SAM), the project will be automatically turned on in the simulation. For scenario-projects with build years after 2040, the CTR team changed the build year to 2040 so that they will be active in the simulation.

Projects from the ODP need to be manually coded into the SAM roadway network to reflect the improvement brought about by those projects. This was done by overlaying the portal's GIS shapefile and modifying the corresponding links in the SAM network manually.

While modeling these projects, various challenges arose as the study team strove to ensure the simulated scenario reflected the real situation as best as possible. Some examples of these issues are discussed below.

- *SAM projects and ODP projects overlap but with different descriptions*
  Sometimes, projects from the SAM project database and the ODP project list propose to make improvements to the same segment of the roadway but with different types of improvements. In these cases, the CTR team compared the project descriptions and modified the network by comprehensively incorporating the two sources. For instance, if an ODP project would widen a segment to eight lanes while the SAM project database indicates widening the same segment to 10 lanes, the CTR team would modify the links along the segment to 10 lanes by 'turning on' the project in the SAM Access table. If the two sources propose non-conflicting modifications to the same segment, both modifications were simulated. For example, if the SAM Access table contains a road-widening project while the ODP contains a project for a new high-occupancy vehicle (HOV) lane or managed lane for the same segment, this segment was widened and a parallel HOV or managed lane was manually added into the SAM network. If an ODP project conflicts with a SAM project, for example, the SAM project expands the segment to eight lanes, but the ODP project expands the segment to 10 lanes (opposite of above), the study had to modify the links in the network manually to 10 lanes and then disable the SAM project so it would not be reduced to eight lanes in the simulation.

- *Some projects are hard to model directly*
  Some improvement projects cannot be modeled by simple modifications to the roadway network. For example, "intersection improvement" is a type of project often seen in the ODP project list without detailed project descriptions regarding how the intersection will be improved. SAM, as a statewide travel demand model, does not use a high enough resolution to model individual intersections. As a compromise, the CTR team increased the functional classes of the minor road of the intersection by one level to reflect the improved intersection performance. Appendix D of this report provides the list of functional classes used in SAM. For interchanges between two interstates, which are already both the highest possible functional class, there is no way within the existing travel demand model to simulate this type of project.

Table 2.3 provides some more examples of how different types of projects are modified in SAM. However, this is not meant to be an exhaustive list. In many cases, projects need to be modeled on a case-by-case basis to best reflect their intended impacts on the network.

Table 2.3 Modification Method for Different Types of Project

Project Type	Modification Method
Road Widening	Change the number of lanes
Adding New Management / HOV Lane	Add a parallel link with attributes to reflect a managed / HOV lane
Intersection Improvement	Increase the functional class of the minor road of the intersection by one level
Upgrade Roadway	Improve the roadway's functional classification
Changing to Divided Facility	Turn on the indicator for roadway division in the attributes
Setting Vehicle Type Separation	Define vehicle types allowed or prohibited along with specific links in the "exclusion set" field in the attributes

It is worth reiterating—because it is often an important aspect of these projects—that the framework and study approach proposed in this study do not consider induced demand. A highway expansion or upgrade can potentially attract more people to travel. This "induced demand" estimation is out of the scope of this study.

For each scenario, the simulation and travel characteristics of the following four cases were run and used for the economic analysis:

- **2018 Base/Project:** Travel characteristics for 2018 "base case" or "project" are obtained by first creating a 2018 roadway network. This network reflects the realistic roadway conditions in 2018 by implementing on the 2010 roadway network all the projects whose build years dated from before 2018. Then the team ran the SAM default 2010 and 2020 travel and demographic data on this 2018 network to get 2010 and 2020 travel characteristics. Finally, 2018 travel characteristics data were obtained by interpolating between the 2010 and 2020 travel characteristics. The study team assumed a constant exponential growth rate for this interpolation.
- **2040 Base:** The 2040 base network is the 2018 roadway network plus all the SAM projects with project years equal to or less than 2040 activated. Then, 2040 travel and demographic data were run on this 2040 base network to obtain 2040 base travel characteristics data.
- **2040 Project:** On top of the 2040 base network, the projects under study (either upgrading a corridor or implementing a set of projects) were implemented to reflect the impacts of these projects on the network. Then, 2040 travel and demographic data were run on this 2040 project network to obtain 2040 travel characteristics data.

The 2018 Base/Project and 2040 Base travel data are the same for all scenarios presented in this report.

2.6 Detailed Safety and Vehicle Operations Analysis

Most travel demand models are set up to be good at tracking congestion and changes in travel times, and SAM is no exception. The study team identified several benefits the original economic analysis did not capture from the types of projects being modeled. For example, in the normal analysis, all vehicle miles traveled (VMT) for a particular mode and trip purpose (e.g., personal automobile travel) are treated equally. The economic model uses the same vehicle operating cost factors and crash rates regardless of where a vehicle travels. In reality, some roads are safer and more efficient to drive on than others. This is why the study team developed what is heretofore referred to as the detailed analysis.

In the detailed analysis, travel is broken down one step further than the normal analysis. The normal analysis breaks travel down by mode and trip purpose. The detailed analysis further breaks travel down by the functional class of the roadway where the travel occurred. Higher functional class roadways tend to have fewer accidents (lower crash rates) and allow vehicles to move more efficiently (lower vehicle operating costs and fuel consumption rates).

Breaking travel down by this extra level allows detailed analysis to use customized rates for each functional class. The study team found crash rates for each functional class by analyzing Texas crash data from the Crash Record Information System (CRIS) database and estimated operational cost rates from vehicle performance data.

More information related to the details analysis, including crash rates and operating costs used for the analysis, can be found in Appendix E.

2.7 Developing a Common Base Case

To evaluate the travel and economic impact of a set of projects, their effects on the network-wide travel conditions are compared with a base case. This base case represents the roadway network without implementing those projects under consideration. To facilitate a fair comparison among different scenarios analyzed in this study, the CTR team developed a common 2018 base case. In this base case, the CTR team modified the SAM network to include all SAM and ODP projects with build years before 2018. In this way, the base case can best reflect the real network condition by 2018 and serves as a basis for comparison regarding the extent of different scenarios' impacts.

The CTR team interpolated the 2010 and 2020 travel forecasts[9] generated by SAM to obtain the travel characteristics data for 2018.

[9] The forecasting years included in the version of SAM used in this study are 2010, 2020, 2030, and 2040.

Chapter 3. Scenarios Analyzed

This chapter provides a detailed description of each scenario the CTR team has analyzed in this project. For each scenario, this report first presents some background information regarding why this scenario is of interest, then introduces what projects are modeled and how they are modeled, and concludes with the analysis results, final benefit-cost ratios, and major takeaways from the analysis results. The scenarios analyzed and their corresponding section numbers are listed in Table 3.1.

Table 3.1 Scenarios Analyzed and their Section Number in this report

Section Number	Scenario	Description	Benefit-Cost Ratio with 3% Discount Rate
3.1	I-2 Full Build Out	Upgrading I-2 to the minimum standard of a four-lane divided interstate highway.	45
3.2	I-69 Full Build Out	Upgrading I-69 to the minimum standard of a four-lane divided interstate highway.	8.5
3.3	I-27/Ports-to-Plains Full Build Out	Upgrading I-27/Ports-to-Plains corridor to the minimum standard of a four-lane divided interstate highway.	2.1
3.4	I-10 within Texas Triangle	Implementing all projects planned or proposed along the segment of I-10 within the Texas Triangle.	2.0
3.5	I-35 within Texas Triangle	Implementing all projects planned or proposed along the segment of I-35 within the Texas Triangle.	2.7
3.6	Interstate Expansion	Expanding all interstates to at least three lanes each direction versus expanding only the interstates within the Texas Triangle.	Expand all interstates: -0.2 Expand interstates within the Triangle: 2.1
3.7	Truck-only Lanes	Evaluating and comparing different types of truck-only lanes along the interstate highways connecting the Texas Triangle.	Full-exclusion: 2.8 Truck-choice lanes: 5.0 Extra general purpose (GP) lanes: 17.9
3.8	Truck Platooning[10]	Examining several hypothetical scenarios with different penetration rates of truck platooning along several corridors.	Conservative: 182 Neutral: 573 Optimistic: 1428
3.9	Clear Lanes Projects	Implementing a list of projects planned under the Clear Lanes congestion relief initiative.	0.6
3.10	Top Congested Locations	Implementing all the projects planned or proposed at the top 20 overall or top 25 trucking congested locations.	Top 20 overall: 5.2 Top 25 trucking: 4.8
3.12	Rural Corridors	Upgrading four key rural corridors within the Texas Highway Trunk System (US 87 from TX/NM State Line to I-10; US 69 from Beaumont to US 175; US 59 from Laredo to Houston; US 281 from San Antonio to I-20) to the minimum standard of a divided four-lane highway.	US 87: 2.9 US 69: 3.8 US 59: 11.3 US 281: 1.2
3.13	Improving I-35 and Upgrading US 281	Implementing all projects planned or proposed along the entire I-35 corridor, and upgrading US 281 to the minimum standard of a four-lane divided highway, focusing on the potential effects of this upgrade on relieving congestion on I-35.	Improving I-35 full corridor: 1.9 Improving I-35 combined with upgrading US 281: 0.004

[10] The benefit-cost ratio of these scenarios are extremely high because only nominal public costs are included in the economic analysis, as most of the investments are coming from the private sector.

3.1 I-2 Full Build Out

3.1.1 Overview

I-2 is a partially completed interstate highway running through the Lower Rio Grande Valley of South Texas. It begins at the intersection of US 83 and Business US 83 in Penitas and heads eastward before terminating at I-69E/US 77/US 83 in Harlingen. For its entire length, I-2 runs concurrently with US 83. The route serves McAllen, Pharr (I-69C), Donna, Weslaco, Mercedes, and Harlingen. Long-range plans may extend I-2 northwest along US 83 to Laredo.

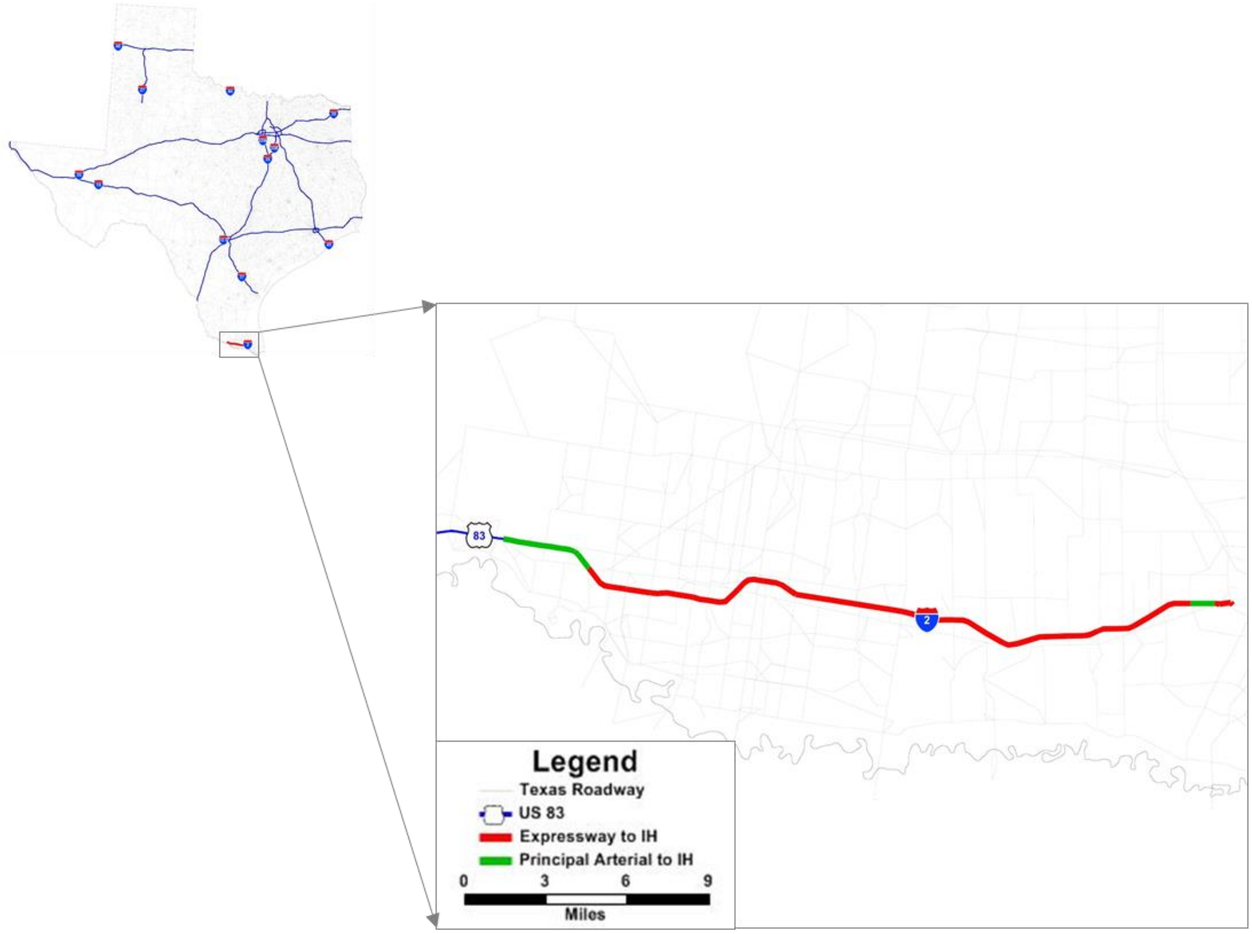
The TxDOT Freight Section was interested in seeing whether improving I-2 would provide cost-effective benefits to the overall travel conditions. After checking the SAM project database and ODP project list, the study team found that no project is currently planned or proposed along I-2. Therefore, the study team ran a scenario that upgrades the entire I-2 corridor to at least the four-lane divided interstate highway standard.

The analysis results indicate that with upgrading 40 miles of expressway and 7.25 miles of other urban principal arterials to the interstate standard, the travel time along the corridor itself would decrease by over 8%. The travel conditions across the statewide roadway network is also improved, with a 0.09% decrease of vehicle hours traveled (VHT) despite a 0.14% increase in VMT. The positive benefits in travel time and reliability improvement, safety improvement, and logistics cost savings outweigh the negative benefits in vehicle operating cost and emission cost, resulting in total benefits of over $2.7 billion and $1.2 billion, respectively, with 3% and 7% discount rates.

3.1.2 Scenario Description

The entire I-2 corridor is located within urban areas, with 40 miles classified as Urban Expressway and 7.25 miles as Other Urban Principal Arterial. To make the entire I-2 corridor meet the minimum standard of four-lane divided interstate highway, the study team upgraded the functional classes of the current I-2 from urban expressway or other urban principal arterial to interstate highway. the entire corridor already has at least four lanes, so lane addition is not necessary at any segment of this corridor. Figure 3.1 shows the location of the segments with the functional upgrades.

Figure 3.1: Extent of I-2 Study Area and Segments Requiring Modification



The cost of these modifications is estimated based on the unit costs the study team developed during the process of this study, as described in Table 2.2. The current facility to be upgraded consists of 40 miles of urban expressway and 7.25 miles of other urban principal arterial. As the entire corridor is to be upgraded to interstate standard, the length to be modified totals 47.25 miles, with an expected total cost of $110.6 million; the cost breakdown is as shown in Table 3.2.

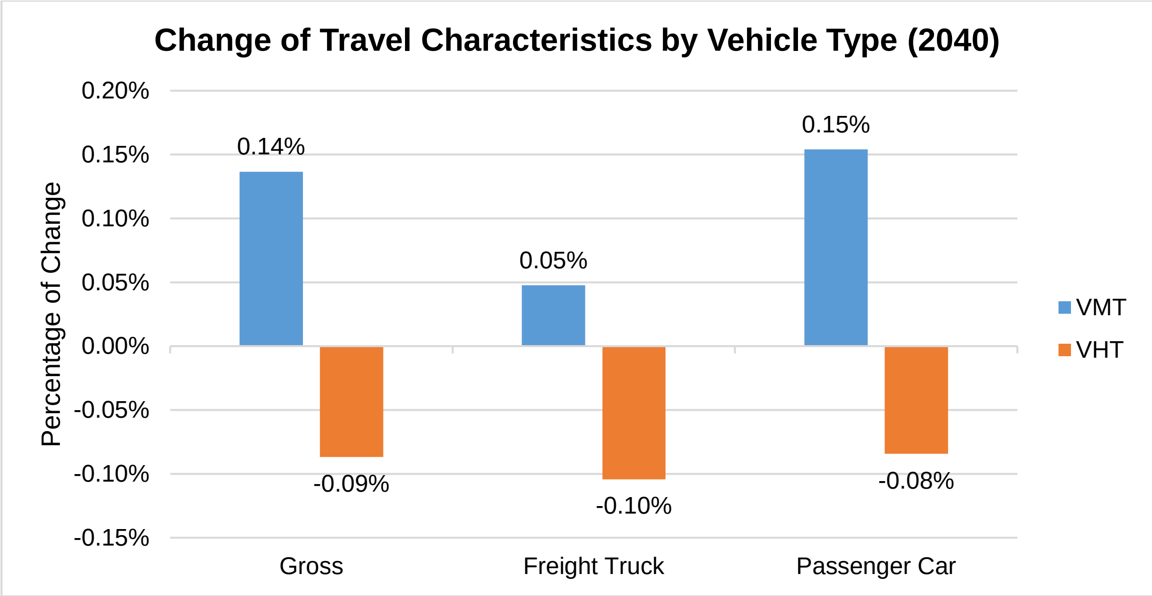
Table 3.2 Lengths and Estimated Costs by Type of Modification

Modification	Length (mile)	Unit Costs (million/mile)
Upgrade from Urban Expressway to Urban Interstate	40.0	$1.939
Upgrade from Urban Principal Arterial to Urban Interstate	7.25	$4.542
Total Costs ($M)	**110.6**	

3.1.3 Analysis Results

As a result of upgrading I-2 to a four-lane divided interstate standard, the overall system observes an 0.09% decrease in VHT despite a 0.14% increase in VMT in 2040, as shown in Figure 3.2. Both freight trucks and passenger cars experience a decrease in VHT despite increase in VMT. Freight trucks have higher than average reduction in VHT with a slight increase of VMT, while more passenger cars are traveling more miles with only a slightly improved congestion level.

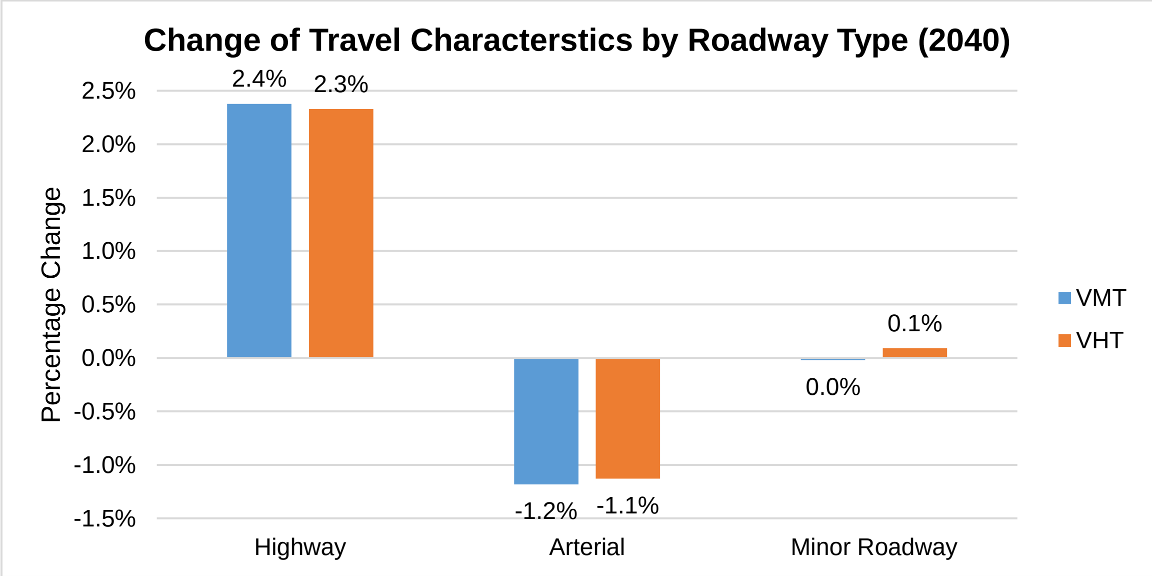
Figure 3.2: Change of Travel Characteristics by Vehicle Type for Upgrading I-2



In particular, the highways see a significant increase in both VMT and VHT, while arterials experience a slight decrease in VMT and VHT, as shown in Figure 3.3. This is as expected since the entire I-2 corridor was upgraded from lower functional class to interstate, which means a large portion of the overall VMT and VHT are moving from arterials to interstate highways.

The corridor of I-2 itself experiences an 8.2% increase in VMT and 1.8% in VHT. However, the average time to traverse the corridor decreases by 8.3%, from 58.6 minutes to 53.7 minutes. In other words, this upgrade not only improves the overall travel condition across the statewide roadway network but also the travel conditions along the I-2 corridor itself since it takes less time to traverse this corridor even though more vehicles are using it.

Figure 3.3: Change of Travel Characteristics by Facility Type for Upgrading I-2



According to TREDIS analysis, the changes in the transportation system due to upgrading I-2 as described in the previous section yield over $2.7 billion total benefits and increase gross regional product (GRP) by over $1.3 billion during the 32-year period from 2018 to 2050. The details of the benefits and costs are summarized in Table 3.3. The majority of the benefits come from the improvement of vehicle travel time and safety. A positive benefit is also observed in logistics/freight cost savings. These benefits are brought about by the slightly decreased network-wide VHT and the safety benefits of having a portion of VMT switch from lower functional class roadways to highways. However, vehicle operating costs and environmental costs both experience an increase due to the increased overall VMT. Overall, the positive benefits outweigh the negative benefits, resulting in total benefits over $2.7 billion with 3% discount rate. The final benefit-cost ratio is 45 and 26 respectively with 3% and 7% discount rate. These benefit-cost ratios are high partially due to relatively conservative estimation of the costs. A more realistic estimation of the construction costs may bring these ratios down but they are still expected to be well over one.

Table 3.3 Benefit-Cost Summary for Upgrading I-2

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**2,743**	**1,236**
	Value of Vehicle Operating Cost	-1,052	-526
	Value of Vehicle Travel Time	1,999	938
	Value of Improved Travel Time Reliability	307	85
	Value of Safety Improvement	1,281	635
	Value of Emission Reduction	-218	-105
	Value of Logistics & Supply Chain Cost Savings	425	208
Present Value of Cost Stream		**60**	**47**
	Capital Investment Costs	80	53
	Operation and Maintenance Costs	3	1
	Cost Adjustments	-22	-7
Net Benefit (Benefits - Costs)		**2,683**	**1,189**
Benefit-Cost Ratio (Benefits / Costs)		**45**	**26**

3.1.4 Conclusions

This scenario evaluated the travel and economic impacts of upgrading the I-2 corridor to the interstate highway standard, as no specific projects are identified from ODP or SAM to be implemented along this corridor.

The results indicate that this upgrade is very cost-effective. This upgrade would reduce total VHT by 0.09% despite a 0.14% increase in VMT over the entire network in 2040. This reduced VHT generates positive benefits in vehicle travel time and reliability, and the shift of a significant portion of VMT from lower functional class to highways after the upgrade brought about significant safety benefits. Even though the increased gross VMT increases costs in vehicle operation and environmental factors, the overall benefits are significantly higher than the costs.

3.2 I-69 Full Build Out

3.2.1 Overview

The I-69 system will extend through Texas, Louisiana, Arkansas, Mississippi, Tennessee, Kentucky, Indiana, and Michigan, providing a continuous new interstate corridor connecting Mexico, the United States, and Canada.

The I-69 system within Texas will eventually extend nearly 1,088 miles along the following highways:

- US 59 from I-30 in Texarkana to Laredo
- US 84 from the Louisiana border to US 59 in Timpson
- US 77 from US 59 in Victoria to Brownsville
- US 281 from US 59 in George West to I-2 in Pharr
- State Highway (SH) 44 from SH 358 in Corpus Christi to US 59 in Freer
- SH-550 (formerly Farm-to-Market Road [FM] 511) from I-69E to SH 48 at the Port of Brownsville

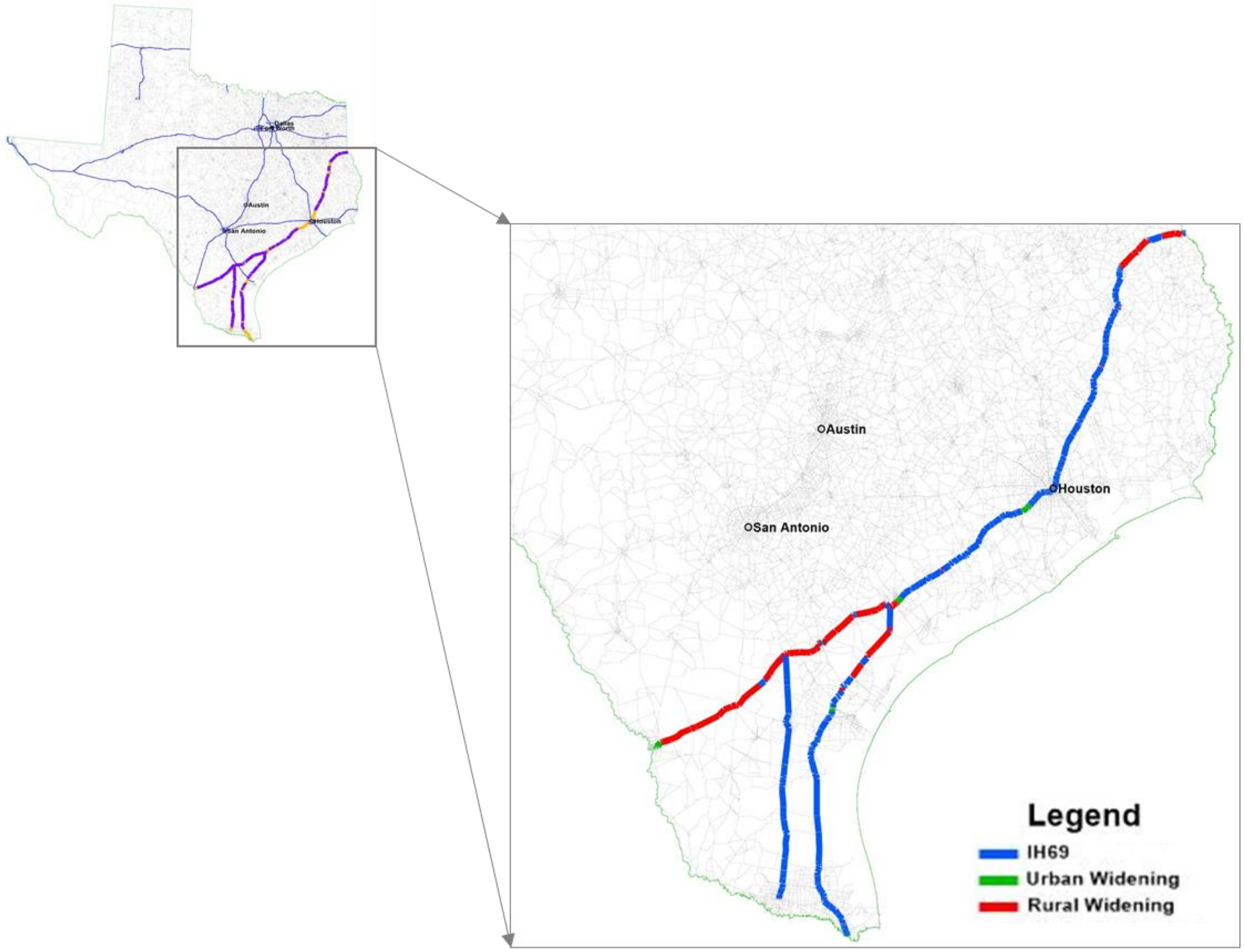
The I-69 system in Texas is being developed through a series of incremental upgrade and relief route projects to bring those highways up to interstate standards. To date, approximately 161 miles of the I-69 system in Texas have been designated as interstate. Almost 100 miles of the network of highways meet or are being constructed to meet interstate standards. Approximately 828 miles remain to be constructed to meet interstate standards.

In this study, the CTR team evaluated the travel and economic impacts of upgrading the entirety of I-69 to at least a four-lane divided highway with functional class equal to interstate highway. The analysis indicates that this upgrade would bring significant benefits in vehicle travel time and reliability, safety, and freight. The overall benefit-cost ratios are over 8 and 4, respectively, with 3% and 7% discount rate.

3.2.2 Scenario Description

The entire existing I-69 corridor (874.7 miles, out of which 159.3 miles are urban and 715.4 miles are rural) within Texas is upgraded to a four-lane divided interstate highway standard. A vast majority (866 miles) of the current corridor is not at the interstate standard in terms of the functional class listed in the SAM model and requires a functional class upgrade. In all, 259.7 miles of the corridor need to be widened from two lanes to four lanes. Figure 3.4 demonstrates the extent of the study areas and those segments that require functional class upgrade and/or widening.

Figure 3.4: Extent of I-69 Study Area and Segments Requiring Modifications



The cost of these modifications is estimated based on the unit costs the study team developed during the process of this study as described in Table 2.2 and the TxDOT Sketch Planning Tool. The detailed breakdown of modification types and costs are shown in Table 3.4.

Table 3.4 I-69 Upgrade Cost Estimation

Modification Type	Length (mile)	Unit Cost ($M/mile)
Upgrade from Rural Principal Arterial to Rural Interstate (FC 2 to 1)	865.98	1.777
Upgrade from Urban Freeway & Expressway to Urban Interstate (FC 12 to 11)	105.07	1.949
Upgrade from Other Urban Principal Arterial to Urban Interstate (FC 14 to 11)	52.57	4.541
Added Rural Lane-mile	241.68	2.50
Added Urban Lane-mile	18.05	5.464
Total Cost ($M)	**2683.8**	

3.2.3 Analysis Results

The simulation results indicate that upgrading I-69 to the interstate standard with at least four lanes divided increases the overall VMT by 0.72% and decreases the overall VHT by 0.06%, as shown in Figure 3.5. However, freight trucks will experience a significant reduction in VHT and a slight reduction of VMT. In contrast, passenger cars will experience a significant increase in VMT. As an important freight corridor connecting Mexico, the U.S., and Canada, the upgrade of this corridor does improve the travel conditions for freight trucks.

Figure 3.5: Change of Travel Characteristics by Vehicle Type for Upgrading I-69

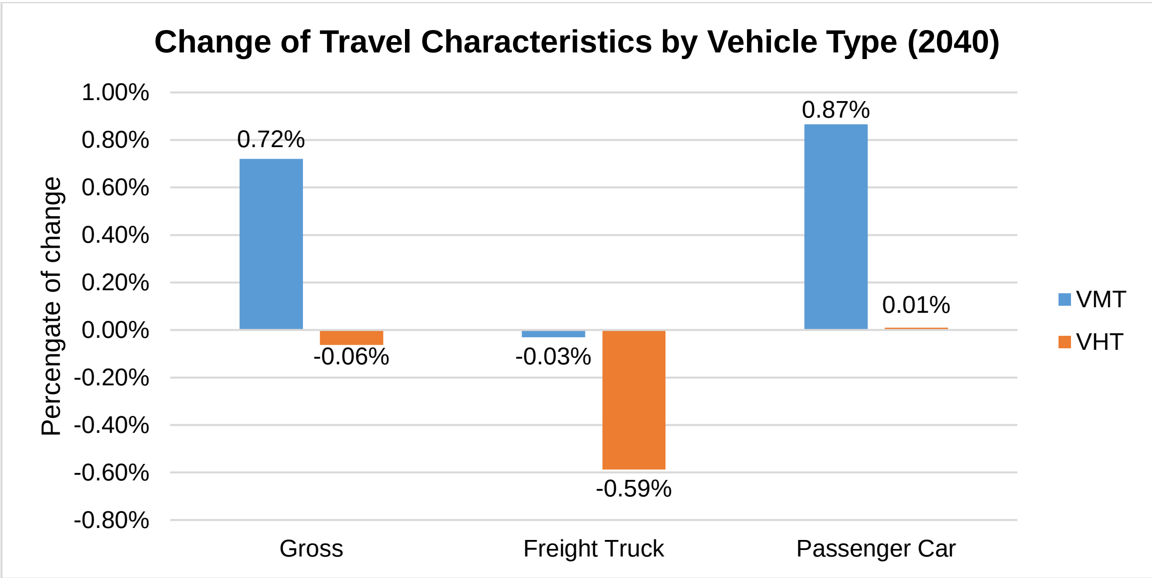
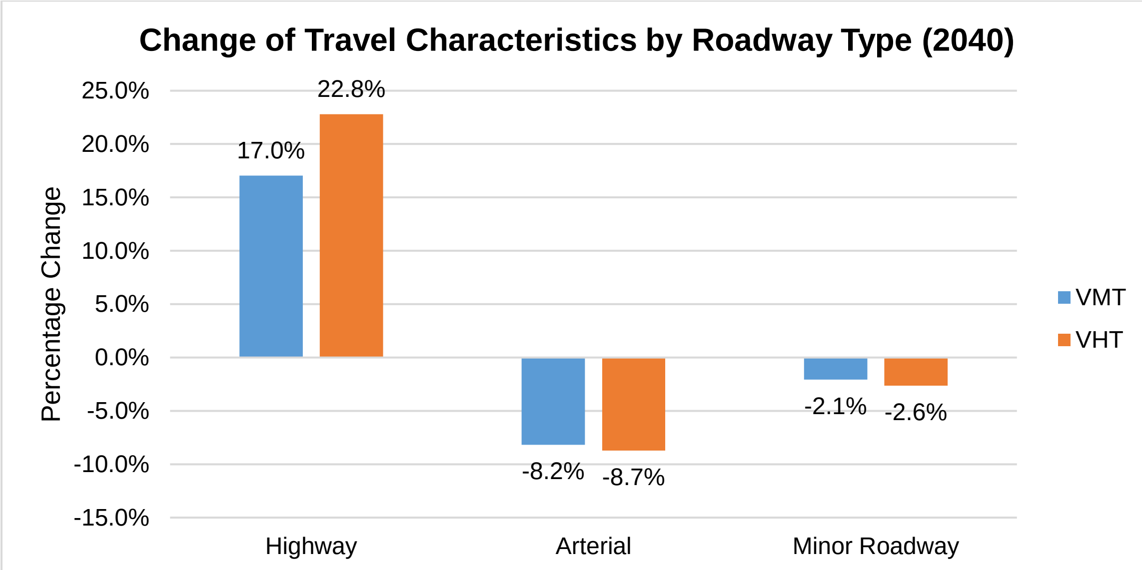


Figure 3.6 demonstrates that the highways experience a significant increase of both VMT and VHT while that on arterials and minor roadways decrease. This is mainly due to the traffic originally on I-69 not being counted as highway traffic since I-69 was not associated with the interstate highway functional class. After the functional class upgrade, a notable portion of the traffic originally on the lower functional class roadways moves to highways. This functional class (design standard) upgrade is expected to bring significant safety benefits.

Figure 3.6: Change of Travel Characteristics by Facility Type for Upgrading I-69



Besides the statewide travel impact of the I-69 upgrade demonstrated in the previous two figures, Table 3.5 lists the travel condition changes along the I-69 corridor itself. As shown in this table, the time required to traverse this corridor reduced by 18% after the upgrade even though both the gross VMT and the heavy truck VMT on this corridor increased significantly, indicating higher travel speed and more efficient freight flow along this corridor.

Table 3.5 Change of Travel Condition along I-69

	Base Case	After Upgrade	Percentage of Change
Traverse Time (hours)	22.4	18.3	-18%
Daily gross VMT	2.53E+09	3.31E+09	31%
Daily Heavy Truck VMT	1.85E+08	3.16E+08	71%

The summary of the benefits and costs of upgrading I-69 to the interstate standard with at least four lanes divided are shown in Table 3.6. The majority of the benefits come from vehicle travel time and reliability and safety improvement, as well as logistics/freight costs savings. This is mainly due to the significant reduction of VHT for freight trucks. The increase in gross and passenger car VMT causes negative benefits in vehicle operating costs and emission. However, the negative benefits are not comparable to the significant positive benefits. Overall, the I-69 upgrade would generate over $10 or $5 billion benefits with 3% or 7% discount rates, with a benefit-cost ratio more than 8 or 4, respectively.

Table 3.6 Benefit-Cost Summary for Upgrading I-69

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**10,524**	**5,526**
	Value of Vehicle Operating Cost	-2,531	-1,286
	Value of Vehicle Travel Time	2,977	1,524
	Value of Improved Travel Time Reliability	2,307	1,296
	Value of Safety Improvement	5,645	2,891
	Value of Emission Reduction	-292	-137
	Value of Logistics & Supply Chain Cost Savings	2,418	1,238
Present Value of Cost Stream		**1,244**	**1,279**
	Capital Investment Costs	1,525	1,349
	Operation and Maintenance Costs	60	35
	Cost Adjustments	-342	-105
Net Benefit (Benefits - Costs)		**9,281**	**4,247**
Benefit-Cost Ratio (Benefits / Costs)		**8.5**	**4.3**

3.2.4 Conclusions

Upgrading I-69 to the minimum four-lane divided interstate standard highway is very cost-effective. I-69 serves as an important freight corridor connecting Mexico, the U.S., and Canada. The upgrade would bring significant benefits in vehicle travel time and reliability, safety improvement and logistics/freight cost savings. Freight trucks benefit the most from this upgrade with a significant reduction of network-wide VHT. The overall benefit-cost ratios are over 8 with a 3% discount rate and over 4 with a 7% discount rate.

3.3 Ports-to-Plains Corridor (I-27) Full Build Out

3.3.1 Overview

The Ports-to-Plains Trade Corridor is a proposed divided highway corridor stretching from Laredo through West Texas to Denver, Colorado. The corridor was designated as a High Priority Corridor in 1998 and will facilitate the efficient transportation of goods and services from Mexico, through West Texas, Oklahoma, New Mexico, Colorado, and ultimately Canada and the Pacific Northwest.

The corridor is expected to:

- Improve safety
- Reduce congestion at ports of entry along the Texas-Mexico border
- Provide alternatives to other congested corridors that run through major metropolitan areas
- Help to increase trade between the U.S., Mexico, and Canada

This corridor serves as an important freight corridor carrying goods between Mexico and Canada. TxDOT has been considering bringing the entire corridor to the interstate standard. The CTR team evaluated the travel and economic impacts of upgrading this corridor to the four-lane divided interstate highway standard. The following sections describe the analysis procedure and results.

3.3.2 Scenario Description

The entire Ports-to-Plains corridor (943 miles), out of which 91 urban miles and 852 rural miles within Texas are upgraded to a four-lane divided interstate highway standard. Along the entire corridor, 251.9 miles of facility needs to be widened, while 815.9 miles needs functional class upgrade. The extent of the modification is shown in Figure 3.7.

The CTR team estimated the total construction costs based on the estimated unit costs presented in Table 2.2 and the TxDOT's Sketch Planning Tool. The detailed breakdown of costs by modification type is shown in Table 3.7.

Figure 3.7: Extent of Ports-to-Plains Corridor Study Area and Segments Requiring Modifications

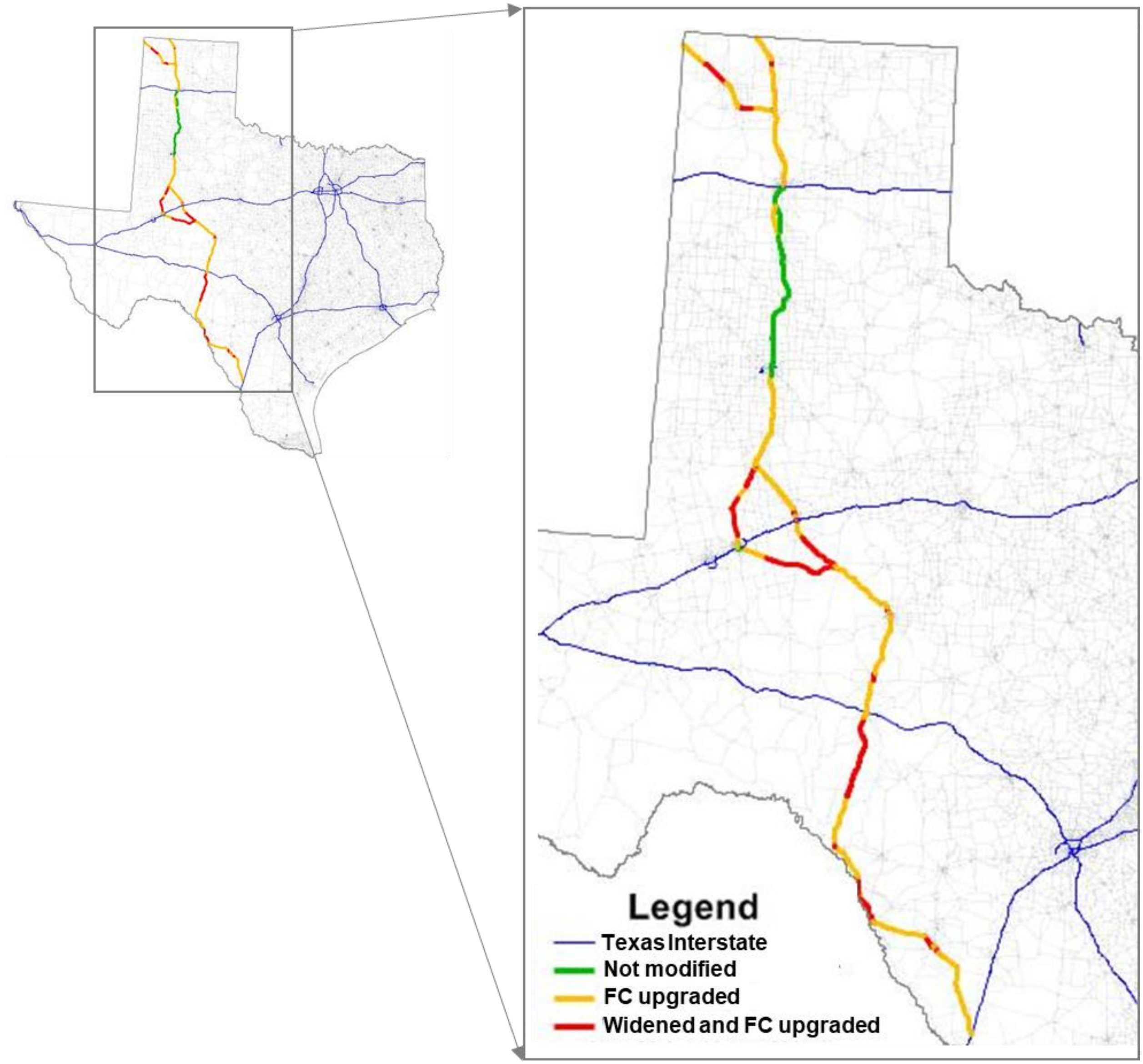


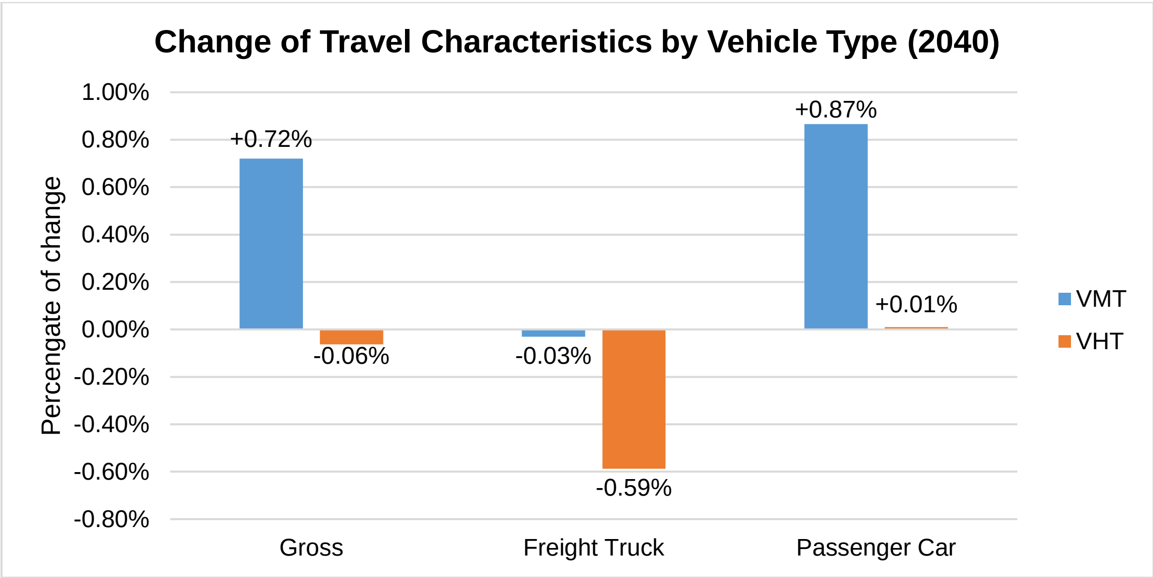
Table 3.7 Ports-to-Plains Corridor (I-27) Full Build Out Cost Estimation

	Length (mile)	Unit Cost ($M/mile)
Rural Upgrade (FC 2 to 1)	733.90	1.777
Rural Upgrade (FC 6 to 1)	23.67	6.745
Urban Upgrade (FC 12 to 11)	14.35	1.939
Urban Upgrade (FC 14 to 11)	44.00	4.542
Rural Lane-mile	481.77	2.50
Urban Lane-mile	22.02	5.464
Total Costs ($M)	**3016.2**	

3.3.3 Analysis Results

The simulation results indicate that after upgrading the Ports-to-Plains (I-27) corridor to a four-lane divided interstate highway, the gross VMT across the entire roadway network increases by 0.72% in 2040 (see Figure 3.8). Despite this increase of overall VMT, the system-wide VHT decreases slightly. Freight trucks benefit the most from this upgrade as they experience a slight decrease in VMT and a significant decrease in VHT. In comparison, passenger cars experience a significant increase in VMT and an almost unchanged VHT.

Figure 3.8: Change of Travel Characteristics by Vehicle Type for Upgrading I-27



The percent change of VMT and VHT by roadway types are demonstrated in Figure 3.9. As expected, after upgrading the I-27 corridor to the interstate highway standard, the overall VMT and VHT along highways increase while that along arterials and minor roadways decrease. Having more traffic using higher standard facilities would help to improve travel safety.

Figure 3.9: Change of Travel Characteristics by Facility Type for Upgrading I-27

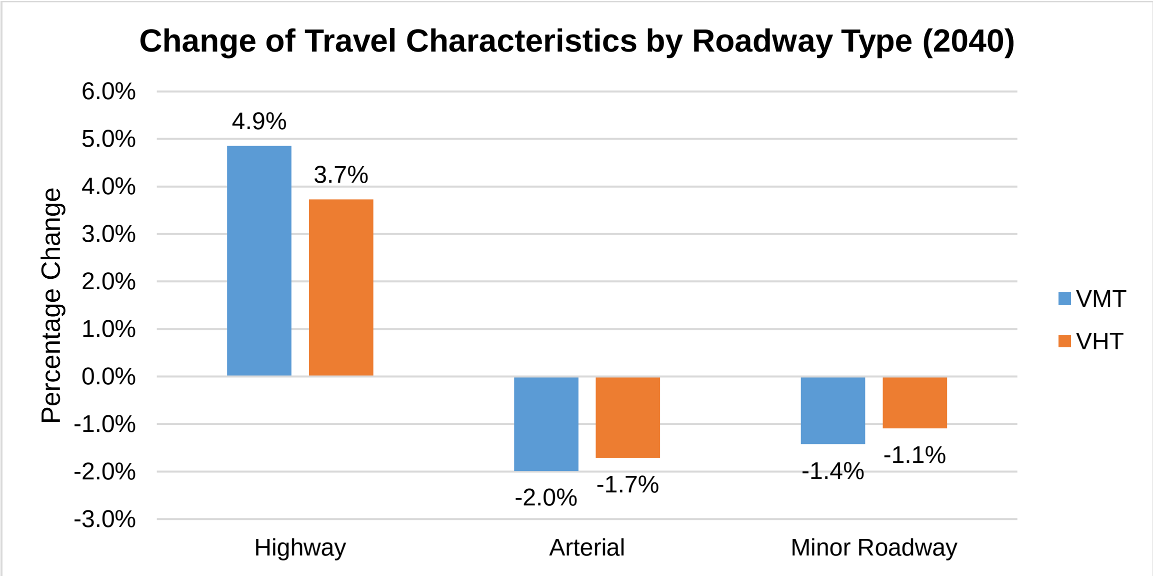


Table 3.8 provides the traverse time, daily gross VMT, and daily heavy truck VMT along I-27 itself before and after the upgrade. The time cost to traverse the entire corridor reduces by 21% despite an over 50% increase of VMT, indicating better travel conditions along this corridor. The upgrade also attracts over 1.5 times more heavy trucks to travel along this corridor, possibly due to the improved travel condition.

Table 3.8 Change of Travel Condition along I-27

	Base Case	Full build (Scenario)	Percentage of Change
Traverse Time (hour)	17.2	13.6	-21%
Daily gross VMT	1.15E+07	1.77E+07	54%
Daily Heavy Truck VMT	1.16E+06	3.13E+06	169%

According to TREDIS analysis results, upgrading the Ports-to-Plains (I-27) corridor to the four-lane divided interstate highway standard would increase GRP by over $12 billion in the period from 2018 to 2050. The details of the benefits and costs are summarized in Table 3.9. The decrease of the gross VHT (especially the significant decrease of freight truck VHT) generates notable benefits in terms of vehicle travel time, safety improvement, and logistics/freight cost savings. The increase in gross VMT causes some negative benefits in vehicle operating costs and emissions. However, these negative benefits are overshadowed by the positive benefits, considering the over $8.6 billion total benefits with a 3% discount rate. The net benefits are over $4 billion with a 3% discount rate and the final benefit-cost ratio of upgrading this corridor is 2.1 and 1.5, respectively, with 3% and 7% discount rates.

Table 3.9 Benefit-Cost Summary for Upgrading I-27

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**8,684**	**4,625**
	Value of Vehicle Operating Cost	-1,413	-467
	Value of Vehicle Travel Time	5,937	3,060
	Value of Improved Travel Time Reliability	807	324
	Value of Safety Improvement	2,205	1,079
	Value of Emission Reduction	-288	-86
	Value of Logistics & Supply Chain Cost Savings	1,437	716
Present Value of Cost Stream		**4,111**	**3,078**
	Capital Investment Costs	5,437	3,442
	Operation and Maintenance Costs	179	81
	Cost Adjustments	-1,505	-445
Net Benefit (Benefits - Costs)		**4,574**	**1,548**
Benefit-Cost Ratio (Benefits / Costs)		**2.1**	**1.5**

3.3.4 Conclusions

The Ports-to-Plains corridor (I-27) serves important agriculture and energy industries from Texas through the American Midwest. Bringing this corridor up to the interstate standard would provide much greater capacity for people and freight, and potentially siphon off some traffic loads from I-25 and I-35 by providing an alternate NAFTA corridor. It can also enhance safety due to access control, reduce travel time due to higher speed limits, and provide a new potential long-distance utility corridor.

Focusing on the travel and economic impact of this upgrade, the CTR simulated the effects of the upgrade in SAM and analyzed the economic benefits in TREDIS. According to the analysis results, this upgrade is cost-effective with a benefit-cost ratio of 2.1 and 1.5, respectively, with 3% and 7% discount rates. This upgrade brings over $4.1 billion net benefits to the state over the period of time from 2018 to 2050. The benefits stem from improved travel conditions for passenger and freight vehicles, as well as improved safety.

3.4 I-10 within the Texas Triangle

3.4.1 Overview

I-10 is one of the most important freight corridors in Texas and one of the three interstate highways connecting the Texas Triangle. Many projects are planned or proposed to improve the travel conditions along this corridor. To evaluate the travel and economic impacts of these projects, the study team conducted an analysis by implementing all planned or proposed projects along I-10 within the Texas Triangle identified from the SAM project database and ODP.

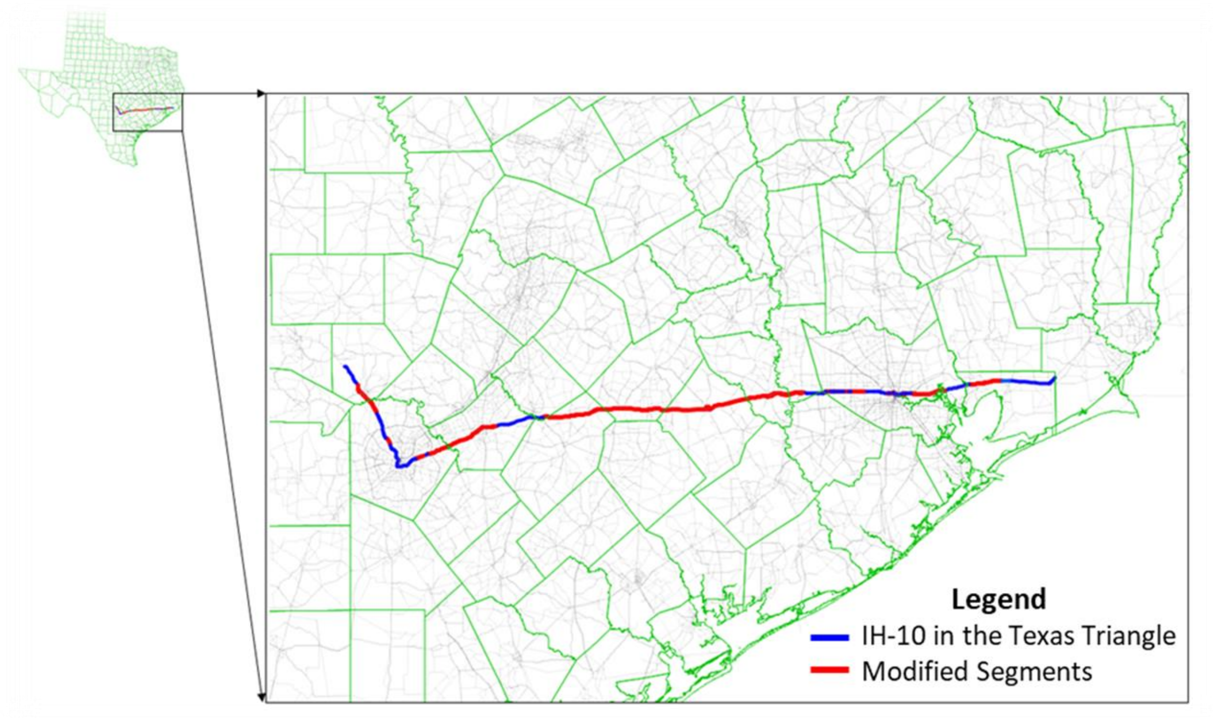
The results of this analysis show that these proposed projects would help improve the network-wide travel condition and bring about net benefits over $1.6 billion at a 3% discount rate or $0.68 billion at a 7% discount rate for a benefit-cost ratio of 2 or 1.8, respectively.

3.4.2 Scenario Description

The SAM project Access Database contains 22 projects along the corridor. Table F1 in Appendix F lists these projects, including their project ID, type, year, and modeling method. There are 11 projects along I-10 with project year after 2017 in the ODP. Table F2 in Appendix F lists the information for these ODP projects, including their control section job number, build year, project type, length, location, estimated construction cost, and modeling method.

Figure 3.10 identifies the section of I-10 considered for this scenario in blue, with the modified links in red.

Figure 3.10: Locations of Modified Links on I-10 within Texas Triangle



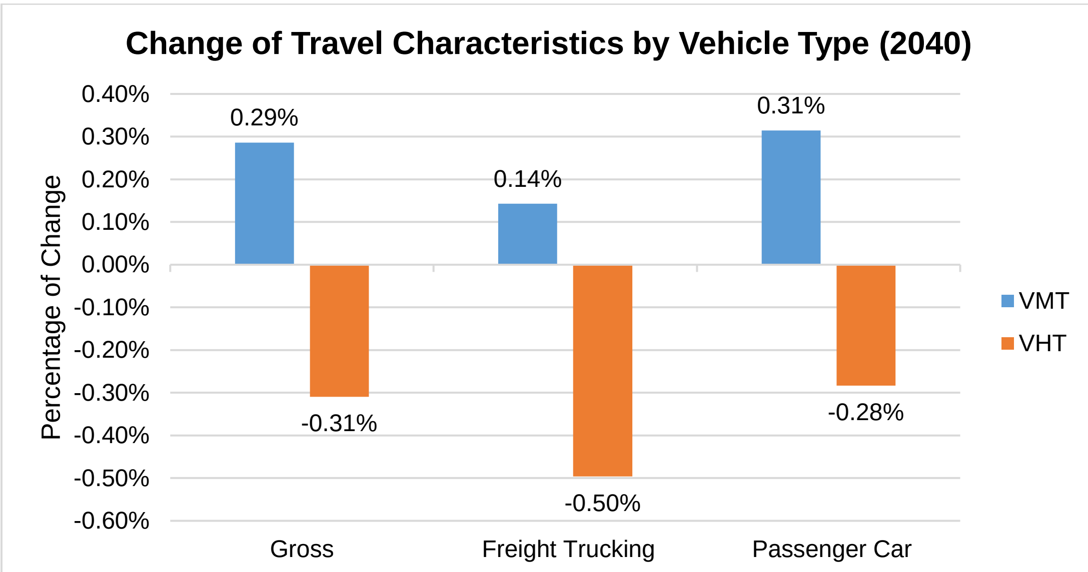
As mentioned before, projects from SAM and ODP can overlap with each other. In this scenario, after comparing descriptions and incorporating information from both sources, the study team “turned on” 20 SAM projects and manually modified the roadway network to reflect the implementation of one ODP project that proposes widening a segment from four lanes to eight lanes.

The SAM Access Database does not provide the costs of those projects listed in Table F1. The costs of these SAM projects are derived using the TxDOT’s Sketch Planning tool based on the link location (urban vs. rural), length, and the number of added lanes.

3.4.3 Analysis Results

The simulation results indicate that by implementing these projects along I-10 within the Texas Triangle, the network-wide VMT would increase by 0.29% and VHT would decrease by 0.31% in 2040 (see Figure 3.11), comparing the “Project” versus the “Base” (i.e., with or without implementing those identified projects, respectively).

Figure 3.11: Change of Travel Characteristics by Vehicle Type for Improving I-10 within the Triangle



This reduction in gross VHT means a significant reduction in congestion levels, which leads to an improvement in travel time and reliability. Freight trucking, in particular, benefits from these projects with an increase of only 0.14% in VMT but a decrease in VHT in excess of 0.5% in 2040. The changes in VHT and the improved reliability lead to total benefits of over $3.2 billion at a 3% discount rate as shown in Table 3.10.

Table 3.10 details the benefits and costs of these projects at 3% and 7% discount rates. The improvement in vehicle travel time and logistics cost saving brings about a majority of the benefits. The increase of VMT brought about some negative benefits in vehicle operating costs, safety, and emission costs. Overall, the positive benefits outweigh the negative benefits and the estimated construction and maintenance costs and renders a benefit-cost ratio of 2 with a 3% discount rate and 1.8 with a 7% discount rate.

Table 3.10 Benefit-Cost Summary for Improving I-10 within the Triangle

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**3,246**	**1,489**
	Value of Vehicle Operating Cost	-2,879	-1,365
	Value of Vehicle Travel Time	6,744	3,161
	Value of Improved Travel Time Reliability	682	309
	Value of Safety Improvement	-2,396	-1,139
	Value of Emission Reduction	-728	-328
	Value of Logistics & Supply Chain Cost Savings	1,824	852
Present Value of Cost Stream		**1,616**	**809**
	Capital Investment Costs	1,929	871
	Operation and Maintenance Costs	389	145
	Cost Adjustments	-701	-207
Net Benefit (Benefits - Costs)		**1,630**	**680**
Benefit-Cost Ratio (Benefits / Costs)		**2.0**	**1.8**

3.4.4 Conclusions

Based on the analysis, improving the I-10 corridor within the Texas Triangle would bring significant benefits to the state. These benefits primarily come from the improvement in travel time and reliability - a key element in passenger travel. These projects could also bring benefits in logistics and supply chain costs by reducing truck VHT. The overall benefit-cost ratio of these projects would be 2 at a 3% discount rate and 1.8 at a 7% discount rate, justifying the implementation of these projects.

3.5 I-35 within the Texas Triangle

3.5.1 Overview

The SAM Access database and ODP include a large number of freight-related projects to be built by 2040 on I-35 in the Texas Triangle. These projects could be crucial to the state economy, considering the role I-35 (especially the section within the Texas Triangle) plays in the Texas freight system and the severe congestion currently happening along this corridor. To evaluate the economic impacts of these projects, the CTR team conducted an analysis using the established SAM+TREDIS framework. This section presents the procedure and results of this analysis.

The analysis results show over $3.4 billion net benefits for the state at a 3% discount rate or over $1 billion net benefits at a 7% discount rate. These benefits lead to benefit-cost ratios of 2.7 and 1.7 respectively. The majority of the benefits stem from improved vehicle travel time and freight cost savings.

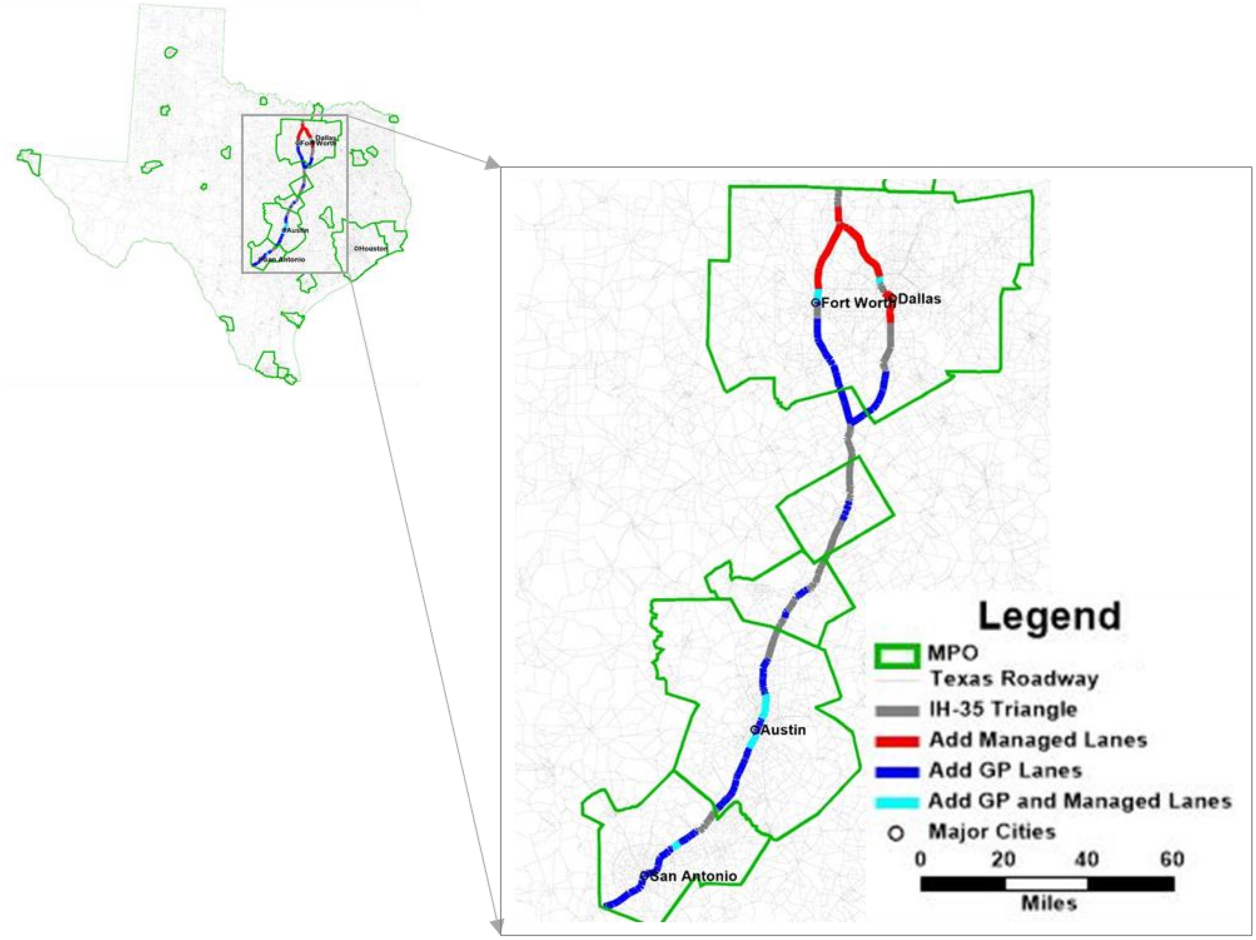
3.5.2 Scenario Description

Along I-35 within the Texas Triangle, the SAM Access database contains 88 projects, and the ODP contains an additional 35. Table G1 in Appendix G lists the 88 projects identified from the SAM project Access database. For each project, the table provides information such as project ID, project type, project year, and how the project is modeled in SAM. Table G2 in Appendix G shows the 35 projects identified from the ODP. Information provided in the table includes control section job number, project year, project type, project length, location information, estimated construction cost, and how it is modeled in the SAM network.

Of the 88 SAM projects along the corridor, 54 are already scheduled for implementation by 2040, meaning they are already included in the base case (projects with the year before 2018 are included in the 2018 base case and projects with the year 2040 and before are included in the 2040 base case). The project scenario simulates the full build-out of all SAM and ODP projects along the corridor, meaning that it includes the additional 34 SAM projects and the ODP projects. Most of the 35 ODP projects identified along I-35 in the Texas Triangle had equivalent SAM projects; only 4 required modification to the network.

Figure 3.12 shows the section of I-35 considered for this scenario, with the modified segments highlighted as indicated in the legend. Along the segment being analyzed, 220 miles of the corridor will have GP lanes added, 100.1 miles will have managed lanes added, while 30.4 miles will have both.

Figure 3.12: I-35 in the Texas Triangle with Modified Segments Highlighted



The project costs are estimated based on the construction cost estimation in either the SAM project Access file or the ODP project attribute table, depending on the source of the project.

3.5.3 Analysis Results

According to the results of the SAM simulation and economics analysis from TREDIS, the I-35 projects in the Texas Triangle would bring significant positive benefits, primarily through travel time savings.

The simulation shows an increase of gross VMT by 0.27% but a more significant decrease of VHT by 0.45%, as shown in Figure 3.13. Freight trucking experiences a lower-than-average reduction in VHT with a small increase of VMT, while passenger vehicles experience a higher reduction in VHT despite a higher-than-average increase in VMT.

Figure 3.13: Change of Travel Characteristics by Vehicle Type for Improving I-35 within the Triangle

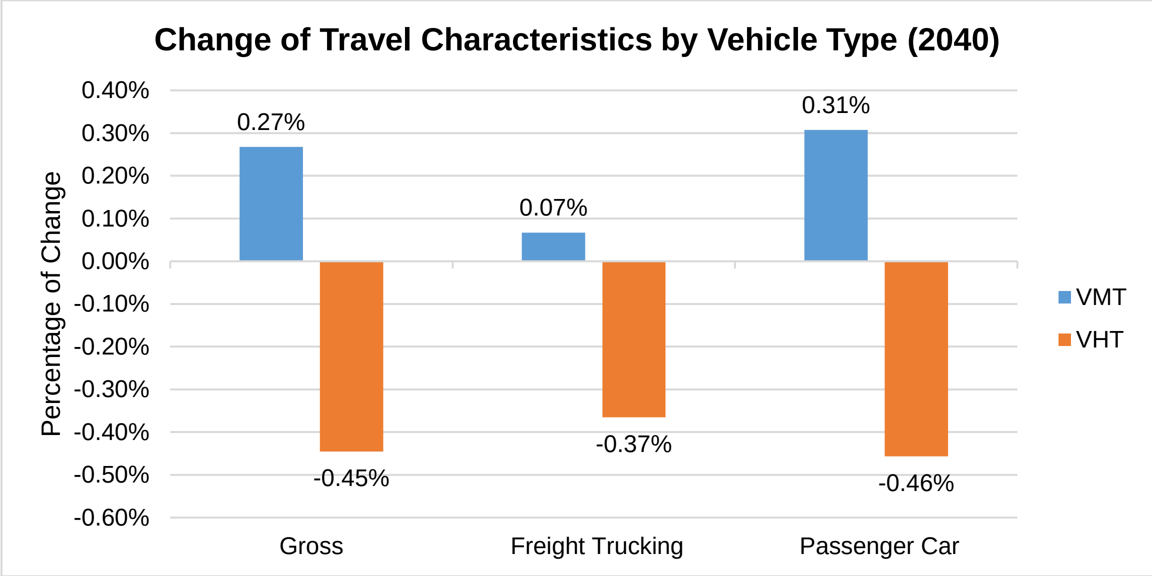


Table 3.11 provides more details of the benefits and costs with a 3% or 7% discount rate. As the table shows, those projects proposed/planned on I-35 within the Texas Triangle could yield significant benefits in travel time improvement and logistics/freight cost savings. Specifically, they generate over $10 billion of benefits in vehicle travel time and reliability and over $1.4 billion in freight cost savings at a 3% discount rate.

Overall, though some negative benefits are incurred in terms of vehicle operating costs and safety costs due to increased gross VMT, the projects in I-35 triangle area would generate net benefits of over $3.4 billion at a discount rate of 3% and over $1 billion at a discount rate of 7%, leading to benefit-cost ratios for this group of projects of 2.7 and 1.7 respectively.

Table 3.11 Benefit-Cost Overview for Improving I-35 within the Triangle

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**5,447**	**2,606**
	Value of Vehicle Operating Cost	-2,860	-1,411
	Value of Vehicle Travel Time	10,142	4,938
	Value of Improved Travel Time Reliability	924	435
	Value of Safety Improvement	-3,253	-1,606
	Value of Emission Reduction	-951	-451
	Value of Logistics & Supply Chain Cost Savings	1,446	702
Present Value of Cost Stream		**2,030**	**1,534**
	Capital Investment Costs	2,813	1,760
	Operation and Maintenance Costs	80	39
	Cost Adjustments	-864	-265
Net Benefit (Benefits - Costs)		**3,418**	**1,072**
Benefit-Cost Ratio (Benefits / Costs)		**2.7**	**1.7**

An analysis of the I-35 corridor within the SAM network shows that these projects do reduce total travel time along this corridor and attract more travelers to use it. Table 3.12 presents the net changes in travel time, average daily VMT, and daily heavy truck VMT along the I-35 corridor within the Texas Triangle. The result shows a 3.6% decrease in travel time, a 4.8% increase in total vehicle flow, and a 12.6% increase in heavy truck VMT. This indicates that the travel time saving of the modeled projects will attract more vehicles to use I-35, especially heavy trucks. Despite the increase in vehicular traffic, however, the simulation shows a reduction in travel time along the corridor.

Table 3.12 Change of Travel along I-35 within the Triangle

	Base Case	After Improvement	Percentage of Change
Travel Time (hour)	8.18	7.88	-3.6%
Daily gross VMT	57,385,344	60,160,901	4.8%
Daily Heavy Truck VMT	7,549,811	8,500,157	12.6%

3.5.4 Conclusions

Based on the SAM Access database and TxDOT's ODP, there are 88 SAM projects and 35 ODP projects proposed for I-35 within the Texas Triangle. After comparing the projects from those two sources, 34 SAM projects and 4 ODP projects are simulated within SAM (the other projects are either already included in the base case, or included in both sources and therefore are only modeled once).

According to the outputs of SAM simulation and economic analysis in TREDIS, the study team found that these projects would reduce travel times along I-35 within Texas Triangle and attract more traffic, especially heavy truck traffic to use this section of the corridor. However, the time required to traverse this section of the I-35 corridor reduces after the implementation of these projects. Besides the immediate benefits to the corridor itself, the network-wide travel condition improves as well. The net benefits of these projects are over $3.4 billion or $1 billion, leading to benefit-cost ratios of 2.7 or 1.7, respectively, with a 3% or 7% discount rate.

3.6 Interstate Expansion

3.6.1 Overview

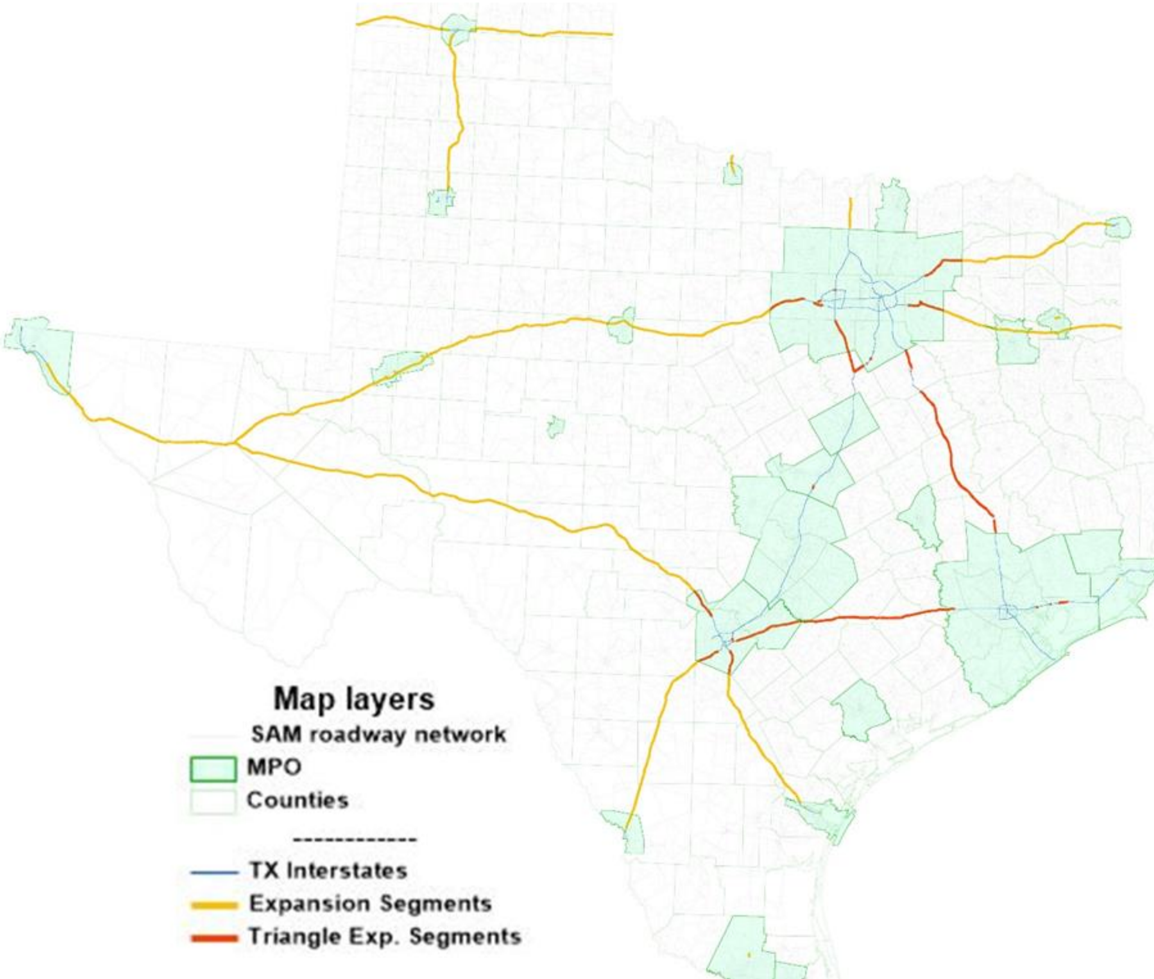
In Part II of this IAC, the CTR team analyzed what would happen if all interstates in Texas were expanded to a minimum of three lanes in each direction. Later, the TxDOT Freight Section requested the study team revisit this scenario, asking for a study specifically looking at expanding only those interstate segments within the Texas Triangle. Because several versions of SAM have been released since CTR simulated the original interstate expansion scenario and a new 2018 base case was created, the study team also re-ran the scenario of expanding all interstates, to create a consistent basis of comparison. The modeling process and analysis results of these two scenarios (i.e., expanding all interstates in Texas and expanding only interstate segments within the Texas Triangle) are described in the following sections.

The study results show that expanding only the interstate segments within the Texas Triangle leads to over $8 billion in overall benefits to the state economy, with a benefit-cost ratio of 2.1. This important finding demonstrates the importance of the Texas Triangle area to the state economy and validates the priority status in terms of receiving funding for highway improvements. Expanding all interstates across the state results in negative benefits because of increases in overall driving, indicating that expanding interstates in some rural areas outside the Texas Triangle would not be as good an investment.

3.6.2 Scenario Description

This scenario was originally driven by the question: “What would happen if all interstates in Texas had at least three lanes in each direction?” When the study team tested this scenario (expanding all interstates in Texas to at least three lanes in each direction) in part II of this IAC, the SAM model contained 2,222 miles of interstates that can be expanded. With the current version of SAM (version 1.0.9), this number changed to 2,173 miles. Only 490 miles of that amount lies within the Texas Triangle. Figure 3.14 shows the extent of the interstate expansion within and outside the Texas Triangle.

Figure 3.14: Interstate Expansion Segments within (red) and without (yellow) the Texas Triangle



3.6.3 Estimating Project Costs

The study team estimated the costs of expanding the interstates in the two scenarios using TxDOT's sketch planning tool. The tool indicates costs of $5.464 million per lane-mile for urban interstates and $2.500 million per lane-mile for rural interstates. This means a total cost of $13.7 billion for 4,412 lane miles of statewide expansion or $3.8 billion for 963.5 lane-miles of expansion within the triangle. For the economic analyses, these costs were distributed evenly from 2020 to 2030. Operations and maintenance costs were calculated the same way as all scenarios: 0.2215% of the cumulative capital cost.

3.6.4 Analysis Results

Expanding All Interstates in Texas

When the interstate expansion scenario was analyzed in Part II of the IAC, the resulting benefit-cost ratio was -1.94, primarily because the increased highway capacity led to more automotive travel. With the newer version of SAM and the updated methodology (see Section 2.6), this ratio improves but is still negative at -0.16.

As before, providing so many roadways results in a significant (1.2%) rise in gross VMT in 2040. This is the primary cause of the negative benefits. While the increased capacity does relieve some congestion and increase reliability, most of the expansion occurs in rural areas that already have excess capacity. Table 3.13 summarizes the benefits and costs of this scenario. The negative benefits in vehicle operating costs, safety, and emission are directly related to the increase in VMT.

Table 3.13 Benefit-Cost Summary of Expanding All Interstates in Texas

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**-1,653**	**-1,019**
	Value of Vehicle Operating Cost	-10,527	-5,205
	Value of Vehicle Travel Time	-146	-72
	Value of Improved Travel Time Reliability	7,363	3,412
	Value of Safety Improvement	-853	-421
	Value of Emission Reduction	-1,736	-825
	Value of Logistics & Supply Chain Cost Savings	4,246	2,093
Present Value of Cost Stream		**10,212**	**8,105**
	Capital Investment Costs	8,884	6,931
	Operation and Maintenance Costs	3,440	1,798
	Cost Adjustments	-2,112	-624
Net Benefit (Benefits - Costs)		**-11,865**	**-9,124**
Benefit-Cost Ratio (Benefits / Costs)		**-0.2**	**-0.1**

Expanding only within the Texas Triangle

Expanding only the interstates within the Texas Triangle results in largely positive benefits. Table 3.14 summarizes the results of the simulation. The overall benefit-cost ratio is 2.1, with most of the benefits accruing from improved travel times. There is a 0.1% rise in VMT, which leads to fairly minor negative benefits for vehicle operations and emissions. Those negatives are outweighed by a 0.4% drop in VHT, leading to notable savings in travel time and travel reliability. The value of travel time saved alone amounts to $5.4 billion, assuming a 3% discount rate, and improved reliability adds another $3.7 billion.

Table 3.14 Benefit-Cost Summary of Expanding Interstates within the Texas Triangle

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**8,169**	**3,889**
	Value of Vehicle Operating Cost	-2,793	-1,269
	Value of Vehicle Travel Time	5,409	2,572
	Value of Improved Travel Time Reliability	3,675	1,658
	Value of Safety Improvement	77	44
	Value of Emission Reduction	-476	-201
	Value of Logistics & Supply Chain Cost Savings	2,277	1,085
Present Value of Cost Stream		**3,906**	**3,130**
	Capital Investment Costs	3,414	2,663
	Operation and Maintenance Costs	1,304	707
	Cost Adjustments	-812	-240
Net Benefit (Benefits - Costs)		**4,263**	**759**
Benefit-Cost Ratio (Benefits / Costs)		**2.1**	**1.2**

3.6.5 Conclusions

The study results shown in Table 3.13 demonstrate that expanding all interstate highways in Texas to at least three lanes each direction is not cost-effective. Adding lanes to highway segments in areas that are not already congested cannot improve travel conditions significantly enough to merit the investment. However, Table 3.14 shows that expanding those interstate highway segments within the Texas Triangle would improve overall travel conditions and bring significant benefits (over $8 billion overall at the 3% discount rate) to the state. The benefit-cost ratio of expanding the Triangle interstate highway segments is about 2.1. This important finding clearly shows that the Texas Triangle is an area meriting high priority for highway improvement.

3.7 Truck-only Lanes

3.7.1 Overview

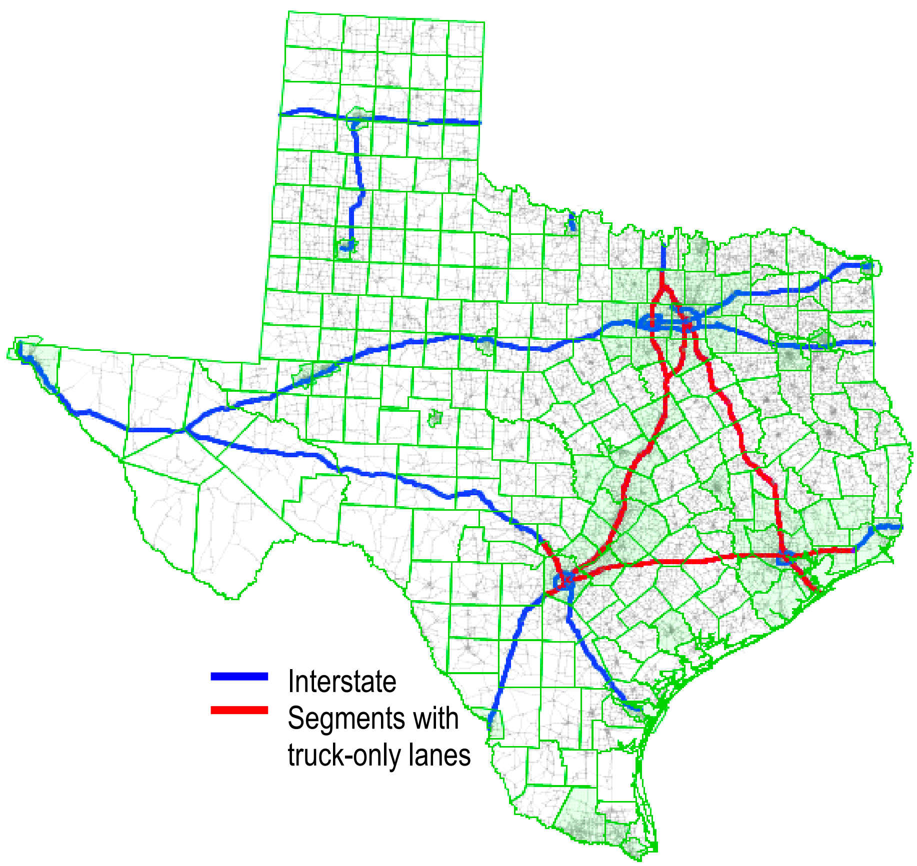
The concept of truck-only lanes includes temporal or spatial separation between heavy trucks and automobiles. Allowing modes to mix imposes constraints on driver behavior that forces each mode to operate outside of optimal conditions and complicates driving, which will impact safety. The simulations show substantial benefits from truck-only lanes, with total net-present value for the state exceeding $35.2 billion, and a benefit-to-cost ratio of 6.8 in the best case. Constructing truck-only lanes while allowing trucks to continue to use the existing facilities may prove a more functional option than creating fully separated facilities for trucks and automobiles.

This section summarizes simulations of truck-only lanes within the Texas Triangle on I-10, I-35, and I-45. There are multiple possible configurations for truck-only lanes, such as full exclusion, in which trucks and cars are fully segregated, or setting aside lanes for trucks only while still allowing trucks to use the GP lanes. In addition to these two situations, the study team modeled the addition of GP lanes for comparison and to parse the influence of the exclusion policy.

3.7.2 Scenario Description and Assumptions

Figure 3.15 shows the interstate segments where the truck-only lanes were modeled. As in other scenarios, MPO boundaries were used to delineate the Triangle (as established by the Alamo Area MPO, the Houston-Galveston Area Council, and the North Central Texas Council of Governments). The total length of the new facilities simulated is 1,024 miles or 2,048 lane-miles.

Figure 3.15: Extent of Modeled Truck-Only Lanes



To model the new facilities, separate links were created in the SAM model paralleling the existing interstate links. The truck-only lanes have the same number of connections to other links as to interstate links, meaning the simulations assume the truck-only lanes would be as accessible as the interstate system (i.e., they would have access to the same number of entry and exit ramps at roughly the same locations).

As stated earlier, the use of SAM precludes the estimation of latent demand. Because adding truck-only lanes without removing GP lanes represents a capacity increase, the simulation may overestimate the amount of congestion mitigation that would occur. In addition to normal travel benefits, such as reductions in travel time or reduced VMT, truck-only lanes provide separation between modes. Because there is a significant speed differential between trucks and automobiles, providing modal separation can result in substantial safety and efficiency benefits. These were captured by inputting travel along with the new facilities separately from other travel in the economic model. For safety, the simulations use the following assumptions:

- 20% reduction in crashes for automobiles traveling in lanes exclusive to automobiles
- 95% reduction in crashes for trucks traveling in truck-only lanes

These assumptions apply to any case where modal separation occurs in the simulations. For example, each simulation with truck-only facilities modifies the truck-crash factors to reflect that trucks would not have to contend with passenger vehicles.

In all, three simulations were used:

1) ***Full-exclusion*****:** Trucks must use the new truck-only lanes, and automobiles must use the existing facilities. This scenario would restrict trucks to a single lane, even though there are segments of the interstate system with enough trucking demand to warrant multiple lanes.

2) ***Truck-choice lanes*****:** Trucks may use the new truck-only lanes, but they may also use the existing GP lanes. Automobiles are restricted from using the truck-only lanes. This prevents some of the trucking bottlenecks that can occur from restricting trucks to a single lane but would still allow traffic to mix, reducing safety benefits.

3) ***Extra GP lanes*****:** For comparison, the same amount of extra lanes is constructed, but there is no restriction on use. These can be considered extra GP lanes.

3.7.3 Analysis Results

The extra GP lanes scenario performed better than either of the full-exclusion or the truck-choice lanes scenarios, but, as stated before, SAM is likely to overestimate the benefits from direct capacity expansions. Table 3.15 presents the estimated benefits of each scenario with a 3% discount rate. In these scenarios, both the full exclusion and truck-choice lanes scenarios likely understate the safety benefits. When trucks and passenger vehicles are separated, there will be fewer conflicts along the roadway, and the crash rates should fall. The benefits in Table 3.15 do not account for this phenomenon.

Table 3.15 Comparison of Estimated Benefits from Each Scenario

3% discount rate ($M)		Full Exclusion	Truck-choice Lanes	Extra GP Lanes
Present Value of Benefit Stream		**14,777**	**26,312**	**93,197**
	Value of Vehicle Operating Cost	4,809	6,183	15,139
	Value of Vehicle Travel Time	-10,625	-4,477	28,132
	Value of Improved Travel Time Reliability	17,625	13,399	30,598
	Value of Safety Improvement	7,116	9,054	15,398
	Value of Emission Reduction	1,354	205	2,618
	Value of Logistics & Supply Chain Cost Savings	-5,502	1,946	1,311
Present Value of Cost Stream			**5,217**	
	Capital Investment Costs		6,638	
	Operation and Maintenance Costs		244	
	Cost Adjustments		-1,666	
Net Benefit (Benefits - Costs)			**9,560**	
Benefit-Cost Ratio (Benefits / Costs)		**2.8**	**5.0**	**17.9**

3.7.4 A Note on Project Costs

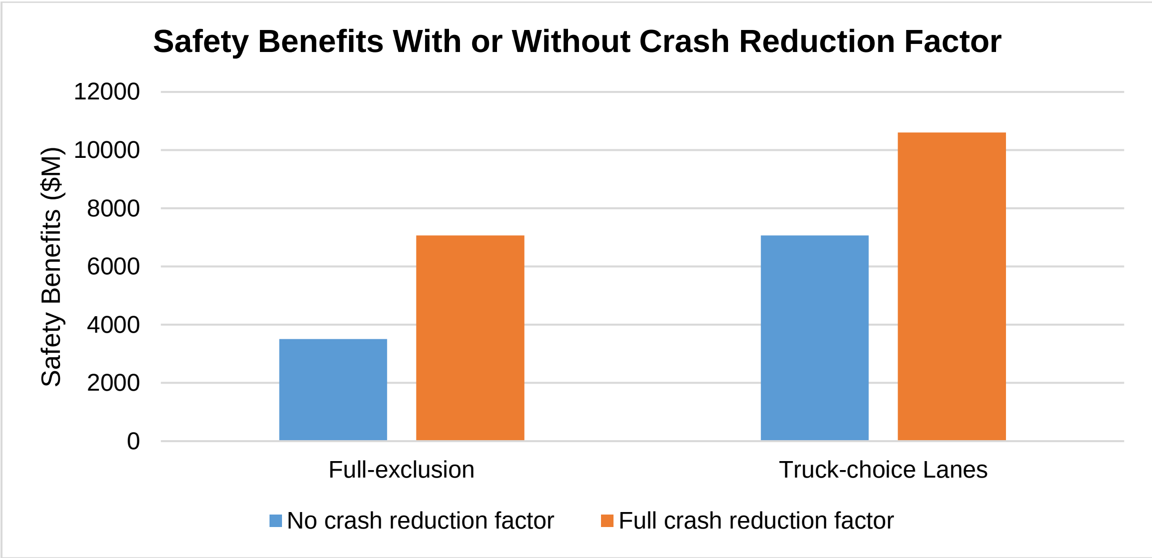
The economic analysis used a constant cost-per-lane-mile based on TxDOT's Sketch Planning Tool. The values used were $5.46 million per lane-mile in urban areas, and $2.50 million per lane-mile in rural areas. Along interstate segments where additional right-of-way acquisition will be necessary, or where grade separation may be required, the cost could be much higher. Additionally, the costs do not consider whether enforcing the truck-only or passenger-only restrictions would incur new operating costs. This is part of why the estimated benefits-to-costs ratios are so high.

3.7.5 Relaxing Assumptions: Sensitivity Analysis of Safety Benefits

Because very few truck-only lanes have been implemented, there is little certainty about the actual crash reduction that should be expected. The study team reran the economic analysis assuming no reductions in crashes. Even without a crash-reduction factor, the simulation results show that in both the full-exclusion and truck-choice lanes scenarios, the net safety effects would be positive.

When no crash-modification factor is included, the safety benefits primarily accrue from changes in travel characteristics, such as reduced VMT. Figure 3.16 shows the value of safety benefits for the two truck-only lane scenarios under either assumption, and gives a sense of how the benefits would vary as the assumed crash reduction factors change.

Figure 3.16: Safety Benefits With or Without the Assumed Crash Reduction Factors along Truck-only and Passenger-only Lanes



3.7.6 Conclusions

Although allowing trucks to use the GP lanes after constructing truck-only lanes would eliminate some of the benefits from separating modes, this approach would allow trucks more flexibility to continue using the interstate system even during congested periods. The model indicates that this flexibility could outweigh the benefits of modal separation. The simulations indicate that allowing trucks to continue using the existing facilities should thus be considered when evaluating truck-only lane alternatives, although there may be other considerations not captured by the simulations.

Both truck-only lane configurations tested performed very well, showing that the concept may be feasible in the Texas Triangle. Neither truck-only lane test performed as well as creating extra GP lanes. This could be caused by ignoring latent demand: latent demand would affect truck-only lanes less than adding GP lanes because truck-only lanes do not add as much capacity for automobiles.

Truck-only lanes warrant additional study. It may be possible to evaluate various financial schemes such as tolling along the truck lanes similar to managed lanes, as well as some of the economic impacts of incentivizing truck platoons along truck-only lanes.

3.8 Truck Platooning

3.8.1 Overview

Truck platooning has been tested or is being tested in various states, including Texas. The potential benefits of truck platooning include:

- Lower operator costs,
- Higher fuel efficiency,
- Less congested travel,
- Reduced emissions, and
- Enhanced safety.

From the policymakers' point of view, it is important to evaluate the long-term economic implication of allowing or encouraging more connected vehicles on our highways. This scenario aims to help answer this question by looking at the economic effects of truck platooning to the state of Texas.

3.8.2 Study Approach

Although the benefits of truck platooning within each of the aspects listed above have not been determined (and will change based on how the technology develops), this study performed the economic analysis by assuming three different levels of impacts of truck platooning to operator costs, fuel efficiency, congestion, and safety. The three levels represent conservative, neutral, and optimistic expectations of the impacts of truck platoons. The results of the analysis at these different levels provide a more comprehensive understanding of the potential benefits of truck platooning to the state of Texas.

3.8.3 Hypothetical Scenarios

The three hypothetical scenarios—conservative, neutral, and optimistic—are presented in this section. Table 3.16 lists the assumptions we made regarding the penetration rate and potential impacts of truck platooning in these three different scenarios.

Table 3.16 Assumptions of Penetration Rate and Potential Benefits of Truck Platoon

	Conservative	Neutral	Optimistic
Penetration rate	10%	30%	50%
Number of drivers	3	3	1
Reduction of vehicle operating cost ($/mile, free flow or congested)	5%	10%	15%
Reduction of average fuel consumption	5%	10%	15%
Safety improvement (crash reduction)	20%	40%	60%
VHT saving for passenger and other truck modes	No	1%	3%
Improvement in congestion affects both passenger car and truck modes (percentage of links experiencing a very low level of service)	2%	5%	10%

The market penetration of truck platooning is predicted to achieve 5.5% by 2025, growing to 22% in 2030 and about 30% in 2035[11]. Based on this information, as shown in Table 3.16, the study team assumed

[11] Platooning toward Sustainable Road Freight Transport. http://transport.sia-partners.com/20160712/platooning-toward-sustainable-road-freight-transport

that the percentage of tractor-trailers in platoons in 2040 will be 10%, 30%, and 50% respectively in the conservative, neutral, and optimistic scenarios. Individual platoons can vary in size from two trucks to several. To simplify the analysis, the study team assumes that all platoons will consist of three trucks.

In both the conservative and neutral scenarios, the study team assumed there will be a driver in each truck to take over control of the truck when necessary; in the optimistic scenario, the study team assumed only one driver is needed in the lead truck to monitor the operation of the three trucks while all three trucks are in the fully automated driving condition.

Due to the aerodynamic effects from closer vehicle spacing, the fuel consumption, and thus the vehicle operating cost, is expected to decrease. The fuel economy testing of a three-vehicle truck platooning system conducted in Canada yielded these findings: "For the range of test conditions examined, the net fuel savings for the full vehicle platoon was measured to be between 5.2% and 7.8%. The combined effect of platooning and aerodynamic trailer devices was measured to be up to 14.2% at the shortest separation distance of 17.4 m."[12] In this analysis, the study team assumed that, compared with regular tractor-trailers, on average, trucks in platoon could reduce the vehicle operating cost and fuel consumption by 5%, 10%, and 15% in the conservative, neutral, and optimistic scenarios respectively.

With innovations in automated vehicle safety technologies, trucks in platoons will have advanced safety systems that are expected to reduce the number of crashes significantly. It is estimated that a 70% reduction in accidents would be feasible if self-driving vehicles represent a considerable share of the car fleet.[13] The study team assumes that with future vehicle-to-vehicle and vehicle-to-infrastructure technology, by 2040, truck platooning can reduce the number of crashes by 20%, 40%, and 60% respectively in the conservative, neutral and optimistic scenarios.

With platooning, truck acceleration and deceleration are more consistent and following distances decrease. This improves the roadway's throughput, mobility, and efficiency, resulting in less congestion and shorter travel time for all travel modes. In this study, the study team assumed 1% and 3% VHT reductions for passenger and other truck modes (regular tractor-trailer and light/medium duty truck). No VHT reduction is assumed for these modes in the conservative scenario. The congestion is assumed to be improved by 2%, 5%, and 10% respectively in these three scenarios.

Except for those aspects discussed above and listed in Table 3.16, everything else is kept the same for regular tractor-trailers and trucks in platoon.

3.8.4 Cost Estimation

Truck platooning technologies are mainly developed by the private sector. The costs from the public section in terms of supporting the implementation of truck platooning is mainly preparing the roadway network and the driving public by setting up proper signs and roadway markers. Generating an accurate estimation of the costs that TxDOT may need to spend to implement truck platooning is difficult at this hypothetical study stage, so the CTR team performed a rough estimation of the nominal public expenditure required to implement truck platooning based on current TxDOT's "signs" and "markers" project costs.

The CTR team collected information from 50 "signs" projects and 152 "pavement makers" projects from the ODP. Unit construction costs of "signs" and "markers" projects are calculated based on these projects. To calculate the total costs, the CTR team assumed the total length of the corridors that will be implementing truck platooning is equal to the total length of Candidate Corridors for Truck Platooning

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[12] Fuel Economy Testing of a Three-Vehicle Truck Platooning System. https://www.tc.gc.ca/eng/programs/fuel-economy-testing-three-vehicle-truck-platooning-system.html

[13] Future Mobility Solutions: What Will Tomorrow Bring? http://www.acea.be/news/article/future-mobility-solutions-what-will-tomorrow-bring

identified by the Texas A&M Transportation Institute (TTI) in TxDOT research project 0-6836 “Commercial Truck Platooning—Level 2 Automation[14]”.

3.8.5 Analysis Results

To conduct the economic analysis, the CTR team assumed truck platooning would be implemented on those corridors identified by TTI in project 0-6836. The average annual daily traffic, truck percentage, corridor length, and speed limit along those corridors were used to calculate the base year annual number of truck trips as well as annual truck VMT and VHT. The 2040 truck trips along these corridors were assumed to increase at the same proportion as the statewide truck trips. Then the study team assumed that respectively 10%, 30%, and 50% of these truck trips will be in three-truck platooning in the three hypothetical scenarios by 2040. These travel data along with the estimated nominal costs were input into the TREDIS for economic analysis[15].

The economic benefit analysis results of the three scenarios are provided in the following sections. Table 3.17 shows the total benefits and the benefit-cost ratio of the three scenarios with 3% and 7% discount rates. As we can see from Table 3.17, even in the conservative scenario, if 10% of tractor-trailers along those truck platooning candidate corridors are in three-truck platoons, the total benefits brought about by truck platooning could exceed $10 billion or $5 billion with 3% and 7% discount rates respectively. In the more neutral scenario, the total benefits are more than 33 billion and 17 billion respectively with 3% and 7% discount rates.

Table 3.17 Total Benefits and Benefit-Cost Ratio of Three Hypothetical Scenarios

Discount Rate	Scenarios	Total Benefits ($M)	Benefit-Cost Ratio
3%	Conservative	$10,665	182
	Neutral	$33,656	573
	Optimistic	$83,835	1,428
7%	Conservative	$5,542	130
	Neutral	$17,133	401
	Optimistic	$41,984	983

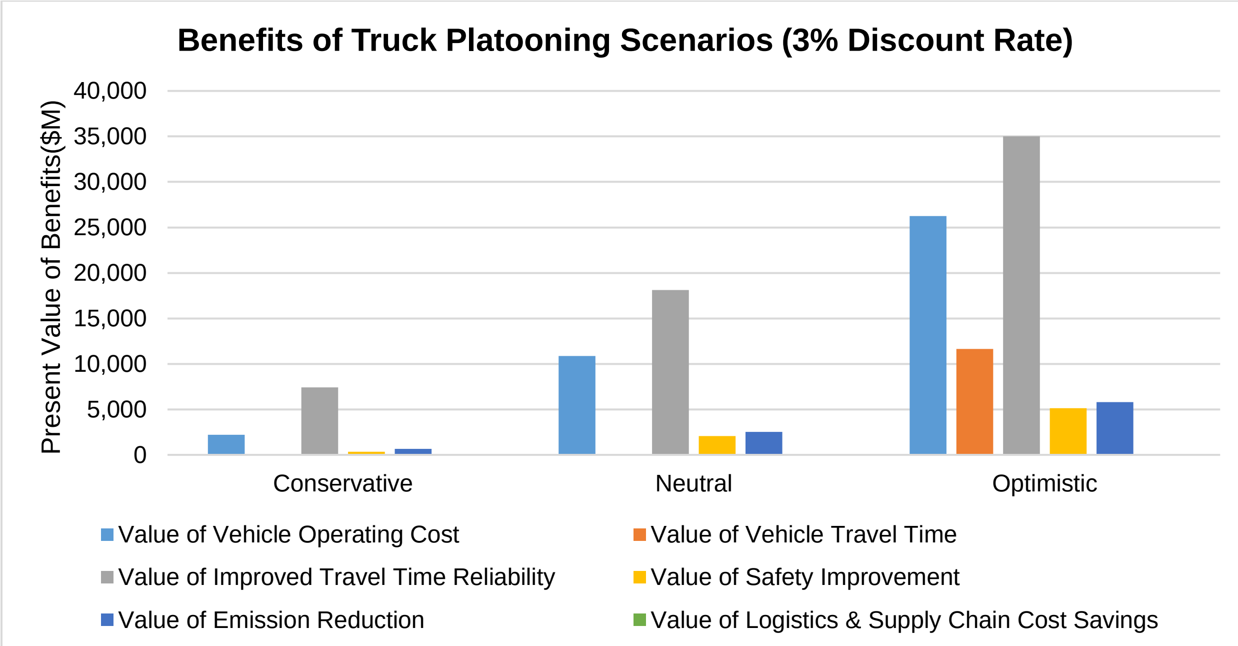
Figure 3.17 breaks down the total benefits by category for the three scenarios. The benefits in terms of vehicle travel time increase significantly in the optimistic scenario, primarily due to the higher percentage of VHT savings and congestion improvement assumed for this scenario. Savings from vehicle operating costs and travel time reliability improvement are the major contributor to the overall benefits.

More detailed results are discussed below for each scenario individually.

[14] Accessed at https://static.tti.tamu.edu/tti.tamu.edu/documents/0-6836-1.pdf

[15] Unlike all the other scenarios documented in the report, the Truck Platooning scenario used 2020 as the base case instead of 2018.

Figure 3.17: Benefits Summary of Three Truck Platooning Scenarios



a) The Conservative Scenario

Truck platoon results reduced number of trips, total VMT and VHT. These changes in the transportation system yield benefits of $1,113 million in 2050. Such changes are expected to increase the GRP of Texas by over $5 billion in the 30-year period from 2020 to 2050. The top industries that will benefit from truck platooning in this scenario in 2050 are manufacturing, agriculture and mining, business, finance, and wholesale. Table 3.18 shows an overview of all categories of benefits with both 3% and 7% discount rates. The majority of the benefits are travel benefits, such as vehicle operating costs, travel time and reliability.

Table 3.18 Benefit-Cost Summary for the Truck Platooning Conservative Scenario

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**10,665**	**5,542**
	Value of Vehicle Operating Cost	2,206	1,091
	Value of Vehicle Travel Time	22	29
	Value of Improved Travel Time Reliability	7,429	3,929
	Value of Safety Improvement	342	162
	Value of Emission Reduction	666	332
	Value of Logistics & Supply Chain Cost Savings	0	0
Present Value of Cost Stream		**59**	**43**
	Capital Investment Costs	63	43
	Operation and Maintenance Costs	4	2
	Cost Adjustments	-9	-3
Net Benefit (Benefits - Costs)		**10,606**	**5,499**
Benefit-Cost Ratio (Benefits / Costs)		**182**	**130**

b) The Neutral Scenario

In this scenario, the changes in transportation are expected to increase the GRP of Texas by over $17 billion in the 32-period from 2020 to 2050. The top four industries that will benefit from truck platooning in 2050 in the neutral scenario are still manufacturing, agriculture and mining, business, and finance. A detailed overview of all categories of benefits with both 3% and 7% discount rates are shown in Table 3.19. Truck platooning in this scenario would generate over $33 billion total benefits to the state economy, with vehicle operating cost savings and travel time reliability improvement being the majority of this benefit.

Table 3.19 Benefit-Cost Summary for the Truck Platooning Neutral Scenario

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**33,656**	**17,133**
	Value of Vehicle Operating Cost	10,864	5,257
	Value of Vehicle Travel Time	66	86
	Value of Improved Travel Time Reliability	18,134	9,594
	Value of Safety Improvement	2,052	972
	Value of Emission Reduction	2,540	1,224
	Value of Logistics & Supply Chain Cost Savings	0	0
Present Value of Cost Stream		**59**	**43**
	Capital Investment Costs	63	43
	Operation and Maintenance Costs	4	2
	Cost Adjustments	-9	-3
Net Benefit (Benefits - Costs)		**33,598**	**17,090**
Benefit-Cost Ratio (Benefits / Costs)		**573**	**401**

c) The Optimistic Scenario

In this scenario, the changes in the transportation system yield benefits of $9,618 million in 2050. The changes in the transportation system are also expected to increase the GRP of Texas by $2,812 million and create 16,124 jobs in 2050. The top five industries that will gain benefits from truck platooning in this neutral scenario are still manufacture, agriculture and mining, business, finance, and wholesale. A detailed overview of all categories of benefits with both 3% and 7% discount rates are shown in Table 3.20.

Table 3.20 Benefit-Cost Summary for the Truck Platooning Optimistic Scenario

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**83,835**	**41,984**
	Value of Vehicle Operating Cost	26,262	12,660
	Value of Vehicle Travel Time	11,628	5,599
	Value of Improved Travel Time Reliability	34,999	18,517
	Value of Safety Improvement	5,129	2,429
	Value of Emission Reduction	5,817	2,779
	Value of Logistics & Supply Chain Cost Savings	0	0
Present Value of Cost Stream		**59**	**43**
	Capital Investment Costs	63	43
	Operation and Maintenance Costs	4	2
	Cost Adjustments	-9	-3
Net Benefit (Benefits - Costs)		**83,777**	**41,941**
Benefit-Cost Ratio (Benefits / Costs)		**1,428**	**983**

3.8.6 Summary

This study analyzed the economic impacts of truck platooning by assuming different adoption rates and different levels of benefits. Three hypothetical scenarios are studied, representing a relatively conservative case, a more neutral case, and an optimistic case. The analysis results demonstrate that truck platooning could yield significant overall benefits even in the most conservative scenario. The majority of the benefits come from savings in vehicle operating costs, travel time reliability, and safety improvement.

3.9 Texas Clear Lanes Projects

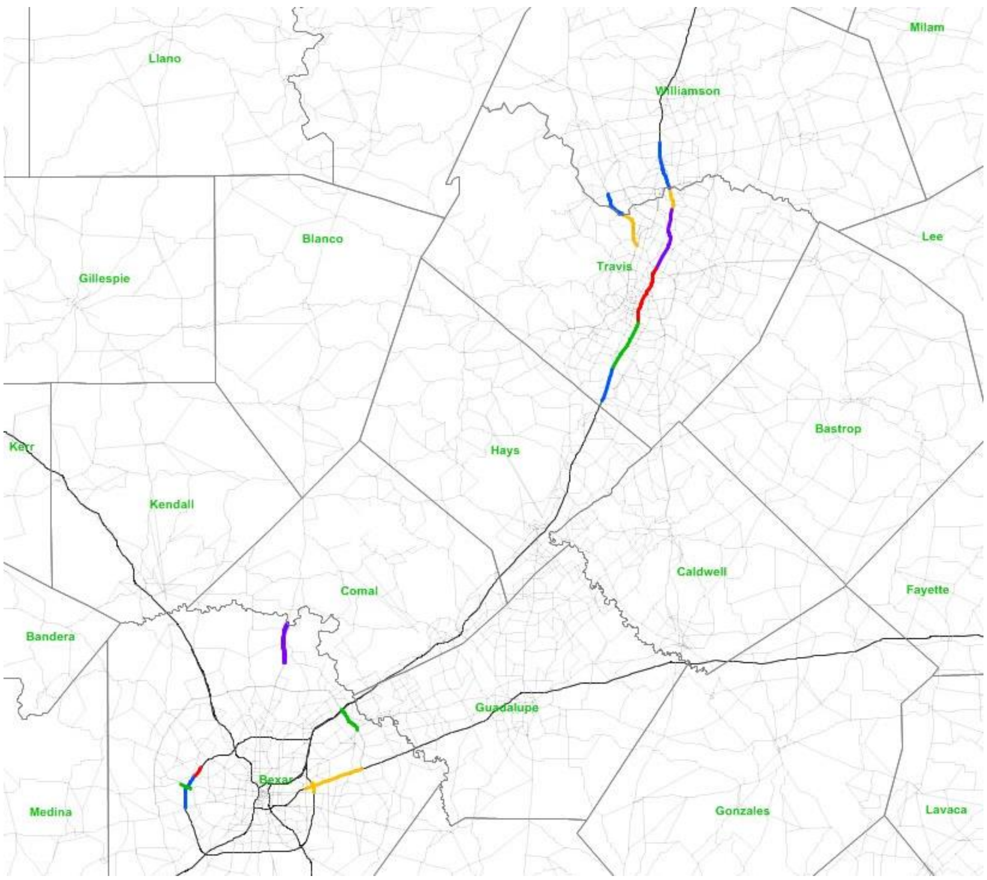
3.9.1 Overview

Texas Clear Lanes, a component of the Texas Congestion Relief Initiative, is aimed at reducing congestion in the metropolitan areas of the state[16]. A set of projects focusing on some severely congested locations within the metropolitan areas are planned or proposed to achieve this goal. The CTR study team conducted an analysis to evaluate the travel and economic effects of these projects. The analysis results indicated these projects would create over $2.7 billion total benefits to the state. The following sections describe the analysis process and the major findings.

3.9.2 Scenario Description

The set of 26 projects examined in this study were provided to the CTR team by the TxDOT Freight Section. Table H1 in Appendix H summarizes each project, including project description and costs, and depicts how each was modeled in the SAM network. The following maps show the locations of these projects within each metropolitan area.

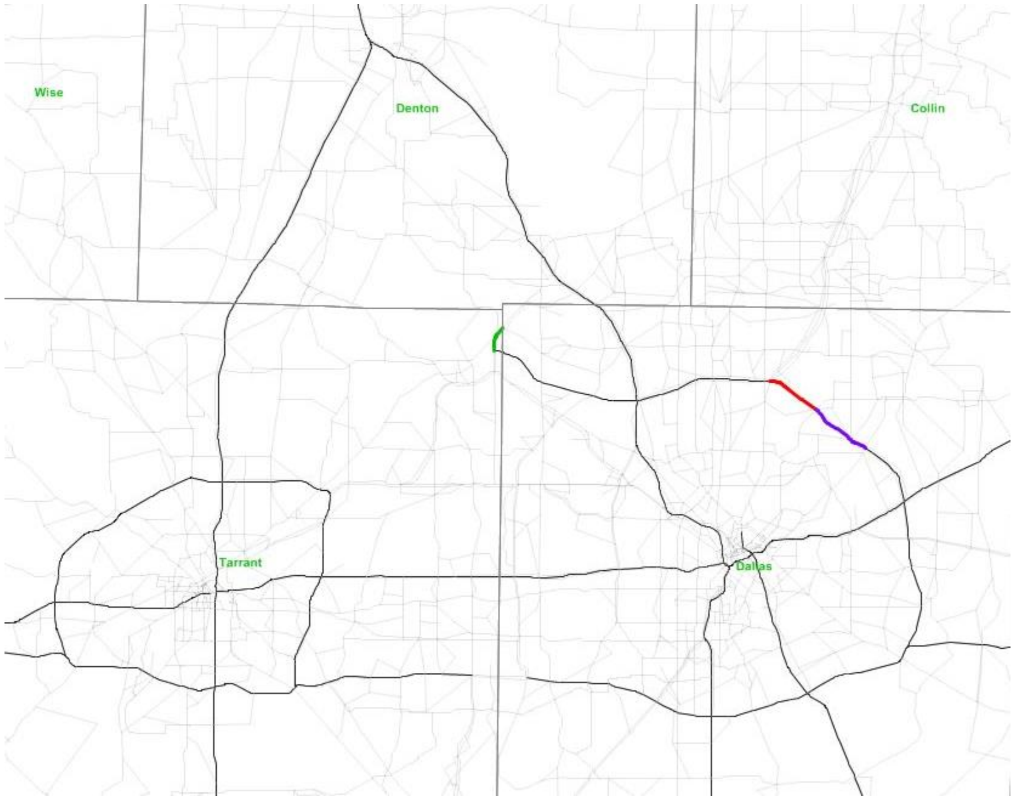
Figure 3.18: Location of Texas Clear Lanes Projects[17]



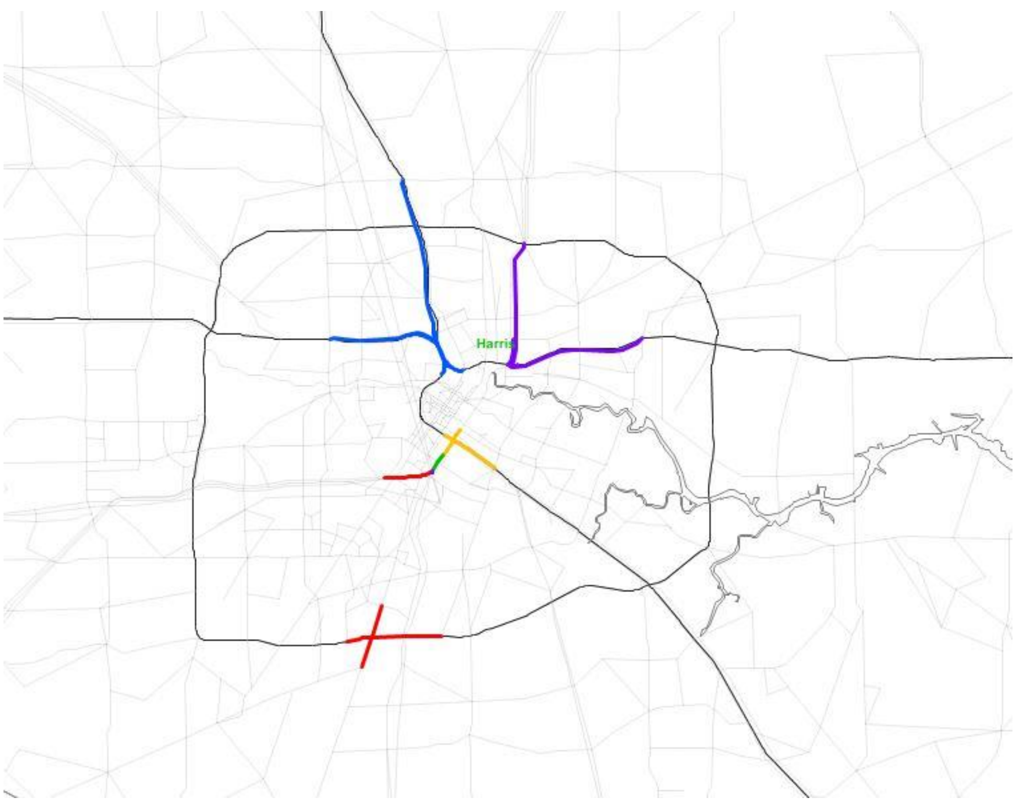
(a) Austin and San Antonio

[16] Texas Clear Lanes - Congestion Relief Initiative. Accessed at: https://ftp.dot.state.tx.us/pub/txdot/tcl/tcl-summary.pdf

[17] Different projects are represented by different colors



(b) Dallas-Fort Worth



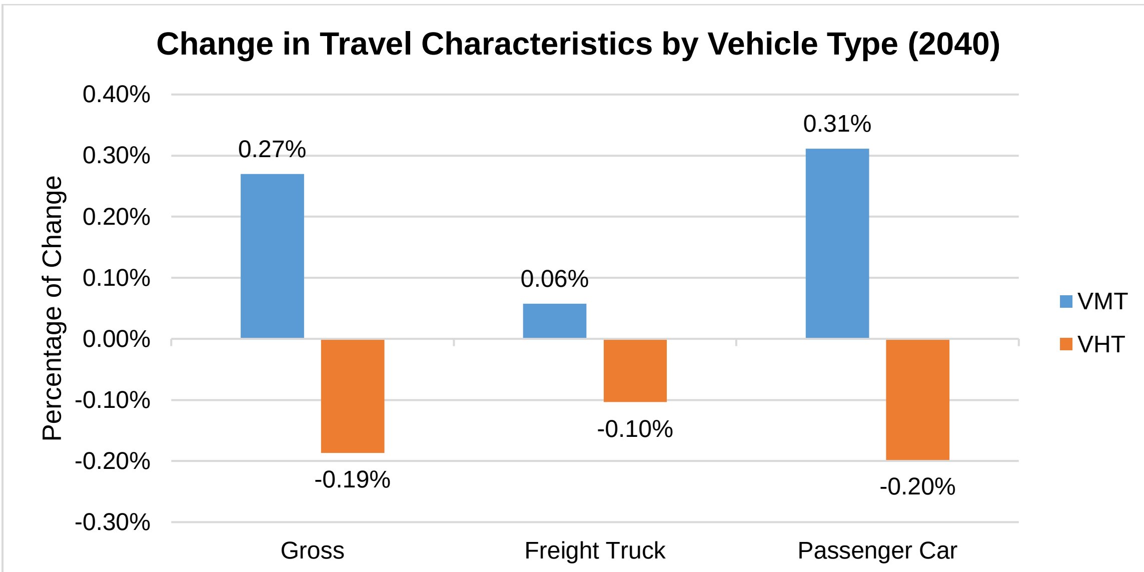
(c) Houston

The well-established SAM+TREDIS analysis framework was used to evaluate the impact of these projects. To better capture the safety and efficiency benefits of these projects, the detailed safety analysis described in Section 2.6 was conducted.

3.9.3 Analysis Results

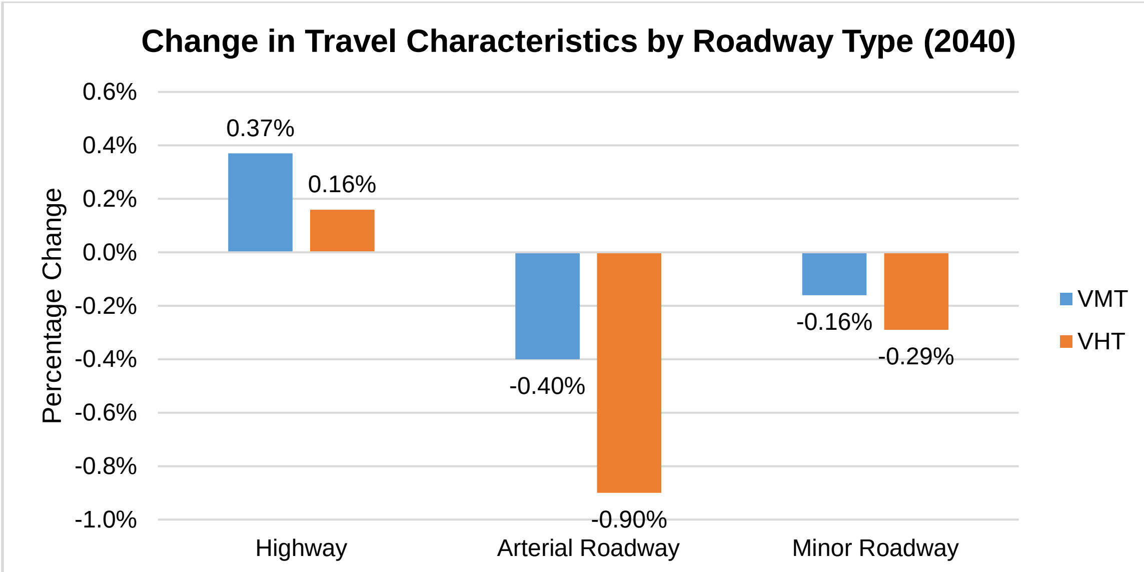
SAM simulation results indicate that the implementation of the projects listed in Table H1 in Appendix H would result in an overall increase in VMT by about 0.27%, as shown in Figure 3.19. The overall VHT decreases by nearly 0.2% due to congestion relief effects of these projects—a decrease in VHT despite an increase in VMT can indicate that total network flow improves. Passenger cars experience more significant change than freight trucks since most of these projects are located on urban roadways.

Figure 3.19: Change in Travel Characteristics by Vehicle Type for Clear Lanes Projects



Additionally, nearly all of the VMT increase is associated with higher functional class roadways, as shown in Figure 3.20. The lower functional class highways have a decline in both VMT and VHT. Arterial roadways see the largest change, with the model indicating that the projects will allow travelers to use highways instead. There is also a decrease in travel along minor roadways. For all facility types, the relative changes in gross VMT and VHT shown in Figure 3.18 indicate that the facilities will be less congested overall (higher average speeds due to less congestion).

Figure 3.20: Change in Travel Characteristics by Roadway Type for Clear Lanes Projects



These combined effects create positive benefits exceeding $2.7 billion at a 3% discount rate, as shown in Table 3.21. The major benefits are from vehicle travel time improvement. Due to the increase in gross VMT, negative benefits are incurred in terms of vehicle operation and emission. Overall, the positive benefits outweigh the negative benefits. However, these benefits are not enough to cover the total project costs, resulting in a benefit-cost ratio less than one.

Table 3.21 Benefits-Cost Summary for Clear Lanes Projects

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**2,746**	**1,302**
	Value of Vehicle Operating Cost	-2,156	-1,058
	Value of Vehicle Travel Time	4,039	1,960
	Value of Improved Travel Time Reliability	389	150
	Value of Safety Improvement	506	254
	Value of Emission Reduction	-460	-215
	Value of Logistics & Supply Chain Cost Savings	428	212
Present Value of Cost Stream		**4,439**	**4,664**
	Capital Investment Costs	5,518	4,960
	Operation and Maintenance Costs	127	74
	Cost Adjustments	-1,206	-370
Net Benefit (Benefits - Costs)		**-1,693**	**-3,362**
Benefit-Cost Ratio (Benefits / Costs)		**0.6**	**0.3**

3.9.5 Conclusions

The analysis results indicate that implementing those projects included in the Clear Lanes Congestion Relief Initiative did help improve vehicle travel time and reliability. These projects also bring about safety and logistics/freight benefits. However, due to the VMT increase possibly caused by more vehicles switching to roadways of higher functional class and traveling more miles for shorter travel time, we did see some negative benefits in terms of vehicle operating costs and environmental costs. However, overall, these projects generate over $2.7 billion in benefits when considering a 3% discount rate.

These benefits are slightly lower than the total construction costs estimated for all these projects, causing the benefit-cost ratio less than one. The CTR team posits that this result arose because some of the projects cannot be directly or fully modeled using the proposed study framework due to some issues discussed in Section 2.5. However, over $2.7 billion in overall benefits with a 3% discount rate proves the effectiveness of these projects in reducing traffic congestion and promoting the state economy.

3.10 Top Congested Locations

3.10.1 Overview

TTI's "100 Most Congested Roadways in Texas 2018 Report[18]" identifies the 100 most congested locations within Texas in 2018 by annual delay hours per road mile. There are separate lists for the most congested locations for trucking and the most congested locations overall. SAM and ODP both list projects that could potentially relieve such congestion. At TxDOT's direction, the CTR team ran two scenarios based on TTI's lists: one focusing on the 20 most congested locations overall, and the other on the top 25 most congested trucking locations. The CTR team simulated the effects of implementing all the planned or proposed projects from SAM and ODP at each of the locations in the scenarios.

For the top-20 overall congested locations, the study team's analyses indicate that with the implementation of 30 identified projects from SAM and ODP, by 2040 the average time needed to traverse all 20 segments could decrease by approximately 10%, from 2.1 hours to 1.9 hours. Implementing those projects also improves the overall travel condition across the entire state road network. For 2040, the total VMT decreases by 0.1% and the total VHT decreases by 1.2% compared to the base case. The economic analysis reveals that the overall benefit-cost ratio is 5.2 with a 3% discount rate and 3 with a 7% discount rate; the greatest benefits are generated from the improvements to vehicle travel time and reliability.

For the top-25 trucking congested locations, the results were similar, although the magnitude of the benefits is smaller. The overall benefit-cost ratios are 4.8 at a 3% discount rate and 2.5 at a 7% discount rate. Most of the benefits come from reduced travel time or improved reliability (over 84%).

3.10.2 Scenario Descriptions

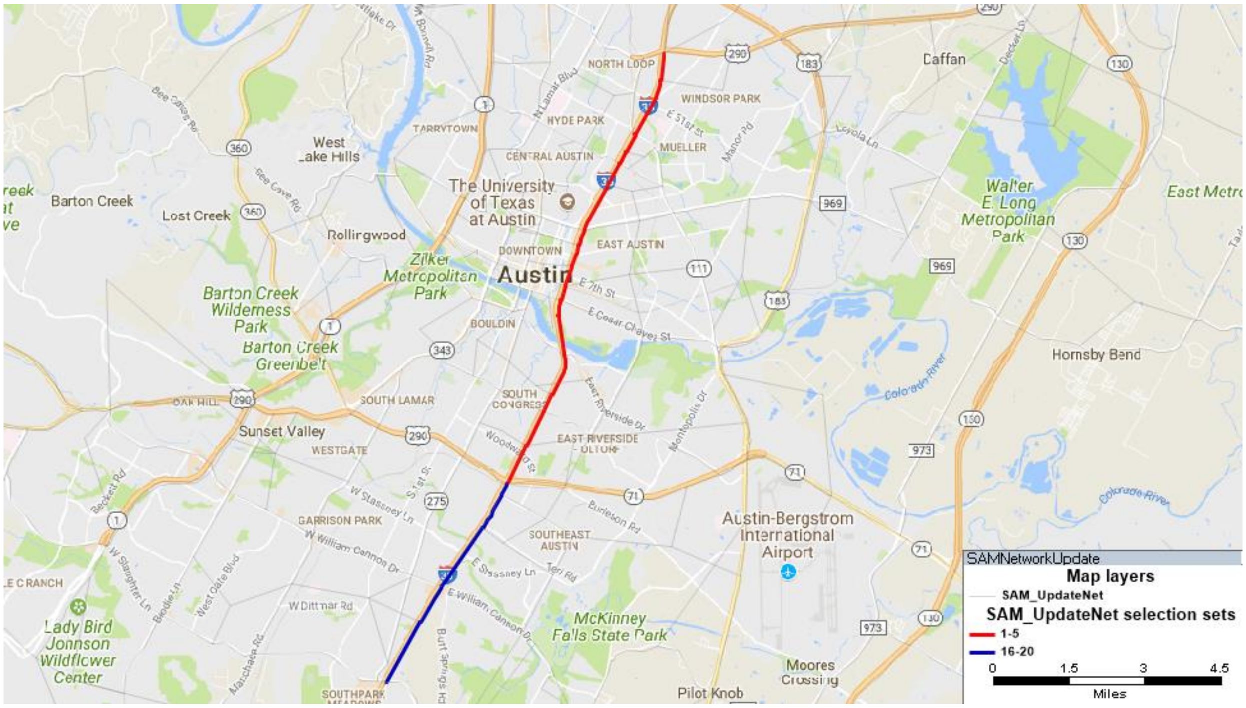
Top-20 Overall Congested Locations

The top-20 congested locations in Texas in 2018, totaling 101.32 miles in length according to TTI's listing[19], are shown separately by region in Figure 3.21. Out of these 20 segments, 12 are located in Harris County, 4 in Dallas County, 2 in Travis County, and 1 each in Tarrant and Bexar Counties. The longest congested segment is located in Harris County along I-45, stretching over 9.26 miles between the Sam Houston Tollway and I-610. Details about each segment are shown in Table I1 in Appendix I.

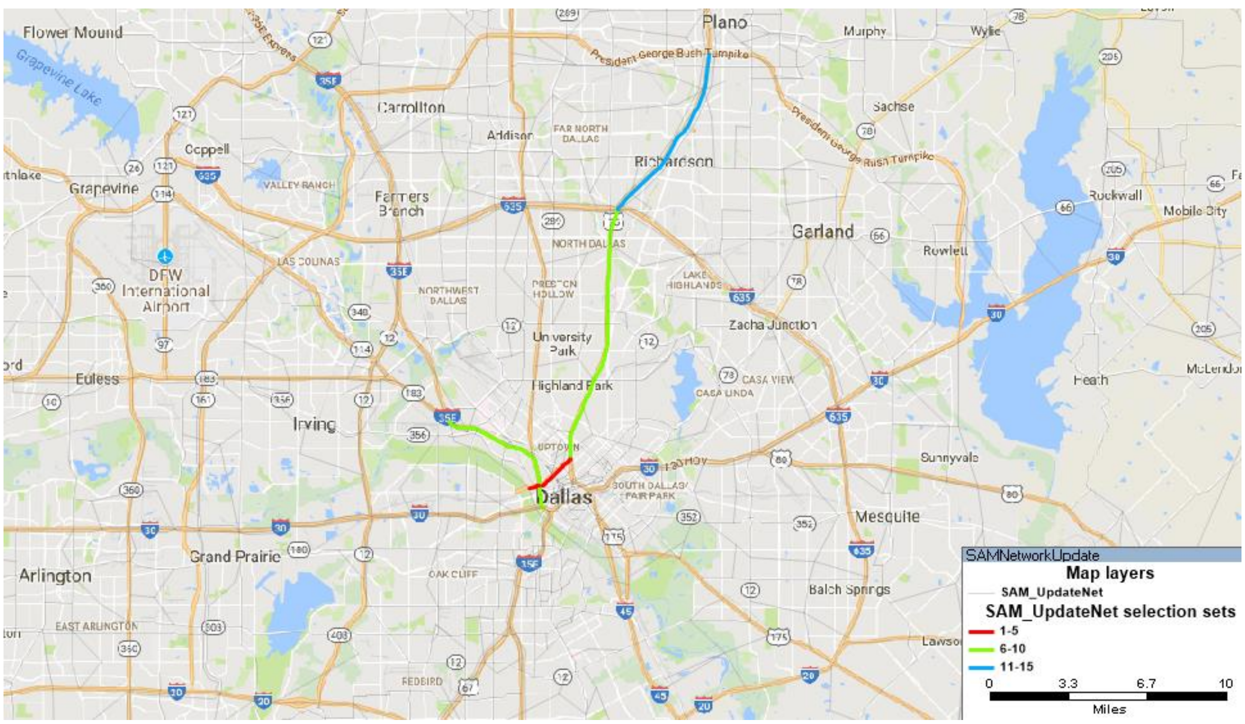
[18] Accessed at: https://static.tti.tamu.edu/tti.tamu.edu/documents/TTI-2018-7.pdf

[19] Texas' Most Congested Roadways 2018. Accessed at: https://mobility.tamu.edu/texas-most-congested-roadways/

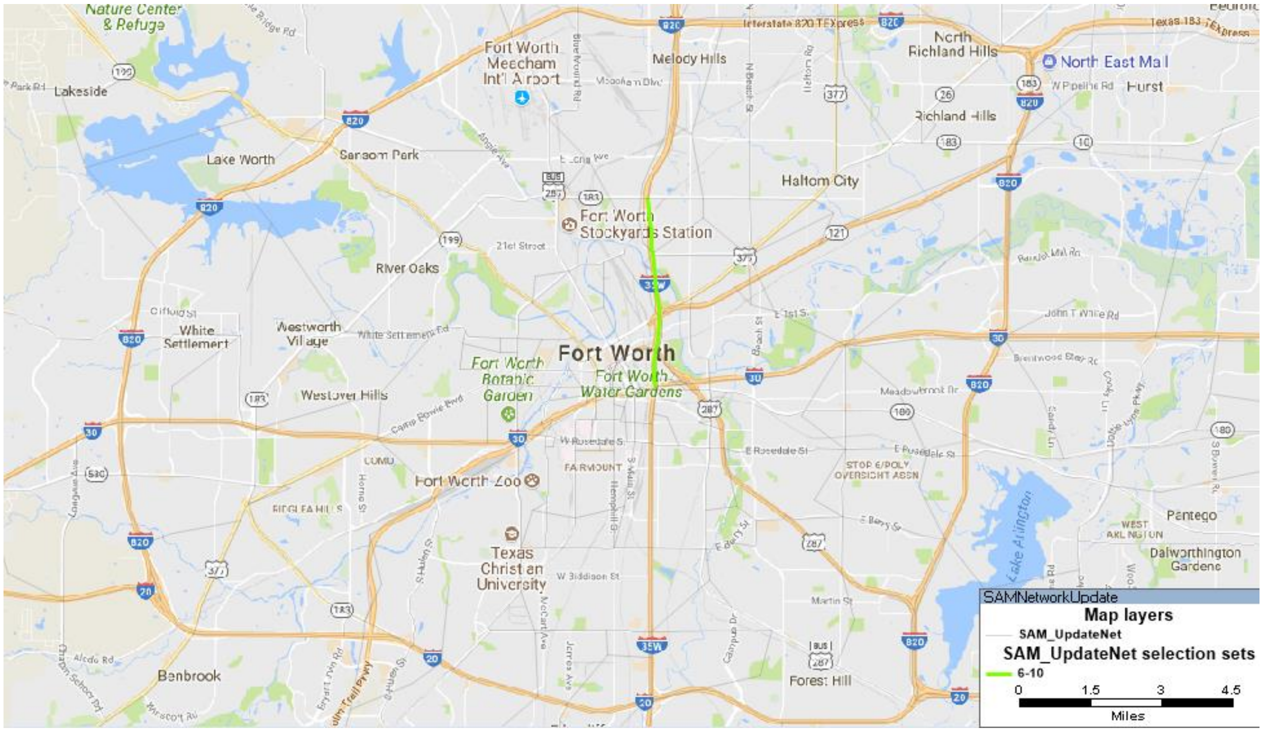
Figure 3.21: Texas Top-20 Congested Locations in 2018



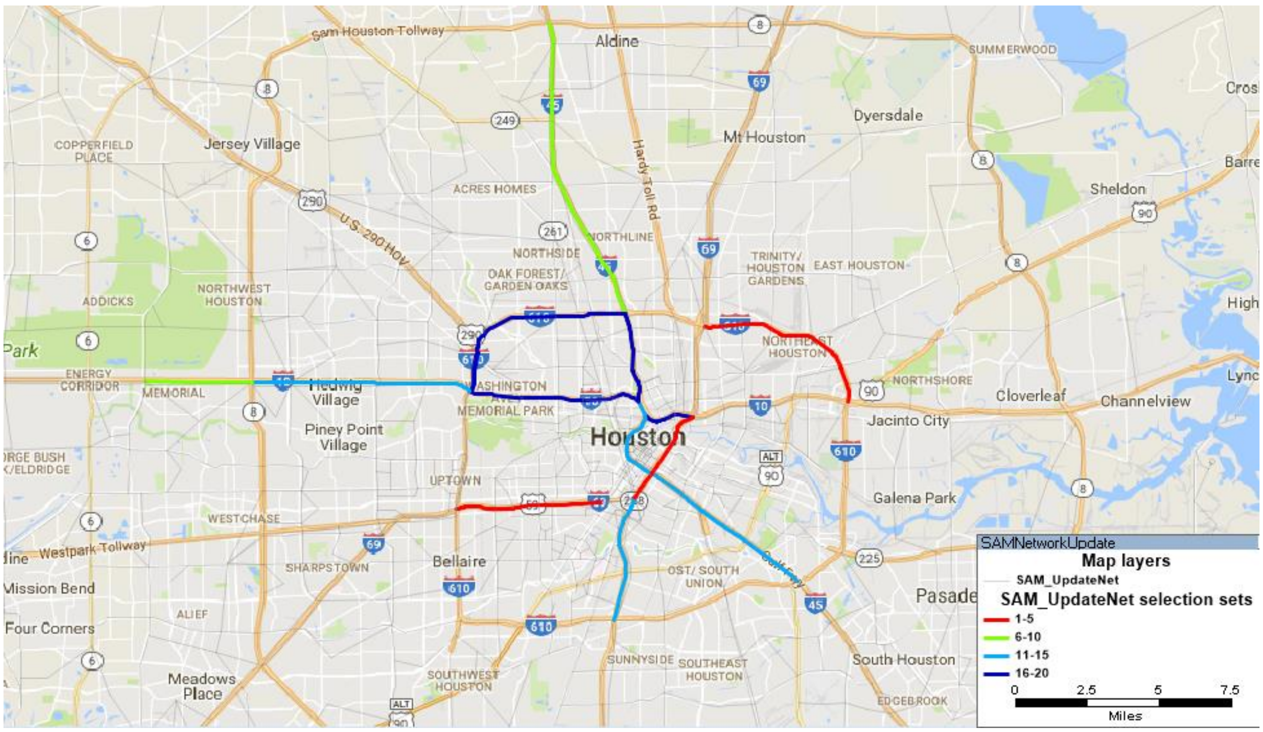
(a) Segments in Austin



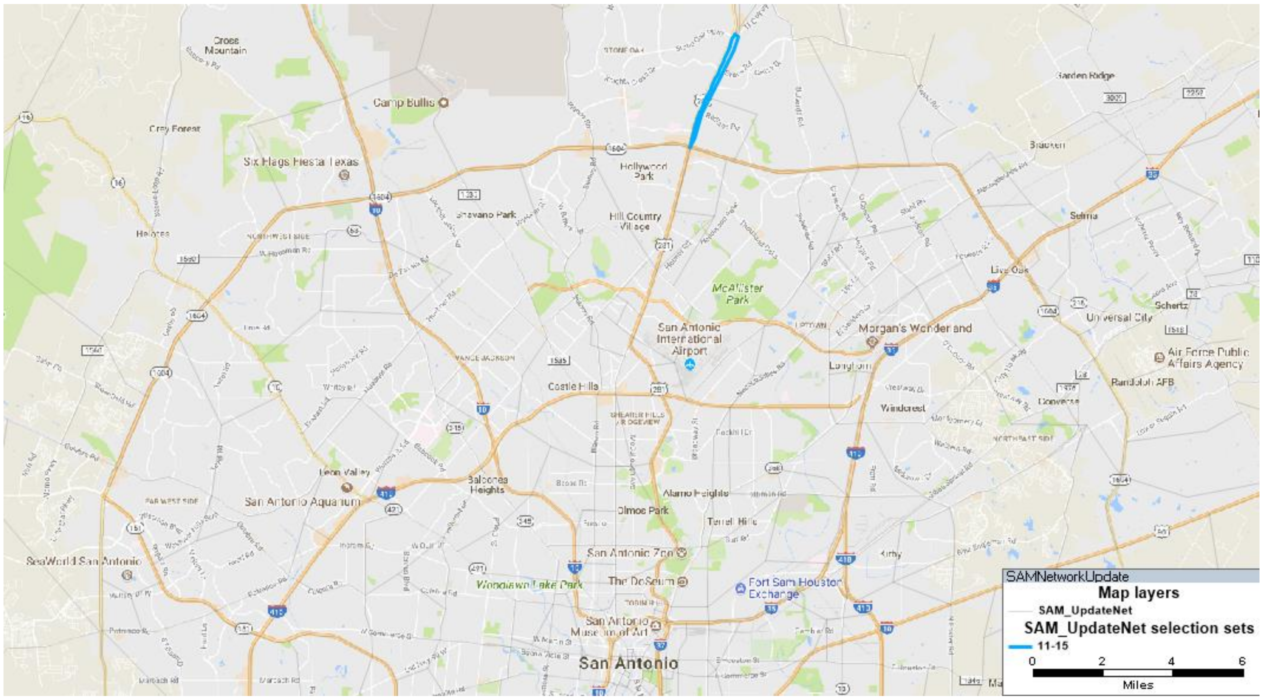
(b) Segments in Dallas



(c) Segments in Fort Worth



(d) Segments in Houston

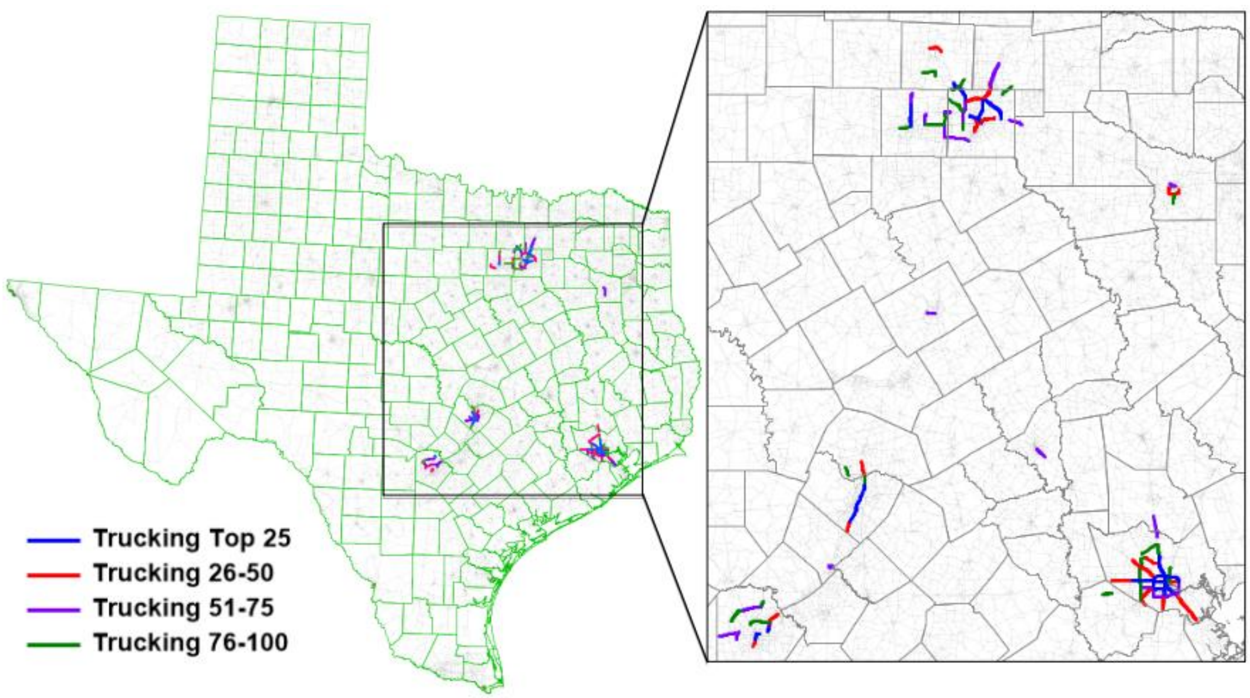


(e) Segments in San Antonio

Top-25 Trucking Congested Locations

Figure 3.22 shows the locations of the top-25 trucking congested locations for the scenario. Appendix J provides further information about the congested locations.

Figure 3.22: Texas Top-25 Trucking Congested Locations in 2018



3.10.3 Simulation Modeling

Top-20 Overall Congested Locations

14 projects from SAM and 16 from ODP are identified that are located at the top-20 congested roadway segments. Table I2 and I3 in Appendix I provide more details of these projects. Half of the congested locations in the top-20 overall (those ranked at 1, 2, 4, 7, 9, 12, 13, 15, 16, and 20 in 2018) have no ODP projects addressing them, and nine (those ranked 2, 4, 7, 9, 10, 11, 13, 16, and 20) have no new SAM projects compared to the base case. Overall, congested locations ranked 2, 4, 7, 9, 13, 16, and 20 are not being addressed by any projects in either database.

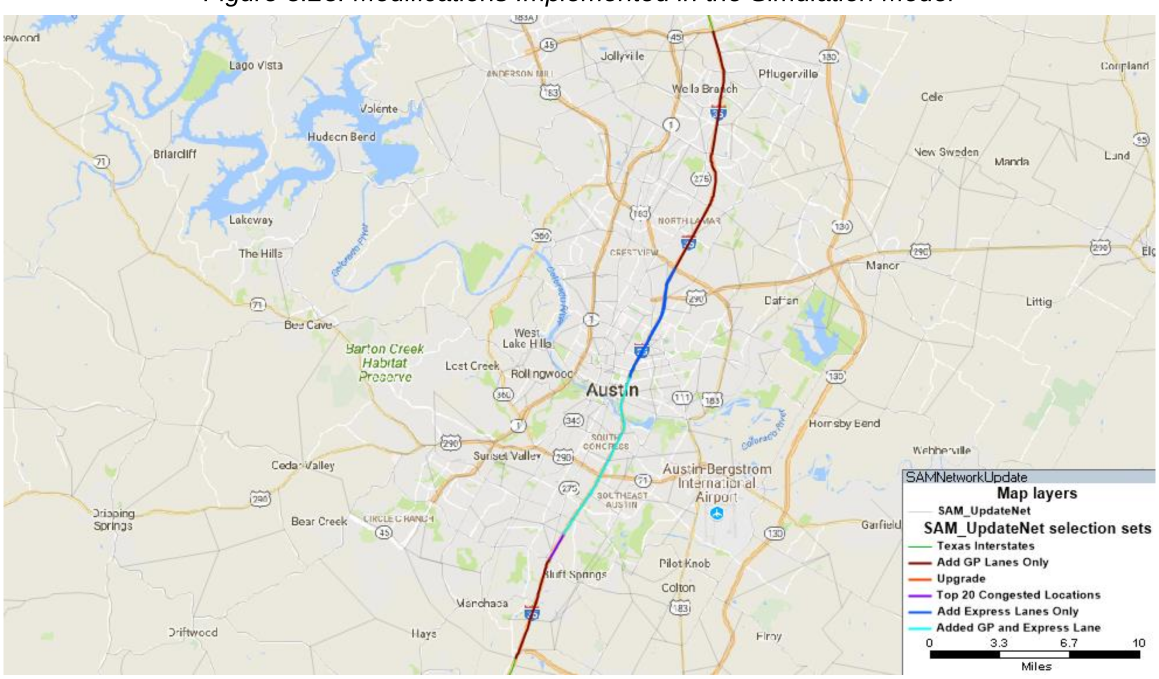
The 30 projects identified from SAM and ODP are simulated using the methods described in Section 2.5. With the implementation of these projects, 55% of the total length of these 20 segments will be upgraded, either by adding GP lanes, express lanes, or both or by being upgraded to an expressway in functional class. The modification lengths of each type of upgrade are shown in Table 3.22.

Table 3.22 Modified Lengths by Types of Change Made

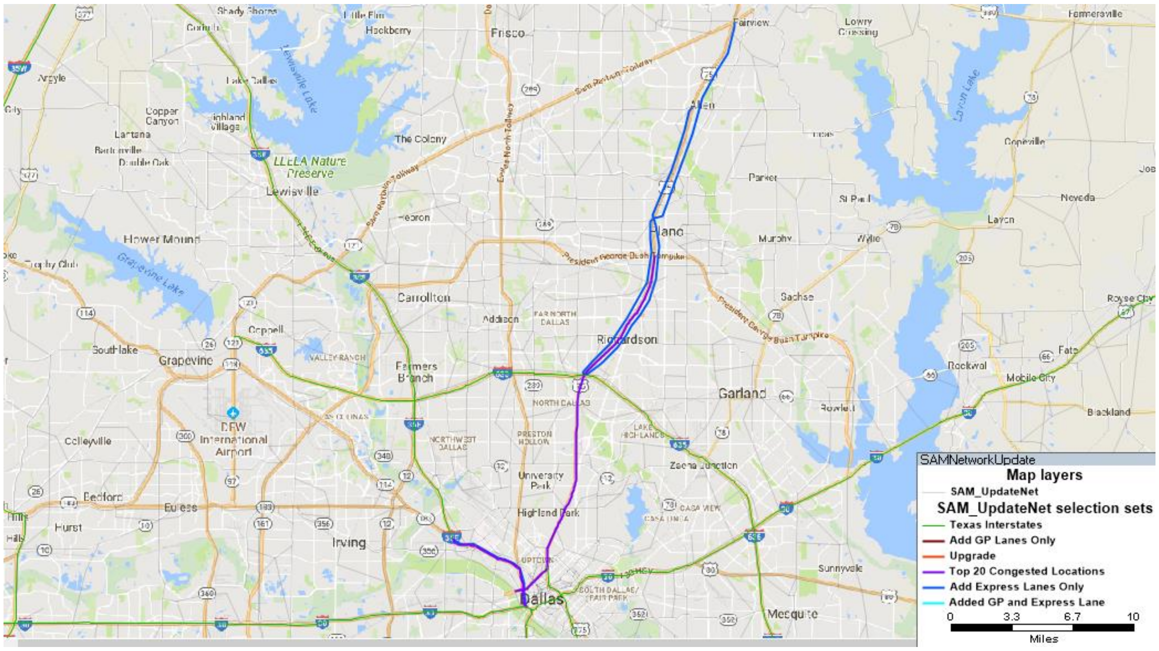
Type of Modification	Length (mile)
Total	102.74
Add GP Lanes Only	32.19
Add Express Lanes Only	13.55
Add GP and Express Lanes	7.24
Functional Class Upgraded	3.88
Unchanged	45.88

Figure 3.23 demonstrates how different segments of those congested locations are treated in the simulation model according to the project descriptions.

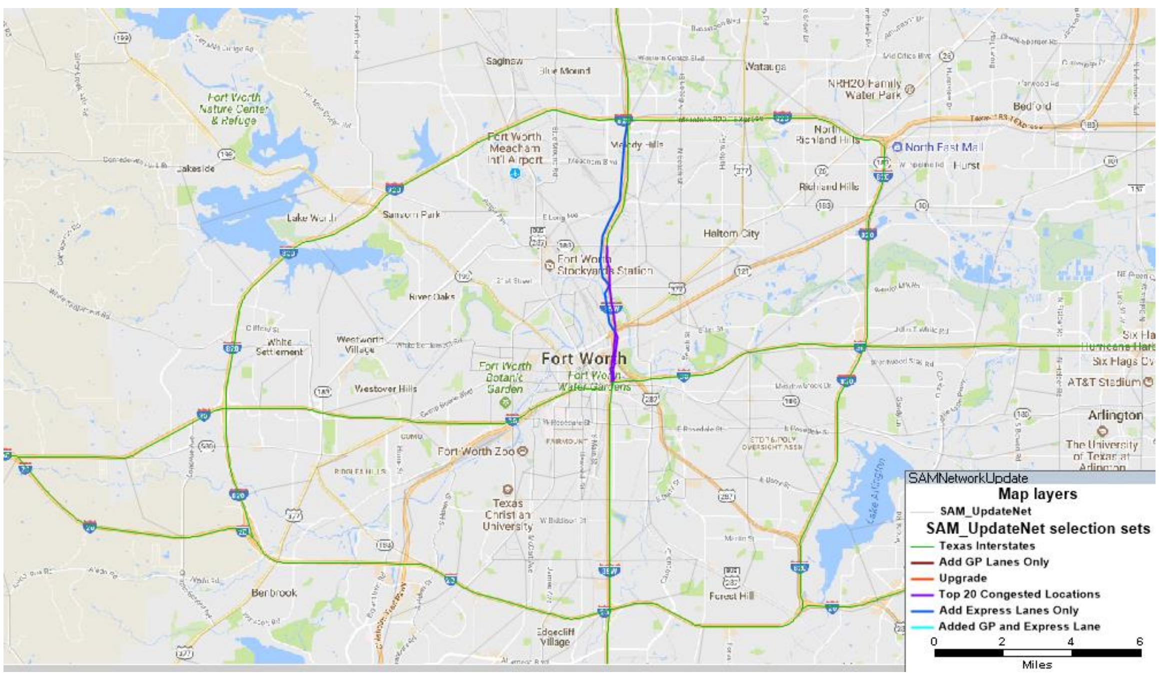
Figure 3.23: Modifications Implemented in the Simulation Model



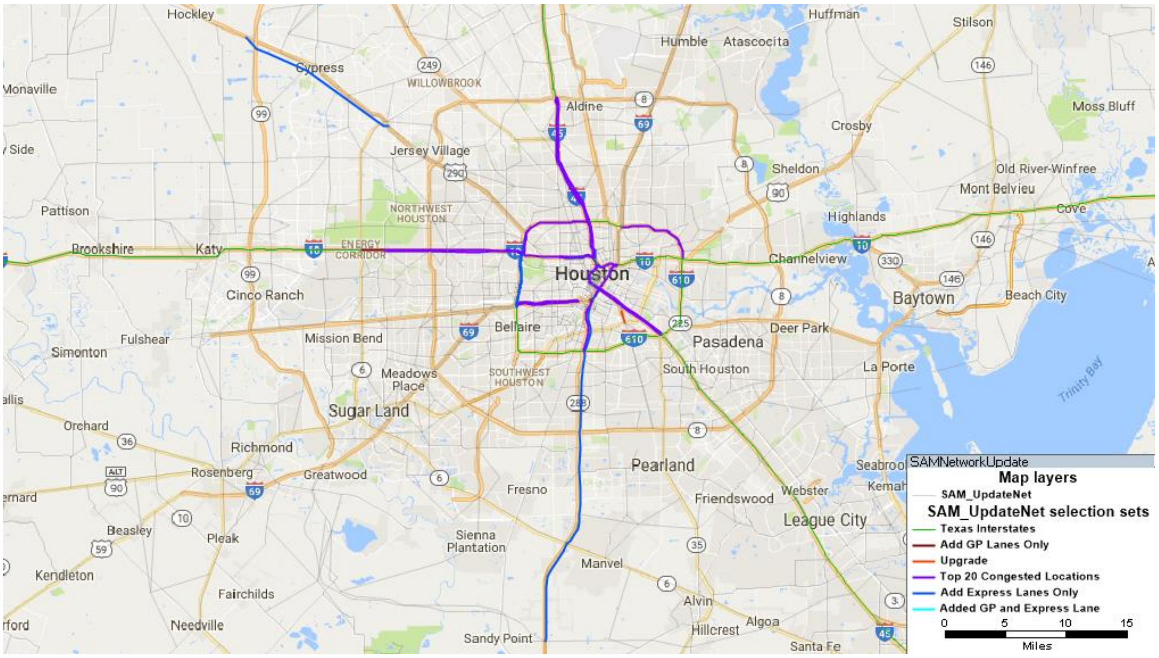
(a) Austin



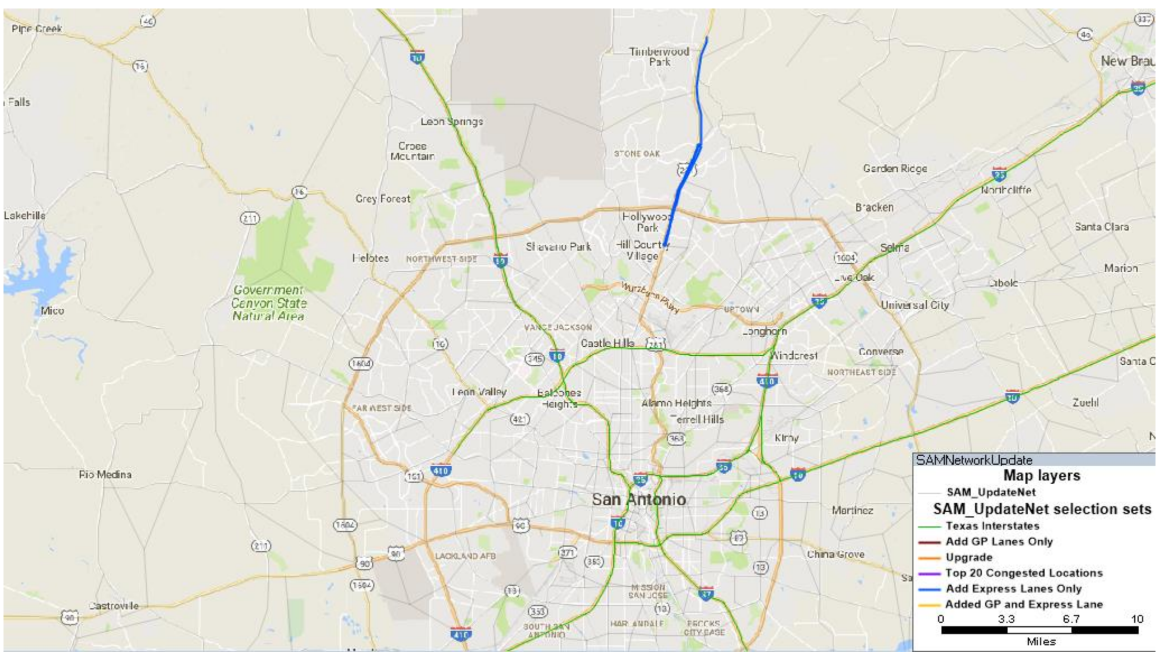
(b) Dallas



(c) Fort Worth



(d) Houston



(e) San Antonio

Top-25 Trucking Congested Locations

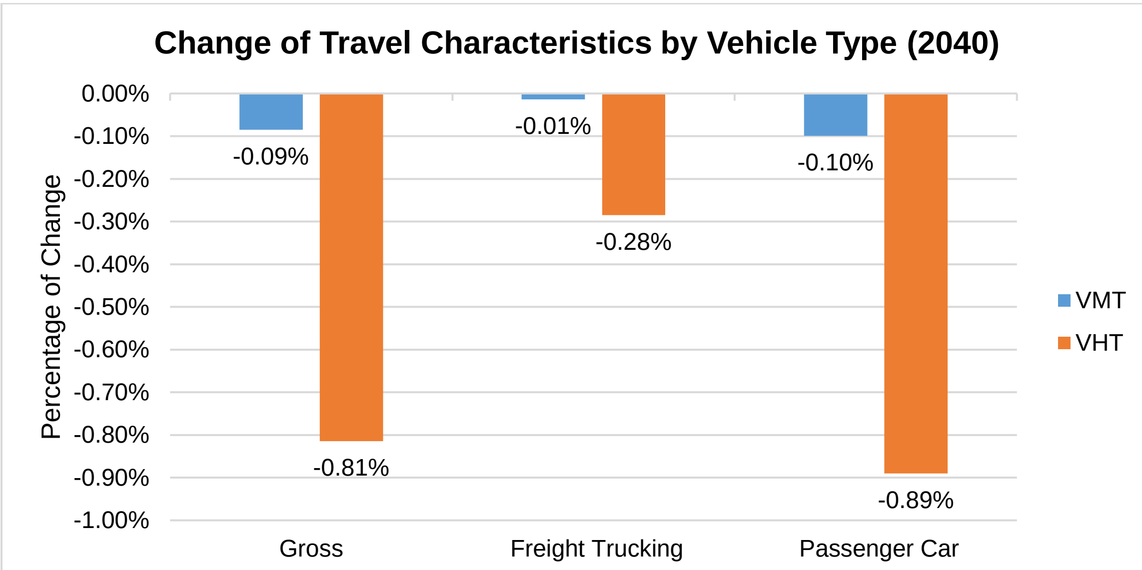
The CTR team completed a similar process for the top-25 trucking congested locations. Together, the SAM and ODP projects call for an additional 468 lane-miles of roadway, all in urban areas. There are a total of 24 SAM projects and 41 ODP projects, although some of those overlap to provide the same improvements to particular links.

3.10.4 Analysis Results

Top-20 Overall Congested Locations

The simulation modeling reveals improvements for the overall travel conditions across the entire state road network with the implementation of these 30 projects. The total VMT decreases by 0.09% and the total VHT decreases by 0.81% compared to the base case in 2040, as shown in Figure 3.24. Passenger cars experience a higher-than-average reduction in VHT while freight trucking experiences a lower-than-average reduction in VHT. Passenger cars benefit more than do freight trucks from the implementation of these projects, as most congested locations are located within the metropolitan areas where roadways mainly serve passenger vehicles.

Figure 3.24: Change of Travel Characteristics by Vehicle Type for Top-20 Overall Congested Locations



The top-five congested locations will see the most significant improvement, with an overall reduction in travel time of 15% on average. The average improvement on the sixth through tenth congested locations is about 6%. It is worth noting that the sixth-most-congested location, along I-35 West within Tarrant County, experiences a slight increase in travel time after the modification, even though four SAM projects are implemented there. The implementation of these projects would increase the GRP by over $13 billion over the 23-year period between 2018 and 2050.

The detailed benefits and costs are displayed in Table 3.23. The cost estimates used were obtained from either SAM or ODP, depending on the source of the specific project. No costs are assumed for projects that solely convert HOV lanes to managed lanes without other modifications, such as widening or functional class upgrade.

As shown in Table 3.23, the implementation of these projects generates positive benefits in all categories. The majority of the benefits come from the improvement of personal and business travel time and reliability. A benefit-cost ratio of 5.2 is returned under a 3% discount rate, and 3 under a 7% discount rate.

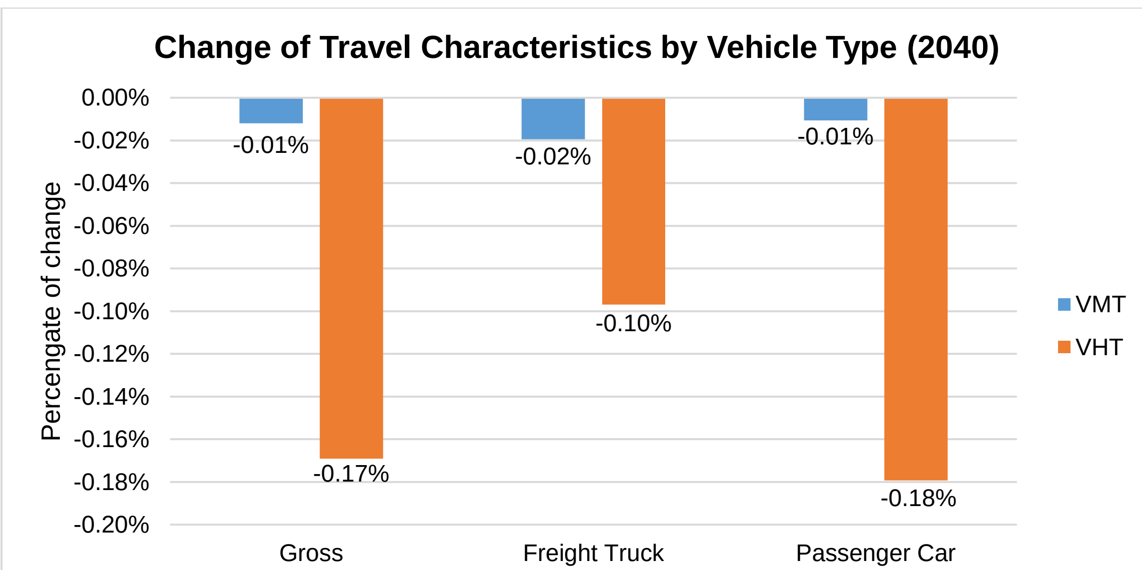
Table 3.23 Benefit-Cost Summary for Top-20 Overall Congested Locations

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**21,167**	**10,326**
	Value of Vehicle Operating Cost	918	450
	Value of Vehicle Travel Time	16,341	7,992
	Value of Improved Travel Time Reliability	2,087	983
	Value of Safety Improvement	794	404
	Value of Emission Reduction	197	93
	Value of Logistics & Supply Chain Cost Savings	830	403
Present Value of Cost Stream		**4,054**	**3,404**
	Capital Investment Costs	5,305	3,753
	Operation and Maintenance Costs	180	91
	Cost Adjustments	-1,431	-439
Net Benefit (Benefits - Costs)		**17,112**	**6,921**
Benefit-Cost Ratio (Benefits / Costs)		**5.2**	**3.0**

Top-25 Trucking Congested Locations

Like the top-20 overall congested locations, the top-25 trucking congested locations scenario results in reductions in overall VMT and VHT (see Figure 3.25). The reductions are smaller as many of the trucking congested locations are further away from locations of large overall traffic.

Figure 3.25: Change of Travel Characteristics by Vehicle Type for Top-25 Trucking Congested Locations



As shown in Table 3.24, implementing all projects proposed/planned at the top-25 trucking congested locations also generates positive benefits in all categories. The overall benefit-cost ratios are 4.8 at a 3% discount rate and 2.5 at a 7% discount rate. Most of the benefits come from personal travel time savings and reliability, but business time and reliability benefits are also large.

Table 3.24 Benefit-Cost Summary for Top-25 Trucking Congested Locations

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**8,042**	**3,832**
	Value of Vehicle Operating Cost	331	161
	Value of Vehicle Travel Time	3,301	1,627
	Value of Improved Travel Time Reliability	3,488	1,622
	Value of Safety Improvement	527	232
	Value of Emission Reduction	122	56
	Value of Logistics & Supply Chain Cost Savings	271	134
Present Value of Cost Stream		**1,670**	**1,542**
	Capital Investment Costs	2,086	1,646
	Operation and Maintenance Costs	81	43
	Cost Adjustments	-497	-147
Net Benefit (Benefits - Costs)		**6,371**	**2,290**
Benefit-Cost Ratio (Benefits / Costs)		**4.8**	**2.5**

3.10.5 Summary

Implementing the projects identified from SAM and ODP at Texas's top-20 most congested segments or top-25 most congested trucking segments results in overall positive impacts on the entire transportation network. The total VMT and VHT across the entire state roadway network decrease. Personal and business travel time and reliability are improved significantly.

For the top-20 overall congested segments, the local travel time along most segments are also improved. Overall, the benefit-cost ratio of implementing these projects to relieve congestion at the top-20 overall most congested locations in Texas is 5.2 with a 3% discount rate or 3 with a 7% discount rate.

Building projects to address the top-25 trucking congested locations results in a benefit-cost ratio of 4.8 at the 3% discount rate and 2.5 at the 7% discount rate.

3.11 Rural Corridors

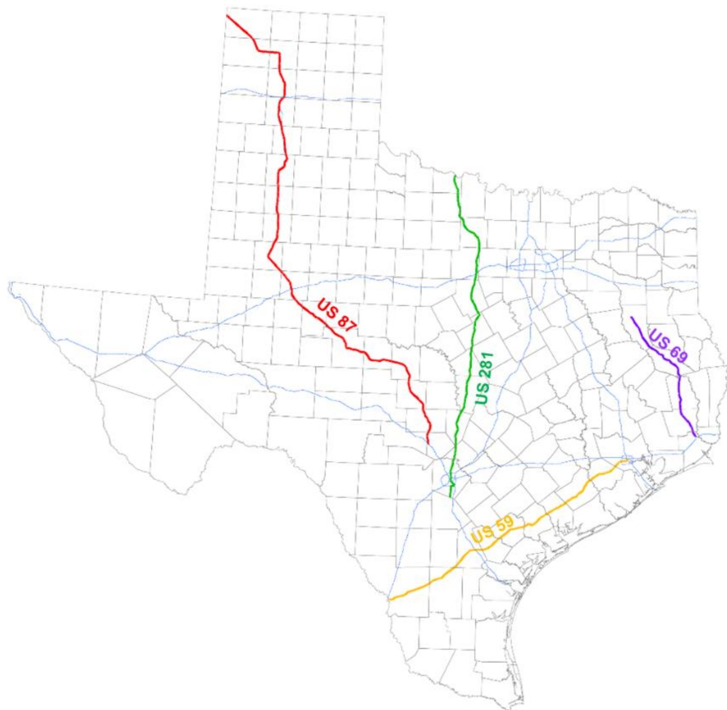
3.11.1 Overview

TxDOT identified the following four key corridors within the Texas Highway Trunk System.

- US 87 from TX/NM State Line to I-10
- US 69 from Beaumont to US 175 (South of Tyler)
- US 59 from Laredo to Houston
- US 281 from San Antonio to I-20 (Wichita Falls)

Their locations in the state are shown in Figure 3.26.

Figure 3.26: Four Key Rural Corridors



TxDOT anticipates that the improvement of these corridors can:

- Help relieve congestion on their parallel interstate systems
- Promote connectivity and economic development throughout Texas
- Strengthen international trade routes
- Address safety concerns with modern/enhanced designs

Within this context, TxDOT asked the study team to analyze the travel and economic impacts of upgrading these four rural corridors to the minimum standard of a four-lane divided highway. The total benefits, costs, and benefit-cost ratio of all four corridors with a 3% discount rate are summarized in Table 3.25.

Table 3.25 Benefit-Cost Summary[20] of Upgrading Four Rural Corridor Segments

	US 87	US 69	US 59	US 281
Present Value of Benefits (million)	$2,663	$2,026	$12,527	$1,535
Present Value of Costs (million)	$919	$538	$1,112	$1,301
Benefit-cost Ratio	2.9	3.8	11.3	1.2

As shown in Table 3.25, the simulation modeling and economic analysis reveal that upgrading segments on US 87, US 69, US 59, and US 281 to the minimum standard of a divided four-lane highway generates more benefits than costs and renders a benefit-cost ratio higher than one with 3% discount rate. The upgrade of US 59 is the most cost-efficient, with a benefit-cost ratio of 11.3 under a 3% discount rate. The benefits generated by upgrading the segment on US 281 is slightly lower than costs with a 7% discount rate according to the study team's cost estimation.

The following sections first present an overview of the modeling procedure and cost estimation methods applied to all four corridors, followed by the detailed analysis procedure and the individual results for each corridor.

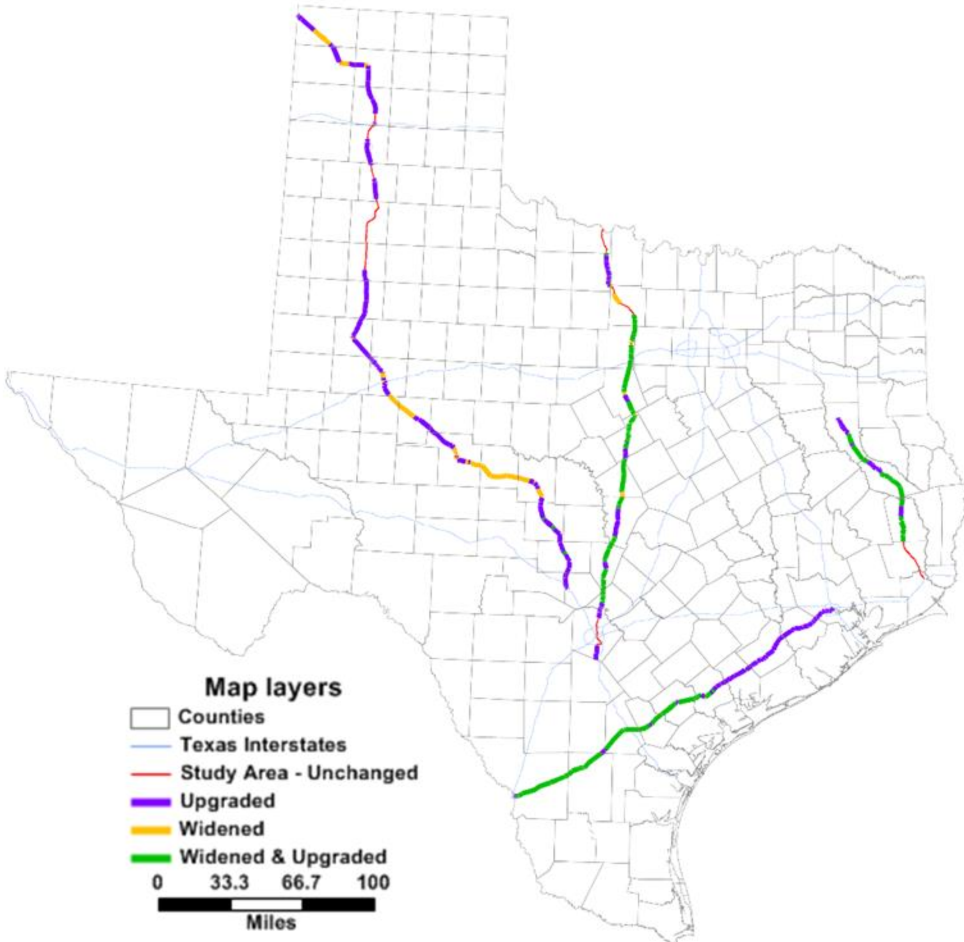
3.11.2 Simulation Modeling

The maps in Figure 3.27 show the segments of these four corridors that are currently below the standards of a divided four-lane highway. Segments marked as upgraded are currently undivided and possibly at a low functional class. They are modified in the simulation model by upgrading their functional class to principal arterial (minimum functional classification for divided roadway). Usually, this involves changing their functional classification from 6 (rural minor arterial) to 2 (rural principal arterial) or from 16 (urban minor arterial) to 14 (urban principal arterial). Note that the functional classifications used in this document follow SAM functional classifications, which are based on FHWA guidelines for functional classification[21]. Segments marked as widened currently have only one lane in each direction. They are modified in the simulation model by increasing the number of lanes to a minimum of two in each direction. Some segments may require both widening and upgrading.

[20] Data shown in this table are based on a 3% discount rate. The results of using a 7% discount rate can be found within the subsection for each corridor.

[21] FHWA classifications can be found at https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/section03.cfm

Figure 3.27. Segments of the Rural Corridors Modified in the Simulations



3.11.3 Cost Estimation

According to cost estimates provided by TxDOT's Laredo District, constructing another roadway bed with two lanes and shoulders would cost $5.5 million per mile. If existing roadways need to be reconstructed to reach the same standard as the newly added lane, an extra $4 million per mile would be needed. Thus, a cost factor of $9.5 million is applied to each mile of roadway widened, regardless of upgrading or dividing that might take place alongside. A cost factor of $4 million is applied to each mile upgraded or divider added without widening.

According to the same source of cost estimation, approximately 25 bridge structures are anticipated to be built across the 267.1 miles of modified roadway along US 59, each with a construction cost of $2.5 million. Assuming similar distribution patterns of bridge structures across all corridors analyzed—US 69, US 87, and US 281, which respectively each have a total of 127.5 miles, 227.5 miles, and 303.8 miles modified (i.e., either upgraded or widened or both)—would result in the construction of 12, 22, and 29 bridge structures, respectively.

A breakdown of the estimated construction cost is presented in Table 3.26. It turns out that US 69 requires the minimum amount of investment to achieve the standard of a four-lane divided highway for the entire study area because more of its current miles meet that standard. US 281 would cost the most, as more than 300 miles need to be modified.

Table 3.26 Rural Corridor Segments Upgrade Construction Cost Breakdown

	Miles Widened	Miles Upgraded or Divided	Total Miles Modified	Estimated Number of Bridge Structures	Bridge Cost (million)	Total Cost (million)
US 87	139.9	87.6	227.5	21.3	$55	$1,734.5
US 69	86.1	41.4	127.5	11.9	$30	$1,013.6
US 59	175.8	91.2	267.1	25	$62.5	$2,097.4
US 281	211.9	91.9	303.8	28.4	$72.5	$2,453.2

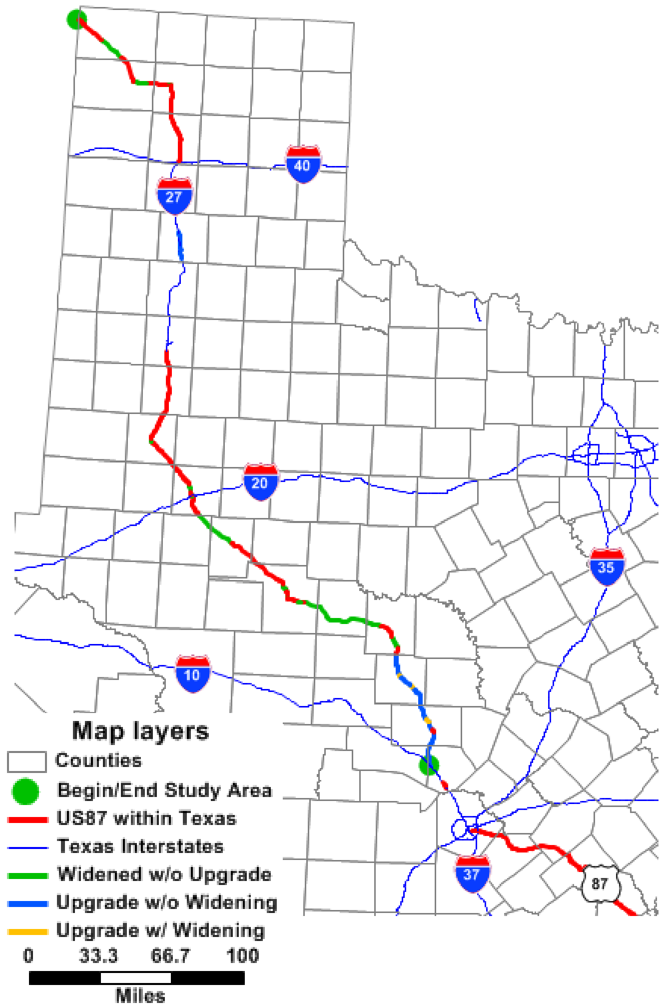
The following sections present the extent of modification required to upgrade the corridor segments to a minimum standard of a four-lane divided highway and the travel and economic impacts of these modifications.

3.11.4 Extent of Modification and Analysis Results

US 87

The segment of US 87 under analysis extends from the Texas-New Mexico state border to I-10.

Figure 3.28: Extent of Modification for US 87 Segment under Analysis



About one-third of the analyzed US 87 segment is currently below the standard of a four-lane divided highway and needs to be modified. The map in Figure 3.28 shows which segments were modified for simulation modeling. Some segments of US 87 in the study area are coincident with I-27; because these segments are already built to interstate standards, they were not changed in the simulation.

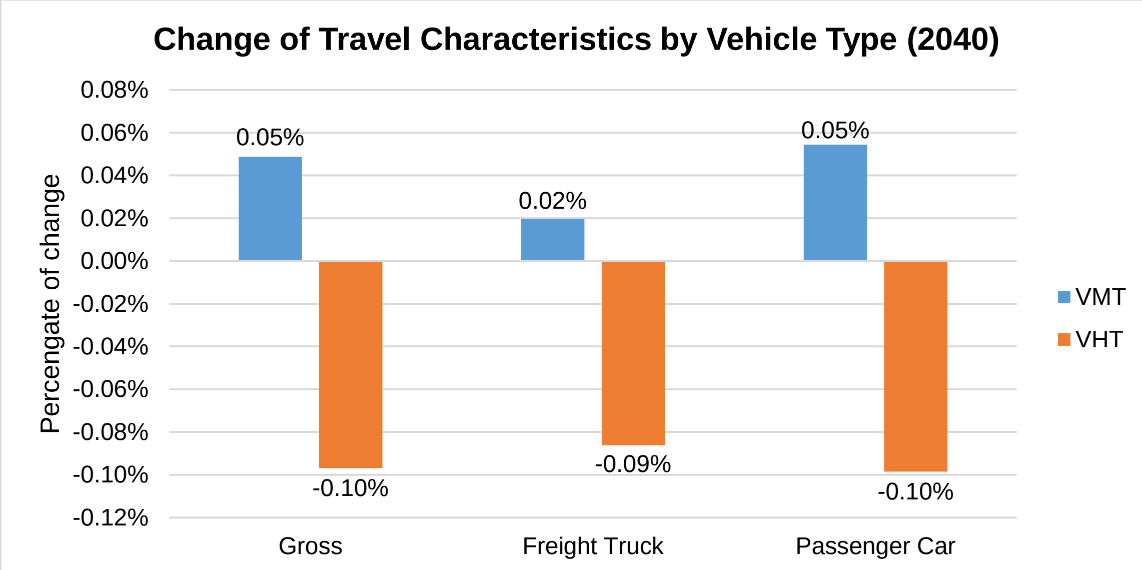
Table 3.27 provides more details regarding the extent of the modifications needed to bring this segment of US 87 to the minimum standard of a four-lane divided highway.

Table 3.27 Extent of Modifications for US 87

Unit	Extent	Miles
	Length of US 87 in Texas	795.9
	Length of the study area (TX/NM state line to I-10)	606.5
	Percentage modified within the study area	37.5%
Length	Total length modified	227.5
	Length upgraded from FC 6 to 2*	94.3
	Length upgraded from FC 6 to 2 and widened	6.6
	Length upgraded from FC 6 to 2 without widening	87.6
	Length upgraded from FC 16 to 14**	0.0
	Length widened without upgrade	133.3
Lane-miles	Number of added lane-miles	279.8
	Lane-miles added with the upgrade	13.3
	Lane-miles added without upgrade	266.5
	Lane-miles upgraded from FC 6 to 2	377.1
	Lane-miles upgraded from FC 6 to 2 and widened	26.6
	Lane-miles upgraded from FC 6 to 2 without widening	350.5
	Lane-miles upgraded from FC 16 to 14	0.0

The simulation modeling reveals that upgrading the segment of US 87 from the TX/NM border to I-10 would reduce the gross VHT across the entire state network by 0.1% while increasing VMT by 0.05% in 2040, as shown in Figure 3.29. The VHT reduction for freight trucks and passenger cars are similar, with a slightly higher increase of VMT for passenger cars. This reduction in VHT despite an increase of VMT indicates that the travel conditions over the entire roadway network are improved. Both the freight trucks and passenger cars experience better travel efficiency.

Figure 3.29: Change of Travel Characteristics by Vehicle Type for US 87



These travel impacts would bring major benefits from vehicle travel time savings and travel time reliability improvement due to decreased VHT. The slightly increased VMT would cause some minor negative benefits in vehicle operating costs and emissions. However, these negative benefits are significantly outweighed by the positive benefits in travel condition improvement. Overall, upgrading US 87 would generate a benefit-cost ratio of 2.9 with a 3% discount rate and 1.8 with a 7% discount rate. Detailed benefits and costs are summarized in Table 3.28.

Table 3.28 Benefit-Cost Summary of Upgrading US 87 Segment under Analysis

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**2,663**	**1,271**
	Value of Vehicle Operating Cost	-264	-110
	Value of Vehicle Travel Time	1,976	938
	Value of Improved Travel Time Reliability	557	247
	Value of Safety Improvement	81	41
	Value of Emission Reduction	-32	-11
	Value of Logistics & Supply Chain Cost Savings	344	167
Present Value of Cost Stream		**919**	**688**
	Capital Investment Costs	1,217	770
	Operation and Maintenance Costs	39	18
	Cost Adjustments	-337	-100
Net Benefit (Benefits - Costs)		**1,744**	**583**
Benefit-Cost Ratio (Benefits / Costs)		**2.9**	**1.8**

US 69

The US-69 segment under analysis extends from Beaumont to US 175 south of Tyler. To improve this segment of US 69 to the minimum standard of a four-lane divided highway, over three-quarters of the corridor needs to be divided, while 53% of the segment length (86.1 out of the 162.9 miles segment under analysis) also needs to be widened. The modifications made to the network are illustrated in Figure 3.30 and detailed in Table 3.29.

Figure 3.30: Extent of Modification for US 69 Segment under Analysis

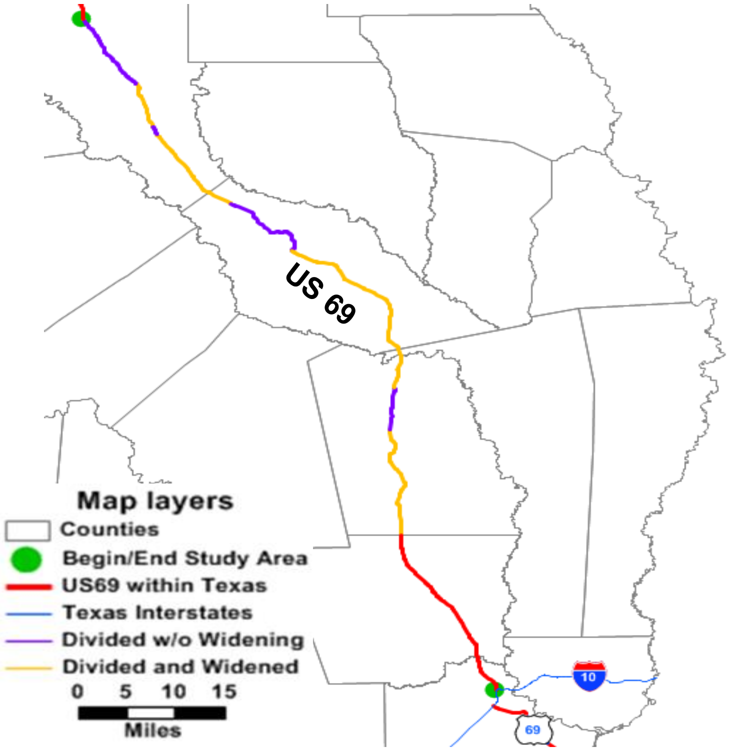
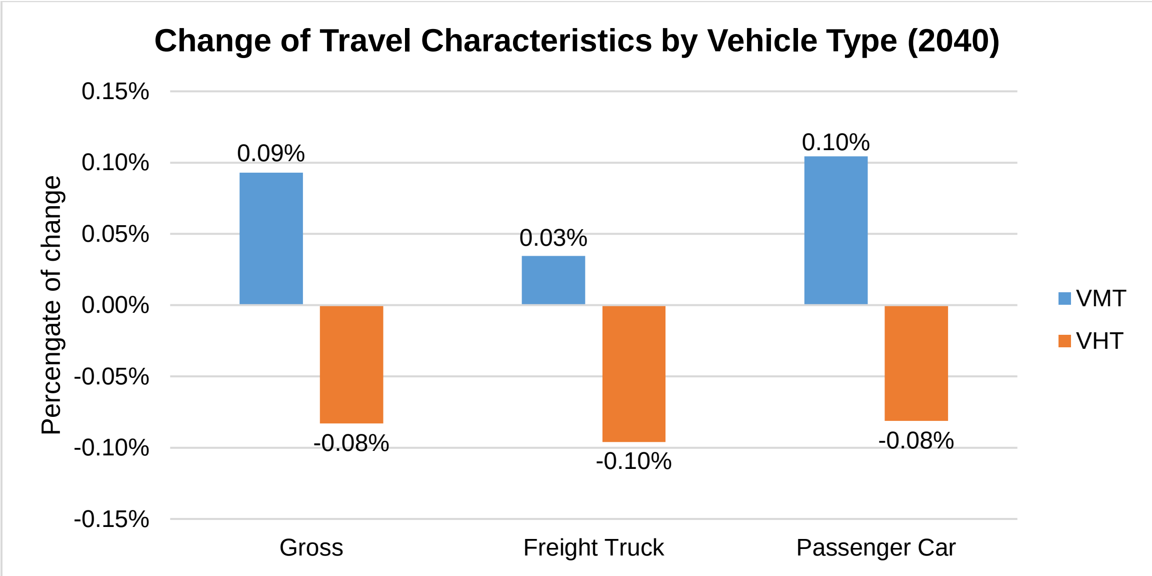


Table 3.29 Extent of Modifications for US 69 Segment under Analysis

Unit	Extent	Miles
	Length of US 69 in Texas	345.7
	Length of the study area (Beaumont to US 175)	162.9
	Percentage modified within the study area	78%
Length	Total length modified	127.5
	Length upgraded from FC 6 to 2	0
	Length upgraded from FC 16 to 14	0
	Divider added without widening	41.4
	Divider added with widening	86.1
	Length widened without upgrade	86.1
Lane-miles	Number of added lane-miles	172.1
	Lane-miles added with the upgrade	0
	Lane-miles added without upgrade	172.1
	Lane-miles upgraded from FC 6 to 2	0
	Lane-miles upgraded from FC 6 to 2 and widened	0
	Lane-miles upgraded from FC 6 to 2 without widening	0
	Lane-miles upgraded from FC 16 to 14	0

The simulation modeling reveals that even though upgrading the segment of US 69 from Beaumont to US 175 would increase VMT across the entire state roadway network by 0.09%, it would reduce the VHT by 0.08% in 2040, as shown in Figure 3.31. Freight trucks experience a higher than average reduction in VHT and a smaller increase in VMT.

Figure 3.31: Change of Travel Characteristics by Vehicle Type for US 69



This decrease in VHT brings about major benefits in terms of travel time and reliability and logistics/freight cost savings, which outweigh the minor negative benefits in vehicle operating costs and emission caused by the slight increase in the VMT, as Table 3.30 demonstrates. Overall, upgrading US 69 between Beaumont and US 175 to a four-lane divided highway is very cost-effective, with a benefit-cost ratio of 3.8 using a 3% discount rate and 2.3 using a 7% discount rate.

Table 3.30 Benefit-Cost Summary of Upgrading US 69 Segment under Analysis

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**2,026**	**913**
	Value of Vehicle Operating Cost	-683	-324
	Value of Vehicle Travel Time	1,592	740
	Value of Improved Travel Time Reliability	746	317
	Value of Safety Improvement	83	40
	Value of Emission Reduction	-110	-49
	Value of Logistics & Supply Chain Cost Savings	398	189
Present Value of Cost Stream		**538**	**402**
	Capital Investment Costs	711	450
	Operation and Maintenance Costs	23	11
	Cost Adjustments	-197	-58
Net Benefit (Benefits - Costs)		**1,488**	**510**
Benefit-Cost Ratio (Benefits / Costs)		**3.8**	**2.3**

US 59

The segment of US 59 under analysis extends from Laredo to Houston. Over 85% of the entire corridor requires some improvement, with over half requiring both widening and dividing, as illustrated in Figure 3.32 and detailed in Table 3.31.

Figure 3.32: Extent of Modification for US 59 Segment under Analysis

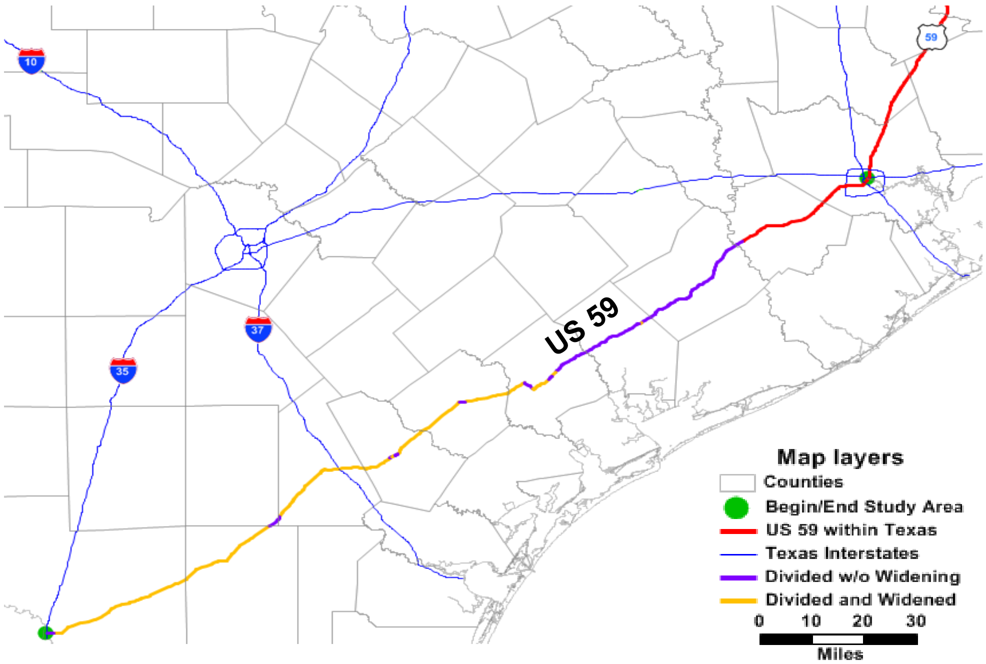
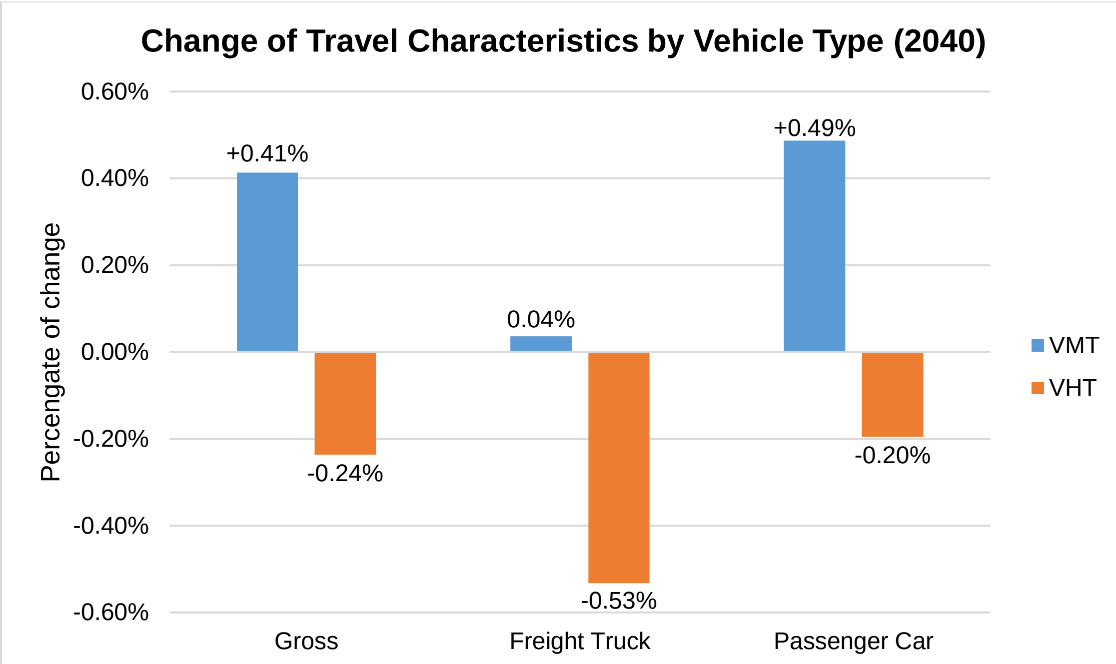


Table 3.31 Extent of Modifications for US 59 Segment under Analysis

Unit	Extent	Miles
	Length of US 59 in Texas	608.3
	Length of the study area (Laredo to Houston)	314.0
	Percentage modified within the study area	85%
Length	Total length modified	267.1
	Length upgraded from FC 6 to 2	0
	Length upgraded from FC 16 to 14	0
	Divider added without widening	91.2
	Divider added with widening	175.8
	Length widened without upgrade	175.8
Lane-miles	Number of added lane-miles	351.7
	Lane-miles added with the upgrade	0
	Lane-miles added without upgrade	351.7
	Lane-miles upgraded from FC 6 to 2	0
	Lane-miles upgraded from FC 6 to 2 and widened	0
	Lane-miles upgraded from FC 6 to 2 without widening	0
	Lane-miles upgraded from FC 16 to 14	0

The simulation modeling reveals that upgrading US 59 would cause a system-wide increase in VMT and decrease in VHT (see Figure 3.33). Freight trucks experience only a slight increase in VMT but a significant decrease VHT, indicating a notable improvement of freight traffic conditions.

Figure 3.33: Change of Travel Characteristics by Vehicle Type for US 59



The economic analysis demonstrates that the decrease of VHT brings about significant benefits in vehicle travel time and reliability, safety and logistics/freight cost savings. Minor negative benefits are seen in vehicle operating costs and emission due to increased VMT. Overall, the simulation implies that improving the US 59 segment between Laredo and Houston to a four-lane divided highway is very cost-effective with a benefit-cost ratio of 11.3 and 8.6, respectively, with 3% and 7% discount rates.

Table 3.32 Benefit-Cost Summary of Upgrading US 59 Segment under Analysis

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**12,527**	**7,186**
	Value of Vehicle Operating Cost	-1,091	-185
	Value of Vehicle Travel Time	5,603	3,395
	Value of Improved Travel Time Reliability	3,266	1,537
	Value of Safety Improvement	2,692	1,334
	Value of Emission Reduction	-40	53
	Value of Logistics & Supply Chain Cost Savings	2,097	1,051
Present Value of Cost Stream		**1,112**	**833**
	Capital Investment Costs	1,471	931
	Operation and Maintenance Costs	49	22
	Cost Adjustments	-407	-120
Net Benefit (Benefits - Costs)		**11,415**	**6,353**
Benefit Cost Ratio (Benefits / Costs)		**11.3**	**8.6**

US 281

From Wichita Falls to San Antonio, US 281 extends 375.4 miles. Of this length, 81% needs to be either upgraded to principal arterial (minimum functional classification for divided roadways), expanded to two lanes each direction, or both.

Figure 3.34 demonstrates the segments of US 281 between Wichita Falls and San Antonio that need to be upgraded in terms of functional class or widened. Outside of Wichita Falls (where US 281 is coincident with I-44) and San Antonio (where US 281 is coincident with I-10), the longest segment (102 miles) that already meets the width criteria of having four lanes is in Burnet County west of Austin. The majority of the rest of the corridor, totaling up to 211.9 miles, would need to be widened. Even long segments that already have four lanes, such as the 102-mile segment in Burnet County, would still need to be upgraded to a divided highway.

Figure 3.34: Extent of Modification for US 59 Segment under Analysis

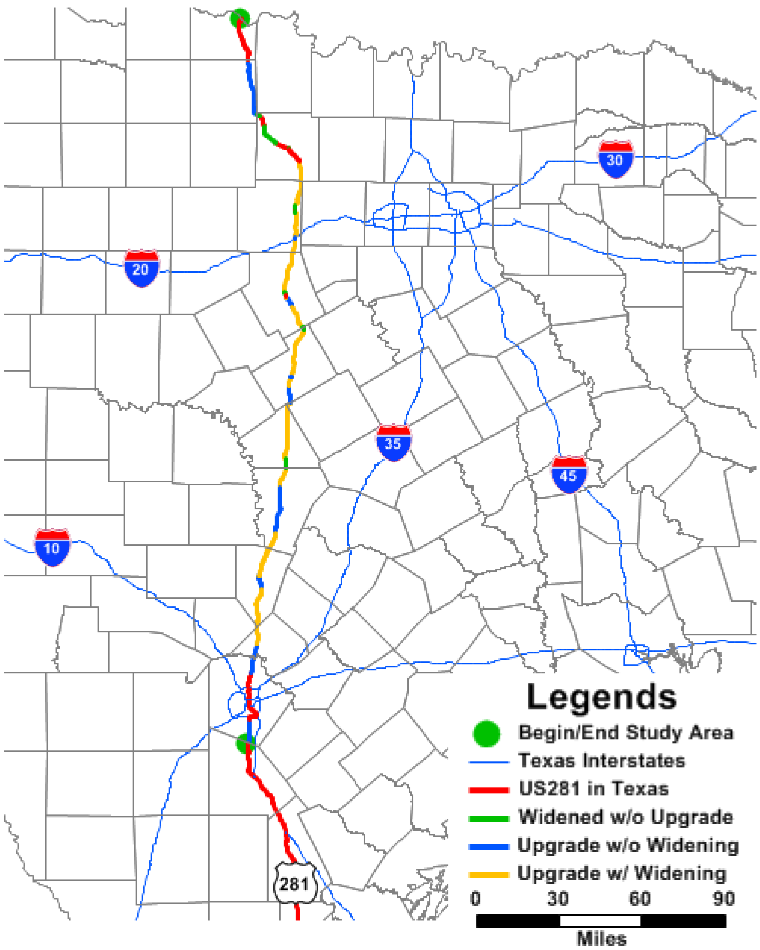


Table 3.33 provides more details of the modifications required to upgrade the corridor to the minimum standard of a four-lane divided highway. Large portions of the corridor are currently classified as rural or urban minor arterials (functional classes 6 and 16 respectively). Those segments were changed to functional class 2 (rural primary arterial) or 14 (other urban principal arterial) in the simulation.

Table 3.33 Extent of Modifications for US 281 Segment under Analysis

Units	Extent of modification	Miles
	Length of US 281 in Texas	627.3
	Length of the study area (Wichita Falls to San Antonio)	375.4
	Percentage modified within the study area	81%
Length	Length upgraded from FC 6 to 2	276.5
	Length upgraded from FC 16 to 14	5.9
	Length upgraded from FC 6 to 2 and widened	190.5
	Length upgraded from FC 6 to 2 without widening	86.0
	Length upgraded from FC 16 to 14 and widened	0
	Length upgraded from FC 16 to 14 without widening	5.9
	Length widened without upgrade	21.4
Lane-miles	Number of added lane miles	423.8
	Lane-miles upgraded from FC 6 to 2 including widening	1114.4
	Lane-miles upgraded from FC 6 to 2 without widening	352.5
	Lane-miles upgraded from FC 16 to 14 including widening	0
	Lane-miles upgraded from FC 16 to 14 without widening	68.8
	Lane-miles added without upgrade	416.0

The simulation modeling reveals that upgrading the segment on US 281 would induce more trips by car and cause a slight increase of system-wide VMT (see Figure 3.35). However, even though more trips are moving on the roadway network, the system-wide VHT decreases, indicating improved travel conditions. Freight trucks experience a slightly lower-than-average decrease in VHT and a much smaller increase in VMT.

Figure 3.35: Change of Travel Characteristics by Vehicle Type for US 281

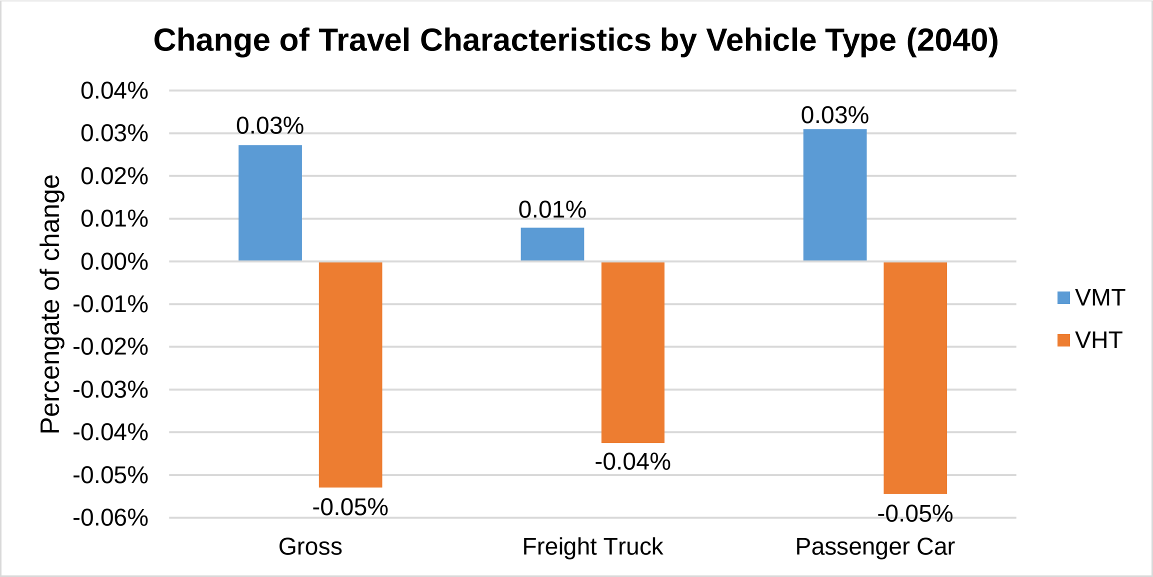


Table 3.34 summarizes the economic benefits and costs of the US 281 upgrade scenario. The overall construction cost of upgrading US 281 might be slightly over $2.4 billion (year-of-expenditure dollars) as

shown in Table 3.26 previously, although the present value of that cost will vary based on when the project is undertaken. For the economic analysis here, the study team assumed that the construction costs would be accrued by 2030, halfway through the analysis period.

As shown in Table 3.34, the upgrades improve system travel conditions with positive benefits in all categories. The benefits are slightly higher than the costs under a 3% discount rate and are not enough to cover the cost of the upgrade under a 7% discount rate, according to the study team's estimation of the potential cost.

Table 3.34 Benefit-Cost Summary of Upgrading US 281 Segment under Analysis

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**1,535**	**818**
	Value of Vehicle Operating Cost	77	85
	Value of Vehicle Travel Time	994	485
	Value of Improved Travel Time Reliability	87	34
	Value of Safety Improvement	159	83
	Value of Emission Reduction	33	27
	Value of Logistics & Supply Chain Cost Savings	184	104
Present Value of Cost Stream		**1,301**	**974**
	Capital Investment Costs	1,721	1,089
	Operation and Maintenance Costs	57	26
	Cost Adjustments	-476	-141
Net Benefit (Benefits - Costs)		**234**	**-156**
Benefit-Cost Ratio (Benefits / Costs)		**1.2**	**0.8**

The simulation results also indicate that upgrading US 281 may have limited effects in terms of relieving congestion on the portion of I-35 parallel to US 281, as shown in Table 3.35. After the upgrade, the US 281 corridor itself will have better flow, leading to improvements in travel time (reduced by 3% from the base case) and reliability, but the travel time along either the full I-35 corridor or the I-35 section within Texas Triangle would barely improve.

Table 3.35 Average Traverse Time Comparison

Corridors	Segment Average Traverse Time in Hour (Percentage of Change from the Base Case)	
	Base Case	Upgrade US 281 Segment under Analysis
I-35 Full Corridor	11.01	10.98 (-0.3%)
I-35 within Texas Triangle	8.18	8.15 (-0.3%)
US 281 from San Antonio to I-20	15.34	14.90 (-2.9%)

3.11.5 Conclusions

US 87 from the TX/NM State Line to I-10, US 69 from Beaumont to US 175 (South of Tyler), US 59 from Laredo to Houston, and US 281 from San Antonio to I-20 (Wichita Falls) are key segments of the Texas Highway Trunk System. Improvements to these corridor segments are expected to help relieve congestion on the parallel interstate highway, promote connectivity, and enhance safety. Currently, significant portions of these corridor segments do not meet the standard of a four-lane divided highway. Upgrading these portions might improve the flow along these important corridors, potentially extending to the entire roadway system. The CTR study team simulated the upgrade of these four corridors and analyzed their travel impacts using SAM, and evaluated their economic impact using economic analysis tool TREDIS.

To upgrade those rural corridor segments to the minimum standard of a divided four-lane highway, different portions of them need to be modified by either upgrading their functional class, increasing the number of lanes, or both. Following are the percentages of these segments that need to be modified:

- US 87: 37.5%
- US 69: 78%
- US 59: 85%
- US 281: 81%

The US 59 segment from Laredo to Houston would need the most modification since 85% of that segment is currently under the standard of a four-lane divided highway. Both US 281 and US 69 require significant modifications as well.

The study team developed a method to estimate the cost required for upgrading these rural corridors, based on work that has been done to estimate the costs along the US 59 corridor. The actual cost might be higher or lower depending on how conditions along individual corridors vary. With the current cost estimates, the simulations and economic analysis indicate that the upgrades on all four rural corridor segments are cost-effective. They all generate positive benefits in travel time and reliability improvement, safety improvement, and logistics/freight cost savings. Overall, the upgrade on US 59 is the most cost-effective with a benefit-cost ratio as high as 11.3 with a 3% discount rate. Upgrades on US 281 may need to be completed at a lower cost to become a better investment, since the benefits are not enough to cover the costs under a 7% discount rate, according to the study team's current cost estimates.

While upgrading US 281 would generate just enough benefits to cover the cost under a 3% discount rate, this upgrade doesn't help much in terms of relieving congestion along I-35. The simulations indicate that very little traffic would be diverted from I-35 to US 281. The travel time along either the full I-35 corridor or the I-35 sections within the Texas Triangle are barely improved after the US 281 upgrade. It is worth noting that SAM, as a travel demand model, captures only travel time savings. People may choose US 281 over I-35, especially after the US-281 upgrades, to avoid traveling alongside a large number of heavy trucks or to bypass larger cities. However, these factors impacting route choice are not captured by SAM and, therefore, are not reflected in the economic benefits shown earlier.

3.12 Improving I-35 and Upgrading US 281

3.12.1 Overview

The study team analyzed the travel and economic impacts of implementing all projects planned or proposed along the entire I-35 corridor. As established, the two sources for identifying these projects are TxDOT's SAM and ODP. While studying the travel and economic impacts of upgrading US 281 to the minimum standard of a four-lane divided highway (see the US 281 discussion in Section 3.11.4), the study team found that upgrades to US 281 offer little congestion relief on I-35. The study team, therefore, created another scenario that examined the combined effects of improving I-35 and upgrading US 281.

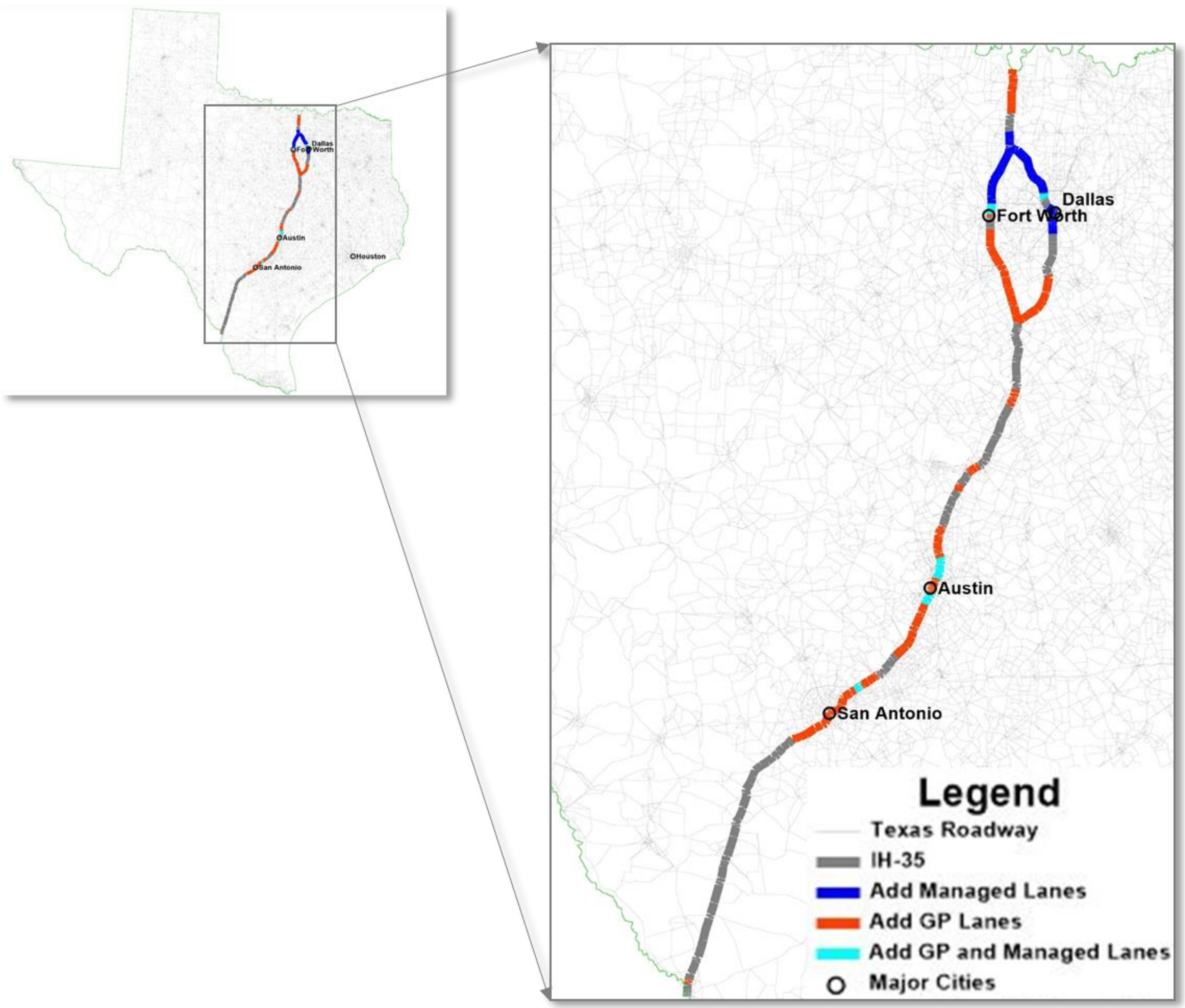
The analysis results indicate that implementing all projects proposed along the entire I-35 corridor would generate significant travel and logistics/freight benefits. The total VHT across the entire state network will reduce by 0.38% despite a 0.39 % increase in VMT. The benefit-cost ratio of these projects is 1.9 and 1.2, respectively, with a 3% and 7% discount rate.

In comparison, the combination of improving I-35 by implementing all projects and upgrading US 281 between San Antonio and Wichita Falls to the minimum standard of a four-lane divided highway caused a system-wide increase in both VMT and VHT, resulting in only minimal benefits—certainly not enough to cover the total costs.

3.12.2 I-35 Full Corridor Analysis

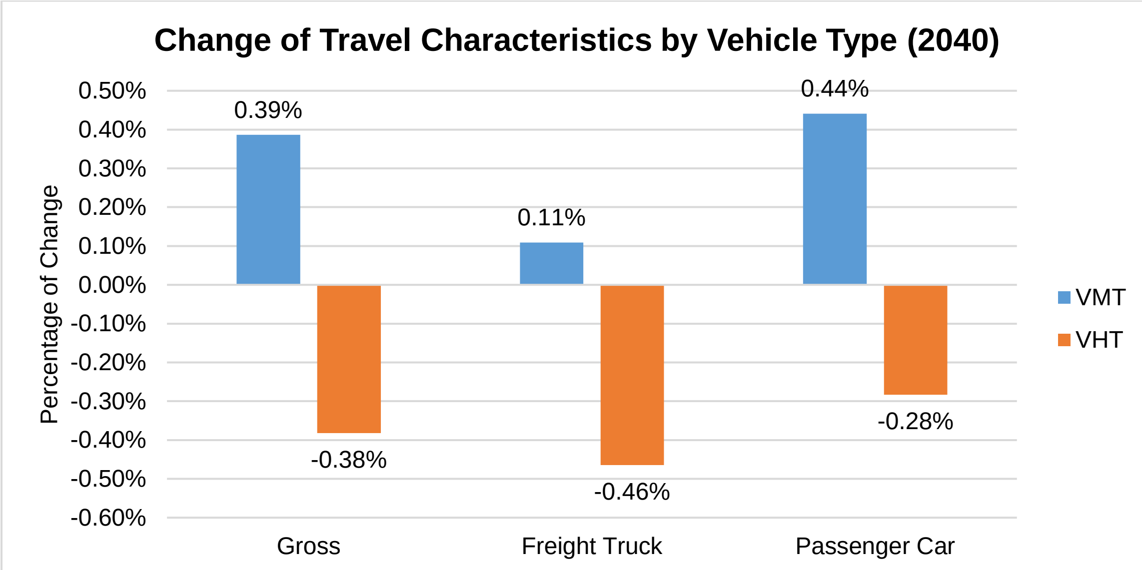
The study team identified 72 projects from SAM and 28 projects in ODP along I-35 with a project year after 2018. To evaluate the effects of these projects, the CTR team modified the SAM network based on the methodology described in Section 2.5. Details of the 72 SAM projects and 28 ODP projects can be found respectively in Table K1 and Table K2 in Appendix K.

Figure 3.36: Extent of Modification for I-35 Full Corridor



The simulation of all these projects along the entire I-35 corridor indicates significant travel impacts to the state roadway network, especially to freight trucks. The overall VMT across the entire roadway network would increase by 0.39% in 2040, while the VHT decreases by 0.38%, as shown in Figure 3.37. The VHT decreases despite the VMT increase, indicating better overall travel conditions along the entire roadway network. The freight trucks experience a higher-than-average drop of VHT with a small increase of VMT, indicating an even more significant improvement in travel conditions for freight trucks after implementing those projects along I-35.

Figure 3.37: Change of Travel Characteristics by Vehicle Type for I-35 Full Corridor



The study team also calculated the travel time needed to traverse the entire I-35 corridor and the section of I-35 within the Texas Triangle. The results are shown in Table 3.36. After implementing those projects identified from SAM and ODP along the entire I-35 corridor, the average time needed to travel through the entire I-35 corridor was reduced by over 6% and that for the Triangle section was reduced by over 3%.

Table 3.36 Travel Time Change along I-35 after Improving I-35

Traverse Time (hour)	Base Case	After Modification	Percent Change
I-35 Full Corridor	11.01	10.34	-6.1%
I-35 within the Triangle	8.18	7.91	-3.3%

The detailed benefits and costs information is summarized in Table 3.37. The project costs are obtained directly from SAM or ODP when they are available or otherwise estimated using TxDOT's sketch planning tool. It is obvious that implementing all those projects along the full I-35 corridor would generate positive benefits in terms of improvements to travel time and reliability, as well as logistics/freight cost savings. The majority of the benefits come from the improvement of vehicle travel time and reliability, rendering a benefit-cost ratio of 1.9 under a 3% discount rate, and 1.2 under a 7% discount rate. These projects are also expected to increase the GRP by over $6.5 billion in the period of time from 2018 to 2050.

Table 3.37 Benefit-Cost Summary for Improving I-35

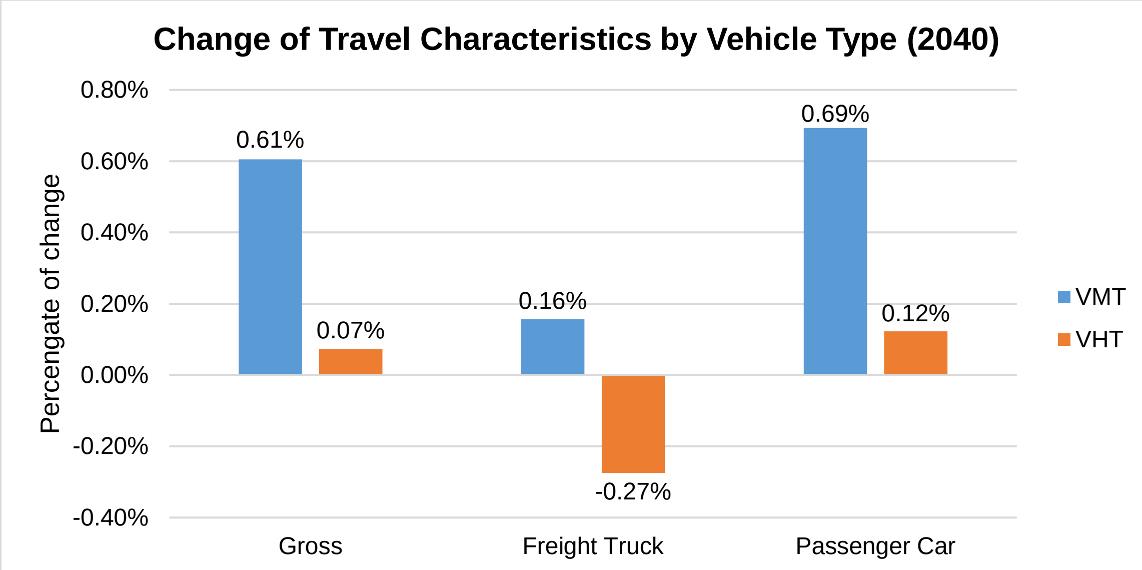
		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**2,793**	**1,217**
	Value of Vehicle Operating Cost	-3,919	-1,863
	Value of Vehicle Travel Time	8,432	3,952
	Value of Improved Travel Time Reliability	2,243	1,004
	Value of Safety Improvement	-4,532	-2,154
	Value of Emission Reduction	-1,231	-564
	Value of Logistics & Supply Chain Cost Savings	1,800	841
Present Value of Cost Stream		**1,493**	**1,014**
	Capital Investment Costs	2,134	1,195
	Operation and Maintenance Costs	55	25
	Cost Adjustments	-695	-205
Net Benefit (Benefits - Costs)		**1,300**	**203**
Benefit-Cost Ratio (Benefits / Costs)		**1.9**	**1.2**

3.12.3 Improving I-35 and Upgrading US 281

As discussed in the US 281 portion of Section 3.11.4, upgrading US 281 did little to relieve congestion along I-35 while improving the full I-35 corridor by implementing all the planned or proposed corridor projects proved to be cost-effective, as shown in Table 3.36. The CTR team was interested in exploring whether the combined effects of improving I-35 and upgrading US 281 would be more or less cost-effective and whether this combined scenario would help relieve some congestion along I-35. The CTR team combined all the changes made to the roadway network described in Section 3.12.2 and the US 281 portion of Section 3.11.4 in this new scenario.

The simulation results indicate that improving I-35 and upgrading US 281 together increases both gross VMT and gross VHT, as shown in Figure 3.38. The increase in VMT is quite significant. Freight trucks experience reduced VHT despite an increase in VMT; however, passenger cars experience a higher-than-average increase in both VMT and VHT.

Figure 3.38: Change of Travel Characteristics by Vehicle Type for I-35 Improvement and US 281 Upgrade



The reduction in freight truck VHT brings about positive benefits in travel time reliability, logistics, and supply chain cost savings, as shown in Table 3.38. However, these positive benefits are almost canceled out by the negative benefits in vehicle operating cost, safety, and emissions caused by the significant increase of VMT, resulting in a very small amount of total benefits and a negative net benefit.

Table 3.38 Benefit-Cost Summary for I-35 Improvement and US 281 Upgrade

		3% discount rate ($M)	7% discount rate ($M)
Present Value of Benefit Stream		**34**	**40**
	Value of Vehicle Operating Cost	-4,497	-2,073
	Value of Vehicle Travel Time	-954	-430
	Value of Improved Travel Time Reliability	5,720	2,592
	Value of Safety Improvement	-548	-250
	Value of Emission Reduction	-783	-339
	Value of Logistics & Supply Chain Cost Savings	1,095	541
Present Value of Cost Stream		**8,150**	**7,177**
	Capital Investment Costs	10,405	7,952
	Operation and Maintenance Costs	370	191
	Cost Adjustments	-2,624	-775
Net Benefit (Benefits - Costs)		**-8,116**	**-7,136**
Benefit-Cost Ratio (Benefits / Costs)		**0.004**	**0.006**

Although improving I-35 combined with upgrading US 281 does not generate much in terms of overall benefits, the travel conditions along I-35 and US 281 improved slightly, as shown in Table 3.39. The travel time needed to traverse the entire I-35 corridor and the section of I-35 within the Texas Triangle reduced by over 5% and 3% respectively. The average time needed to travel the segment of US 281 from San Antonio to I-20 reduces by over 2%.

Table 3.39 Travel Time Change along I-35 after Improving I-35 combined with Upgrading US 281

Traverse Time (hour)	Base Case	After Modification	Percent Change
US 281	15.34	14.97	-2.4%
I-35 Full Corridor	11.01	10.44	-5.2%
I-35 within the Triangle	8.18	7.91	-3.3%

3.12.4 Conclusions

The analysis results indicate that implementing all projects planned or proposed along the entire I-35 corridor would generate significant travel and logistics/freight benefits. The total VHT across the entire state network will reduce by 0.38% in 2040 despite a 0.39% increase in VMT. The travel time required to traverse the full I-35 corridor and the I-35 segments within the Texas Triangle reduce by 6% and 3% respectively. The total benefits ($2.36 billion with 3% discount rate) outweigh the total costs ($2.19 billion with 3% discount rate), rendering a benefit-cost ratio of 1.6 and 1.0, respectively, with 3% and 7% discount rates.

In comparison, improving I-35 and upgrading the segment of US 281 between San Antonio and Wichita Falls to the minimum standard of a four-lane divided highway didn't provide many benefits. The total benefits ($34 million with 3% discount rate and $40 million with 7% discount rate) are too small to cover the costs ($8.1 billion with 3% discount rate and $7.2 billion with 7% discount rate). The simulations indicate that the travel time along the full I-35 corridor, the I-35 Triangle section and US 281 between San Antonio and Wichita Falls are all improved slightly after the combination of I-35 improvement and US 281 upgrade.

Chapter 4. Conclusions and Recommendations

To evaluate the statewide travel and economic impacts of planned or proposed freight corridor projects, in collaboration with TxDOT Freight and International Trade Section, the CTR study team developed a systematic framework based on the statewide travel demand model SAM and the widely used economic analysis model TREDIS. This framework examines the travel and economic impacts of a set of projects from the perspective of the entire roadway network. This study was necessary because while certain projects may help improve local travel conditions in the short term, they may cause negative travel and economic impacts to the wider region (e.g., the entire state) in the long term due to route and mode shift of traffic and goods.

The framework developed in this project includes an automated data processing tool that can be used by TxDOT to easily build the connection between SAM and TREDIS, allowing the analysis of different scenarios as future projects are proposed.

Using this framework, the CTR team helped evaluate the travel and economic impacts of various scenarios. These scenarios include upgrading important freight corridors to a higher standard (e.g., the standard of a four-lane divided highway or interstate highway), implementing all planned or proposed projects along an important freight corridor, and implementing projects that aim to relieve severe traffic congestion; also considered were some hypothetical scenarios exploring the potential of using truck-only lanes or truck platooning to improve freight efficiency. These scenarios result in different impacts on the network-wide travel conditions and result in both positive and negative effects according to the various benefits categories. Most of the scenarios analyzed in this project are proved to be cost-effective with overall benefit-cost ratios higher than one.

All the scenarios examined in this projects are analyzed against the same base case, enabling comparison across different scenarios. Table 4.1 ranks all the scenarios examined by the CTR team based on the final benefit-cost ratio with a 3% discount rate. Note that though the Truck Platooning scenario was included in this table, it is not really comparable with other scenarios since the public sector is not expected to contribute significant funds to implement truck platooning. All scenarios except the one expanding all interstates to at least three lanes each direction generate positive overall benefits. Seventeen of them result in benefit-cost ratios higher than one, indicating they are cost-effective investments. Only two scenarios resulted in benefits that were not high enough to cover the costs: implementing a list of projects planned under the Clear Lanes initiative and implementing all projects along the entire I-35 corridor combined with upgrading US 281 to the minimum standard of a four-lane divided highway.

Table 4.1 Ranking of Scenarios Based on Benefit-Cost Ratio with 3% Discount Rate

Ranking	Scenario Description	Benefit-Cost Ratio with 3% Discount Rate
1	Examining several hypothetical scenarios with different penetration rates of truck platooning along several corridors.	Conservative: 182 Neutral: 573 Optimistic: 1428
2	Upgrading I-2 to the minimum standard of a four-lane divided interstate highway.	45
3	Add a GP lane along the interstate highways connecting the Texas Triangle.	17.9
4	Upgrade US 59 from Laredo to Houston to the minimum standard of a divided four-lane highway.	11.3
5	Upgrading I-69 to the minimum standard of a four-lane divided interstate highway.	8.5
6	Implementing all the projects planned or proposed at the top 20 overall congested locations.	5.2
7	Add truck-choice lanes along the interstate highways connecting the Texas Triangle.	5.0
8	Implementing all the projects planned or proposed at the top 25 trucking congested locations.	4.8
9	Upgrading US 69 from Beaumont to US 175 to the minimum standard of a divided four-lane highway.	3.8
10	Upgrading US 87 from TX/NM State Line to I-10 to the minimum standard of a divided four-lane highway.	2.9
11	Add full exclusion truck-only lanes along the interstate highways connecting the Texas Triangle.	2.8
12	Implementing all projects planned or proposed along the segment of I-35 within the Texas Triangle.	2.7
13	Upgrading I-27/Ports-to-Plains corridor to the minimum standard of a four-lane divided interstate highway.	2.1
14	Expanding interstates within the Texas Triangle to at least three lanes each direction.	2.1
15	Implementing all projects planned or proposed along the segment of I-10 within the Texas Triangle.	2.0
16	Implementing all projects planned or proposed along the entire I-35 corridor.	1.9
17	Upgrading US 281 from San Antonio to I-20 to the minimum standard of a divided four-lane highway.	1.2
18	Implementing a list of projects planned under the Clear Lanes congestion relief initiative.	0.6
19	Implementing all projects planned or proposed along the entire I-35 corridor combined with upgrading US 281 to the minimum standard of a four-lane divided highway	0.004
20	Expanding all interstates to at least three lanes each direction.	-0.2

The study team expects that the study framework and tools developed in this study can be used by TxDOT to evaluate many more projects; the analysis results from the scenarios included in this study or any future scenarios will help inform project selection and freight corridor improvement investment decision-making.

Appendix A. TREDIS Benefit-Cost Analysis Overview

A.1 Discount Rate

The discount rate is used to convert dollar measures through time. Higher discount rates generally apply to situations where there is a high opportunity cost—the money spent on a scenario could be spent on something else with a very high return on investment. Because most transportation projects accrue high initial costs and see benefits later (after the project is built), higher discount rates generally correspond to lower benefit-cost ratios.

The Federal Office of Management and Budget (OMB) recommends the use of 3% and 7% discount rates for the analysis of regulations or public investments. These rates respectively correspond to the equivalent "social rate of time preference" and the US economy's rate of return for private capital[22].

The analyses presented by the study team show the results of both 3% and 7% discount rates.

A.2 Traveler Benefits

This is a category defined by TREDIS as "benefits accruing to drivers, passengers and vehicle costs as a result of improvements in travel times, travel expenses, and travel safety." This category also includes the benefits associated with modal shifts and changes in origin-destination patterns. The net benefits for this category are aggregated from all modes in the analysis. Within the traveler benefits category are several subcategories of benefits:

- Value of vehicle operating costs (VOC)
- Value of in-vehicle travel time (IVTT)
- Value of improved travel time reliability
- Value of safety improvements
- Value of consumer surplus from induced new activity

In the following formulae, a superscript of *scenario* indicates that the value will change for each simulation. A subscript of *mode purpose* means that a value can vary across modes or across trip purposes. The formulae generally represent costs. Value (either positive or negative) is obtained in each category by taking the difference from the base case. For example, if a scenario has a smaller VOC than the base case, it will have a positive benefit for the VOC category.

A.2.1 Vehicle Operating Costs (VOC)

For passenger cars and freight trucks, TREDIS uses the following formula to calculate VOC:

$$VOC_{modepurpose}^{scenario} = VMT_{modepurpose}^{scenario} \cdot \{(\text{CpM\_C}_{modepurpose} \cdot \%Congested_{modepurpose}^{scenario}) + \left(\text{CpM\_FF}_{modepurpose} \cdot (1 - \%Congested_{modepurpose}^{scenario})\right)\}$$

Where:

- $VOC_{modepurpose}^{scenario}$ is the VOC within a scenario for a particular mode purpose
- $VMT_{modepurpose}^{scenario}$ is the sum of the VMT within a scenario for a particular mode purpose
- $\text{CpM\_C}_{modepurpose}$ is the per-mile cost of travel for a particular mode purpose in congested conditions
- $\text{CpM\_FF}_{modepurpose}$ is the per-mile cost of travel for a particular mode purpose in un-congested conditions

[22] US Office of Management and Budget. "Circular A-4; regarding Regulatory Analysis." September 17, 2003: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf

- $\%Congested_{modepurpose}^{scenario}$ is the fraction of travel (on a per-mile base) within a scenario that is along congested links ($\mathrm{v/c} > 0.80$)

The per-mile travel costs reflect user costs, such as fuel, maintenance, and depreciation. For non-road modes, such as air and rail, TREDIS incorporates a per-hour operating cost with the per-mile cost, in lieu of using the percentage of congested travel.

This value will incorporate both trucking and non-trucking values, although trucking values tend to compose a small share of the total. For a typical scenario involving highway improvements, it is common to see the percentage of congested travel go down while the total VMT increases. This means that the difference from the base case might be positive or negative.

A.2.2 Travel Time Costs

IVTT, or simply travel time costs, represents the opportunity cost of time spent traveling. IVTT comprises three distinct elements: passenger travel time cost, crew travel time cost, and freight travel time cost. The first two can simply be calculated based on VHT, average vehicle occupancy, and a value of time factor:

$$PassengerTimeCost_{modepurpose}^{scenario} = VHT_{modepurpose}^{scenario} \cdot PassPerVeh_{modepurpose} \cdot PassVOT_{modepurpose}$$

$$CrewTimeCost_{modepurpose}^{scenario} = VHT_{modepurpose}^{scenario} \cdot CrewPerVeh_{modepurpose} \cdot CrewVOT_{modepurpose}$$

For freight time costs, the model calculates the value for each mode based on the commodity mix:

$$\begin{gathered} FreightTimeCost_{modepurpose}^{scenario} = VHT_{modepurpose}^{scenario} \cdot \\ \sum \big(AvgTonsPerVeh_{modepurpose}^{scenario} \cdot CommodityMix_{modepurpose,c}^{scenario} \\ \cdot AvgCostPerTonHr_{modepurpose} \cdot CommodityValueFactor_c \big) \end{gathered}$$

The commodity mix for each commodity, c, is based on TransSearch data internal to TREDIS.

The difference in IVTT value between a scenario and the base case will be positive if the VHT, weighted by each mode, falls.

A.2.3 Reliability Costs

In TREDIS, reliability is based around the buffer time index (BTI): the amount of time that travelers need to add to a trip in order to reliably arrive on time. TREDIS calculates an average BTI using an internal, empirically determined function based on the fraction of congested travel:

The TREDIS documentation does not specify the exact form of this function, but testing shows that it can approximately be given by:

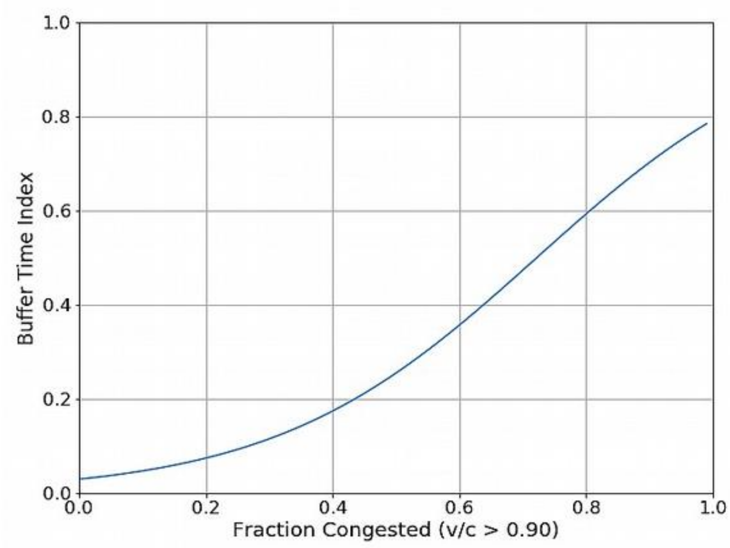
$$BTI(\%Congested) = \frac{1}{1 + exp\big(-4.83 \cdot ([\%Congested] - 0.721875)\big)}$$

Once the average BTI is calculated, the model computes the reliability cost for each mode:

$$\begin{aligned} &ReliabilityCost_{modepurpose}^{scenario} \\ &\quad = BTI\big(\%Congested_{modepurpose}^{scenario}\big) \cdot VHT_{modepurpose}^{scenario} \cdot CostPerBufferHr_{modepurpose} \end{aligned}$$

The cost per buffer hour is a parameter that varies by mode and trip purpose. It reflects the opportunity cost of time budgeted to ensure a higher percentage of on-time arrival, as well as the cost of late arrivals for the remaining fraction of trips.

Figure A1: Buffer Time Index as a Function of the Fraction of Travel Congested



A.2.4 Safety Costs

TREDIS calculates the safety costs by mode based on per-mile crash rates and fixed per-crash costs. TREDIS uses three crash categories:

- Fatal crashes, corresponding to category K in the KABCO scale
- Injury crashes, corresponding to categories A, B, or C in the KABCO scale
- Property-damage-only crashes, corresponding to category O in the KABCO scale

The safety cost for a particular mode purpose within a scenario can be given by the following equation:

$$SafetyCost_{modepurpose}^{scenario} = VMT_{modepurpose}^{scenario} \cdot \big(\mathrm{CR\_Fatal}_{modepurpose}^{scenario} \cdot FatalCrashCost + \mathrm{CR\_Injury}_{modepurpose}^{scenario} \cdot InjuryCrashCost + \mathrm{CR\_Other}_{modepurpose}^{scenario} \cdot OtherCrashCost\big)$$

Note that in most scenarios, the crash rates, designated as CR in the formula, are the same from the base case to the scenario. One exception to this was in the study team's analysis of truck platooning, which used a lower crash rate for platooned vehicles. Another exception is that separate crash rates can be applied for travel along with different types of facilities—because highway travel is generally safer (on a per-mile basis), it has a lower than crash rate than, for example, urban arterial travel.

A.3 Non-Traveler Benefits

A.3.1 Environmental Costs

The environmental costs are calculated based on vehicle emissions rates and pollutant costs. TREDIS uses separate emissions rates for congested and non-congested travel (vehicles tend to have higher emissions in more congested conditions). The model uses constant emissions cost factors, meaning that it does not account for proximity to urban centers.

The following equation provides the environmental costs for each mode purpose in a scenario:

$$EnvironmentalCost_{modepurpose}^{scenario} = VMT_{modepurpose}^{scenario} \cdot \big(\mathrm{ECpM\_C}_{modepurpose} \cdot \%Congested_{modepurpose}^{scenario} + \mathrm{ECpM\_FF}_{modepurpose} \cdot (1 - \%Congested_{modepurpose}^{scenario})\big)$$

Where $ECpM\_C$ and $ECpM\_FF$ are respectively the emissions costs per mile in congested and non-congested conditions. These costs can be calculated based on a specific mode's emissions rates for different pollutants, such as NO_X, SO_X, and CO_2.

Appendix B. Parameters for TREDIS Benefit-Cost Analysis

The tables in this appendix present the default parameters used for the analysis in TREDIS. Fields highlighted in green are parameters that affect trucking benefits. The parameters are grouped by the type of benefit they affect.

Category	Mode	Symbol	Default Value	Description
Vehicle Operating Costs	Heavy Truck	$CpM\_C_{HeavyTruck}$	$0.4513/mile	The per-mile cost of operating a vehicle in congested (C) and non-congested (FF) conditions. Includes maintenance, tires, and mileage-based depreciation and insurance. Fuel cost is treated separately from other vehicle operating costs. It is calculated based on the unit cost of fuel, applicable fuel taxes, and the per-mile fuel consumption rate.
		$CpM\_FF_{HeavyTruck}$	$0.4513/mile	
	Other Truck	$CpM\_C_{OtherTruck}$	$0.4513/mile	
		$CpM\_FF_{OtherTruck}$	$0.4513/mile	
	Cars	CpM_C_{Car}	$0.1437/mile	
		CpM_FF_{Car}	$0.143667/mile	
	gasoline vehicles	$FuelCost_{gasoline}$	$1.79/gallon	Cost per gallon of gasoline, less taxes
		$StateFuelTax_{gasoline}$	$0.20/gallon	State excise tax on gasoline, per gallon
		$FedFuelTax_{gasoline}$	$0.184/gallon	Federal excise tax on gasoline, per gallon
	diesel vehicles	$FuelCost_{diesel}$	$1.93/gallon	Cost per gallon of diesel, less taxes
		$StateFuelTax_{diesel}$	$0.20/gallon	State excise tax on diesel, per gallon
		$FedFuelTax_{diesel}$	$0.244/gallon	Federal excise tax on diesel, per gallon
Fuel Consumption	Heavy Truck	$FuelCons\_FF_{HeavyTruck}$	0.172414 gal/mi	Per-mile fuel consumption in congested (C) and non-congested (FF) conditions, measured in gallons; trucks are assumed to use diesel and cars are assumed to use gasoline
		$FuelCons\_C_{HeavyTruck}$	0.241379 gal/mi	
	Other Truck	$FuelCons\_FF_{OtherTruck}$	0.136986 gal/mi	
		$FuelCons\_C_{OtherTruck}$	0.191781 gal/mi	
	Cars	$FuelCons\_FF_{Car}$	0.046296 gal/mi	
		$FuelCons\_C_{Car}$	0.053241 gal/mi	

Category	Mode	Symbol	Default Value	Description
Travel Time Costs	Heavy Truck	$CrewPerVeh_{HeavyTruck}$	1 crew/veh	Crew per heavy truck
		$TonsPerVeh_{HeavyTruck}$	24.05 US tons/veh	Average cargo weight per heavy truck
		$CrewVOT_{HeavyTruck}$	$31.54/hr	Per-hour cost of labor and fringe benefits for heavy truck operators
		$AvgCostPerTonHr_{HeavyTruck}$	$1.67/ton-hr	Freight logistics per hour cost, meant to capture the business opportunity cost of freight delay
	Other Truck	$CrewPerVeh_{OtherTruck}$	1 crew/veh	Crew per truck
		$TonsPerVeh_{OtherTruck}$	4.15 US tons/veh	Average cargo weight per truck
		$CrewVOT_{OtherTruck}$	$25.29/hr	Per-hour cost of labor and fringe benefits for truck operators
		$AvgCostPerTonHr_{OtherTruck}$	$1.67/ton-hr	Freight logistics per-hour cost, meant to capture the business opportunity cost of freight delay
	Cars	$PassPerVeh_{Car;Business}$	1.41 pass/veh	Passengers per vehicle for each type of travel, including the driver, and per-passenger value of time for each type of travel
		$PassVOT_{Car;Business}$	$33.58/hr	
		$PassPerVeh_{Car;Personal}$	1.91 pass/veh	
		$PassVOT_{Car;Personal}$	$23.06/hr	
		$PassPerVeh_{Car;Commute}$	1.18 pass/veh	
		$PassVOT_{Car;Commute}$	$11.53/hr	
Reliability Costs	Heavy Truck	$\text{CostPerBufferHr}_{HeavyTruck}$	$74.84/hr	Per-hour cost of lost scheduling time due to unreliable travel conditions; equal to the value of time for passenger modes
	Other Truck	$\text{CostPerBufferHr}_{OtherTruck}$	$32.21/hr	
	Cars	$\text{CostPerBufferHr}_{Car;Business}$	$33.58/hr	
		$\text{CostPerBufferHr}_{Car;Personal}$	$23.06/hr	
		$\text{CostPerBufferHr}_{Car;Commute}$	$11.53/hr	

Category	Mode	Symbol	Default Value	Description
Safety Costs	All Modes	$FatalCrashCost$	$9 600 000/fatality	Cost per fatality, based on the value of statistical life
		$InjuryCrashCost$	$174 030/personal injury	Average cost per injury in crash types A, B, and C
		$OtherCrashCost$	$4252/property damage accident	Average cost per property damage only crash, type O
	Heavy Truck	$\text{CR\_Fatal}_{HeavyTruck}$	0.2 fatalities per 100M VMT	Crash rate by mode and crash type; measured per million vehicle-miles traveled
		$\text{CR\_Injury}_{HeavyTruck}$	6.9 injuries per 100M VMT	
		$\text{CR\_Other}_{HeavyTruck}$	96 PDO crashes per 100M VMT	
	Other Truck	$\text{CR\_Fatal}_{OtherTruck}$	0.2 fatalities per 100M VMT	
		$\text{CR\_Injury}_{OtherTruck}$	6.9 injuries per 100M VMT	
		$\text{CR\_Other}_{OtherTruck}$	96 PDO crashes per 100M VMT	
	Cars	CR_Fatal_{Car}	1.15 fatalities per 100M VMT	
		CR_Injury_{Car}	75 injuries per 100M VMT	
		CR_Other_{Car}	186 PDO crashes per 100M VMT	

Category	Mode	Symbol	Default Value	Description
Environmental Costs	Heavy Truck	$ECpM\_C_{HeavyTruck}$	$0.3256/mi	Environmental cost per mile by mode for congested (C) and non-congested (FF) travel, derived from the other parameters in this section
		$ECpM\_FF_{HeavyTruck}$	$0.2326/mi	
	Other Truck	$ECpM\_C_{OtherTruck}$	$0.1095/mi	
		$ECpM\_FF_{OtherTruck}$	$0.0782/mi	
	Cars	$ECpM\_C_{Car}$	$0.0318/mi	
		$ECpM\_FF_{Car}$	$0.0289/mi	
	Heavy Truck	$VOCemissions\_FF_{HeavyTruck}$	4.9273e-07 ton/mi	Emissions rates in US tons per mile for congested (C) and non-congested (FF) travel for each mode; there are separate rates for volatile organic compounds (VOC), oxides of nitrogen (NOX), oxides of sulfur (SOX), and particulate matter
		$NOXemissions\_FF_{HeavyTruck}$	9.4942e-06 ton/mi	
		$SOXemissions\_FF_{HeavyTruck}$	6.2832e-09 ton/mi	
		$PMemissions\_FF_{HeavyTruck}$	2.3204e-07 ton/mi	
		$VOCemissions\_C_{HeavyTruck}$	6.8983e-07 ton/mi	
		$NOXemissions\_C_{HeavyTruck}$	1.3292e-05 ton/mi	
		$SOXemissions\_C_{HeavyTruck}$	8.7964e-09 ton/mi	
		$PMemissions\_C_{HeavyTruck}$	3.2485e-07 ton/mi	
	Other Truck	$VOCemissions\_FF_{OtherTruck}$	1.3492e-06 ton/mi	
		$NOXemissions\_FF_{OtherTruck}$	1.0472e-06 ton/mi	
		$SOXemissions\_FF_{OtherTruck}$	6.2832e-09 ton/mi	
		$PMemissions\_FF_{OtherTruck}$	5.1809e-09 ton/mi	
		$VOCemissions\_C_{OtherTruck}$	1.8889e-06 ton/mi	
		$NOXemissions\_C_{OtherTruck}$	1.4661e-06 ton/mi	
		$SOXemissions\_C_{OtherTruck}$	8.7964e-09 ton/mi	
		$PMemissions\_C_{OtherTruck}$	7.2532e-09 ton/mi	

Category	Mode	Symbol	Default Value	Description
Environmental Costs (continued)	Cars	$\text{VOCemissions\_FF}_{Car}$	1.1398e-06 ton/mi	Emissions rates in US tons per mile for congested (C) and non-congested (FF) travel for each mode; there are separate rates for volatile organic compounds (VOC), oxides of nitrogen (NOX), oxides of sulfur (SOX), and particulate matter
		$\text{NOXemissions\_FF}_{Car}$	7.6390e-07 ton/mi	
		$\text{SOXemissions\_FF}_{Car}$	negligible	
		$\text{PMemissions\_FF}_{Car}$	4.6848e-09 ton/mi	
		$\text{VOCemissions\_C}_{Car}$	1.1398e-06 ton/mi	
		$\text{NOXemissions\_C}_{Car}$	7.6390e-07 ton/mi	
		$\text{SOXemissions\_C}_{Car}$	negligible	
		$\text{PMemissions\_C}_{Car}$	4.6848e-09 ton/mi	
	Cars	$CO2pGal_{gasoline}$	8.89 kg/gallon	Unlike other pollutants, CO_2 emissions are based directly on fuel consumption
	Trucks	$CO2pGal_{diesel}$	10.16 kg/gallon	
	All Modes	$CostPerTon_{VOC}$	$1872/ton	Cost per US ton for VOC, NOX, SOX, and PM
		$CostPerTon_{NOX}$	$7377/ton	
		$CostPerTon_{SOX}$	$43600/ton	
		$CostPerTon_{PM}$	$337459/ton	
		$CostPerTon_{CO2;2019}$	$43/ton	Cost per US ton for CO_2 emissions in 2019; unlike other pollutants, the real cost of CO_2 emissions might rise each year
Conversion factor	All Modes	$UStonsPerTonne$	1.10231 tons per tonne	The conversion factor between metric tonnes and US tons

Appendix C. Automated Data Processing Tool User Guide

The automated data processing tool developed by the CTR study team allows for quick conversion of SAM outputs to TREDIS inputs. This appendix provides step-by-step instructions for using the tool, along with screenshots of each step.

C.1 Necessary Software

In order to process the results of a simulation, the user will need to re-open TransCAD, meaning it is normally best to process the results on the same computer that ran the simulation. Additionally, access to Microsoft Excel and version 2.7 of Python is required.

C.2 Code Directory

All of the processing code is contained within the TREDIS Files 1.1.1v1.1 directory. This is version 1.1 of the code designed to process outputs of version 1.1.1 of SAM. The directory contains the following files and subdirectories:

- Centroid Files/
  This subdirectory contains the TransCAD files necessary for updating the matrix indices in TransCAD.

- TransCAD Macro/
  This subdirectory contains the GISDK macros for the automated steps that occur within TransCAD.

- xlsxwriter/
  This subdirectory contains a Python module that allows the Python code to interact with the Excel spreadsheets. This module is included here because it is not a part of some default Python installations.

- changelog.docx
  This Word file was made to keep track of different versions of the processing code.

- changelog.pdf
  This PDF contains the same information as the Word file.

- Cost Sources.csv
  This CSV file contains information about cost sources for the cost estimates of the SAM projects. These sources are discussed in detail in the final report of Part II of this Freight IAC, which was submitted to TxDOT in 2016.

- cost_est.csv
  This CSV file contains information from Cost Sources.csv in a format that the rest of the code can interpret. Updating Cost Sources.csv will not affect the results of the processing code—this file would need to be adjusted to change the cost of a project in the automated process.

- TREDIS Input from Python.xlsx
  This Excel spreadsheet is read and overwritten by Python as part of the automated process. It does not need to be opened at any point in normal operations.

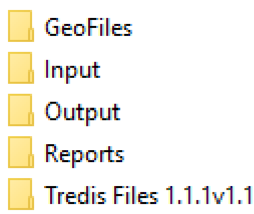
- TREDIS Input_Template.xlsm

This Excel Macro Spreadsheet is the primary way to interact with the code. It contains the button to start the automated process as well as the sheets that record the results of the processing code for input into TREDIS or input into the detailed analysis process.

- TREDIS.py
  This is the non-compiled Python code.

- TREDIS.pyc
  This is the compiled Python code.

A copy of the code directory must be placed in the directory of the SAM simulation before proceeding, as shown below:



C.3 Manual Steps

This section goes through the manual steps that must be completed before running the code.

C.3.1 Open SAM Output Files

The following files from the SAM simulation directory need to be opened in TransCAD:

- /Output/Freight/ModeChoice/Annual_Tons_by_Mode_Rail.mtx
- /Output/Freight/ModeChoice/Weekday_Truck_Trips_TAZ.mtx

C.3.2 Open Code Directory Files

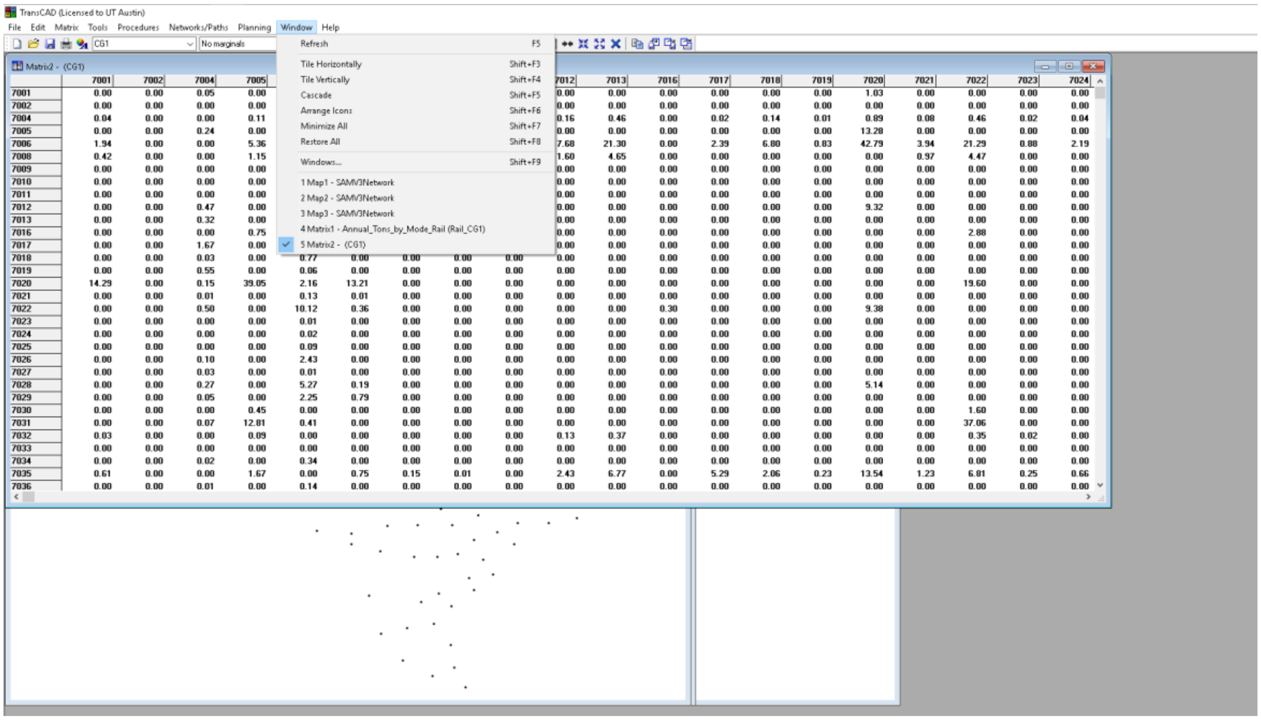
Next, the following files from the code directory need to be opened in TransCAD:

- /Tredis Files 1.1.1v1.1/7k_8k/centroids_7k_8k.dbd
  This file contains the centroids of SAM's external zones.

- /Tredis Files 1.1.1v1.1/20k_25k/centroids_20k_25k.dbd
  This file contains the centroids of SAM's traffic analysis zones (TAZs).

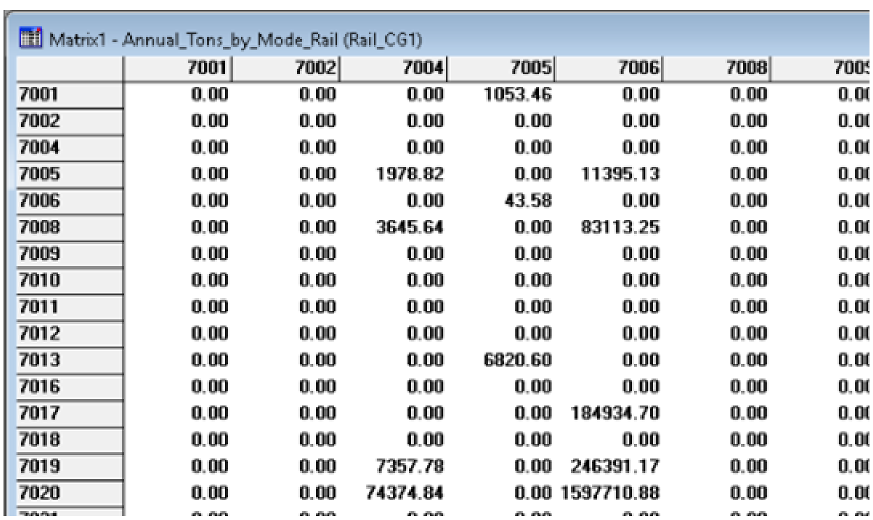
- /Tredis Files 1.1.1v1.1/48k_49k/centroids_48k_49k.dbd
  This file contains the centroids of Texas counties, which are used in lieu of TAZs for some modes such as freight rail.

There should now be five files open in TransCAD.



C.3.3 Add Matrix Indices

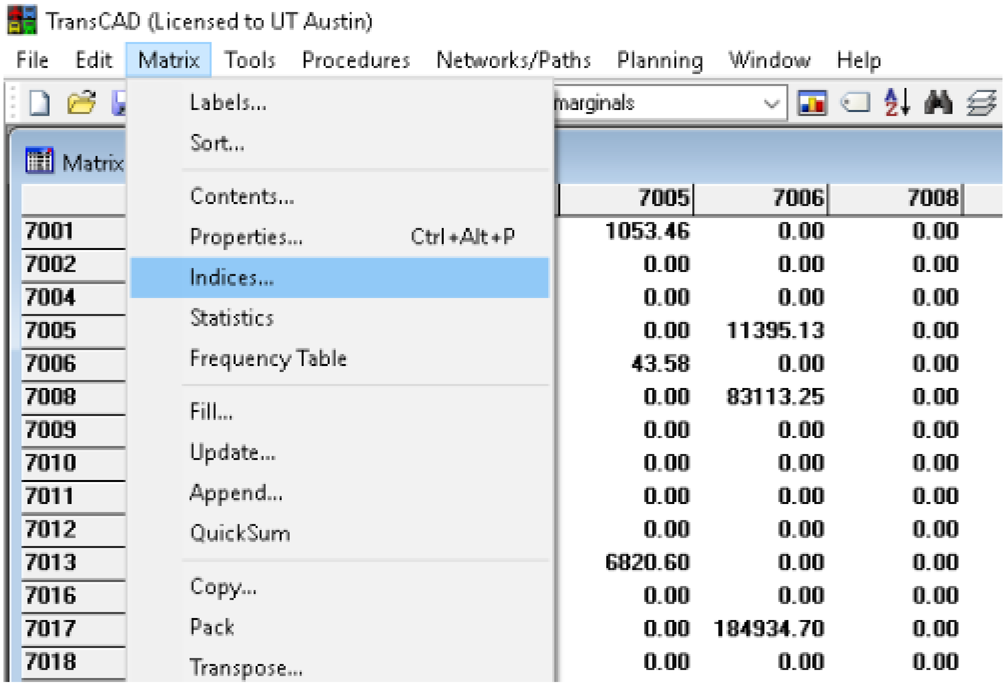
Make Annual_Tons_by_Mode_Rail.mtx the active window in TransCAD. If this was the first matrix file opened, its window might be referred to as Matrix1 in TransCAD.



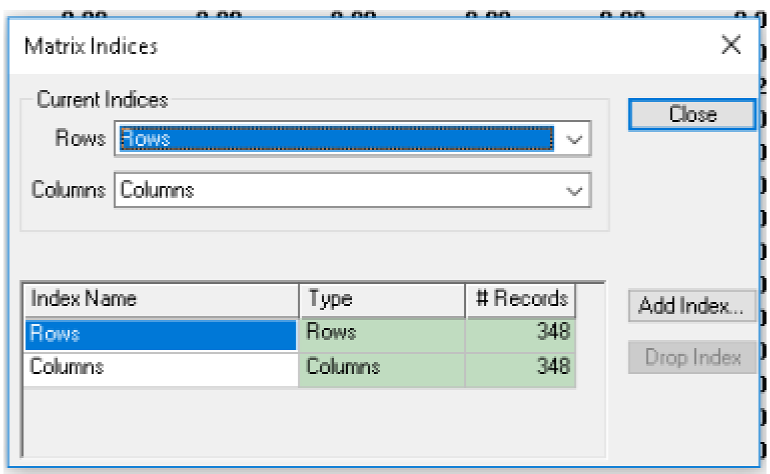
Matrix1 - Annual_Tons_by_Mode_Rail (Rail_CG1)

	7001	7002	7004	7005	7006	7008	700
7001	0.00	0.00	0.00	1053.46	0.00	0.00	0.0
7002	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7004	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7005	0.00	0.00	1978.82	0.00	11395.13	0.00	0.0
7006	0.00	0.00	0.00	43.58	0.00	0.00	0.0
7008	0.00	0.00	3645.64	0.00	83113.25	0.00	0.0
7009	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7010	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7011	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7012	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7013	0.00	0.00	0.00	6820.60	0.00	0.00	0.0
7016	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7017	0.00	0.00	0.00	0.00	184934.70	0.00	0.0
7018	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7019	0.00	0.00	7357.78	0.00	246391.17	0.00	0.0
7020	0.00	0.00	74374.84	0.00	1597710.88	0.00	0.0

With Annual_Tons_by_Mode_Rail.mtx as the active window, go to “Matrix → Indices…”.

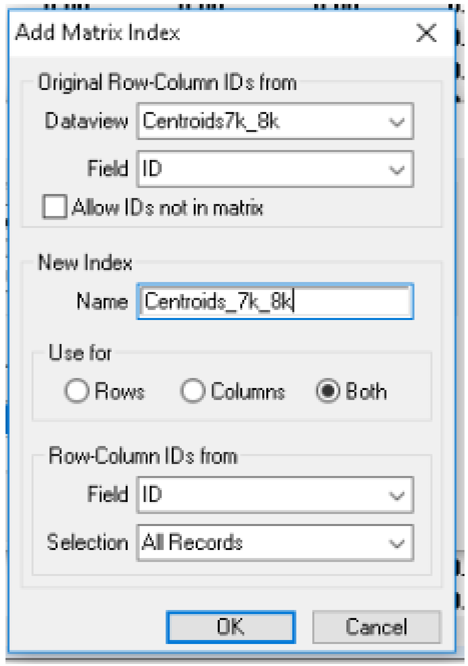


Click the “Add Index...” button.

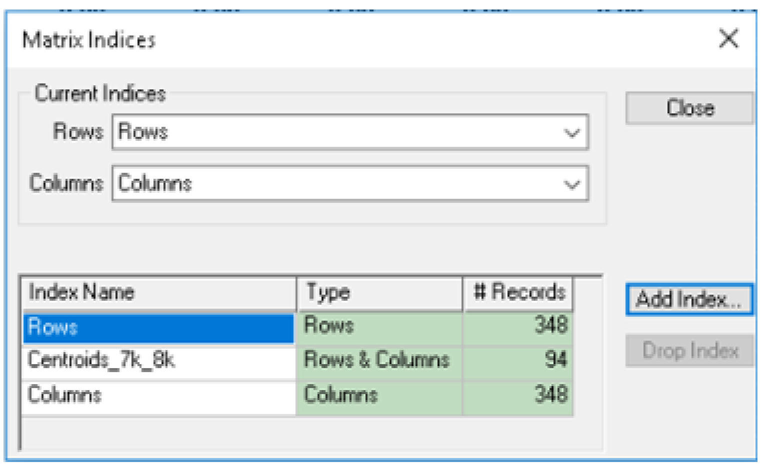


In the resulting window, select “Centroids7k_8k” from the Dataview dropdown menu and change Name to “Centroids_7k_8k” (note the extra underscore under the name). If Centroids7k_8k does not appear in the dropdown menu, the centroid files might not be opened in the same instance of TransCAD.

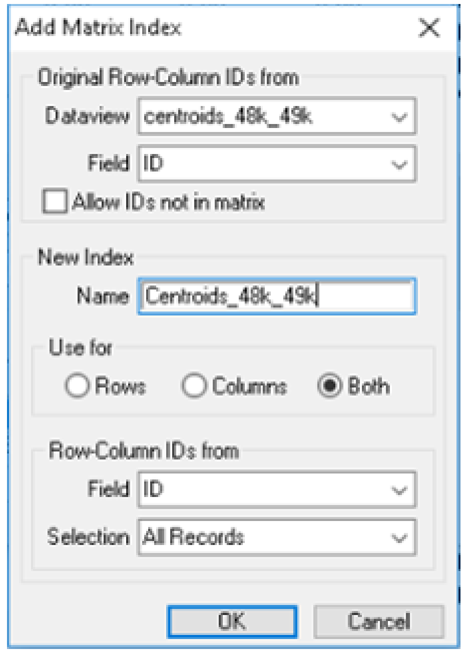
Click “OK”.



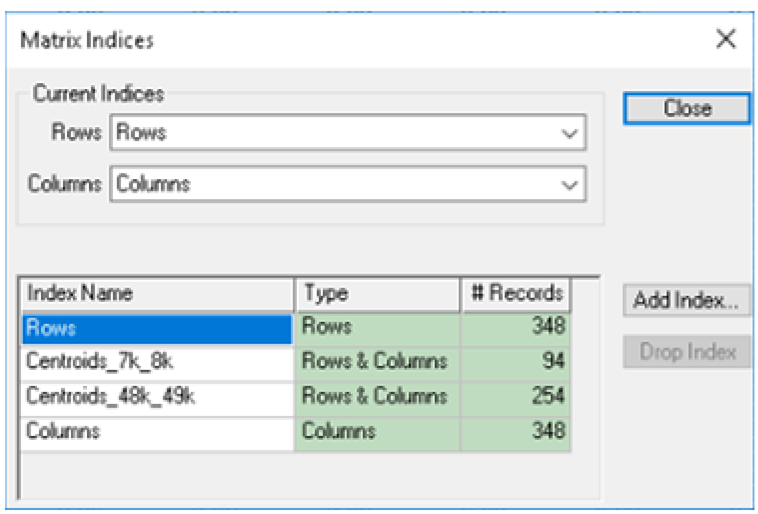
Click “Add Index...” again.



This time “centroids_48k_49k” should be selected under the Dataview dropdown menu and the Name should be changed to “Centroids_48k_49k” (note that “Centroids” is capitalized) before clicking “OK”.

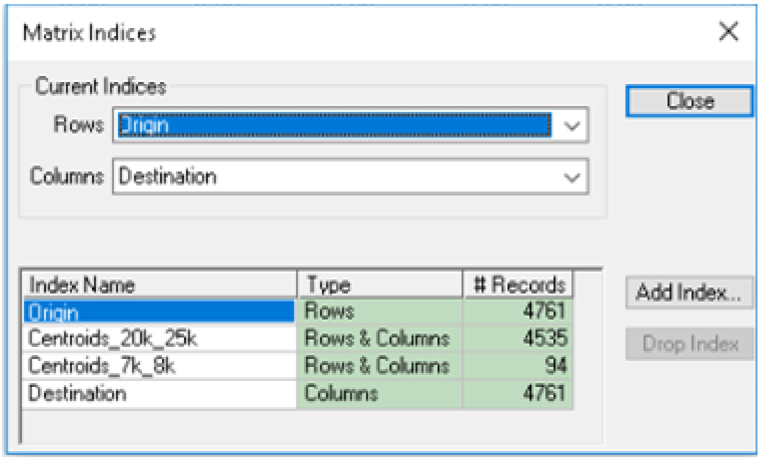


If the “Matrix Indices” window looks like the screenshot below, it can be closed.



Annual_Tons_by_Mode_Rail.mtx can now be closed. Weekday_Truck_Trips_TAZ.mtx should now be made the active window. If it was the second matrix file opened in TransCAD, it might be titled Matrix2.

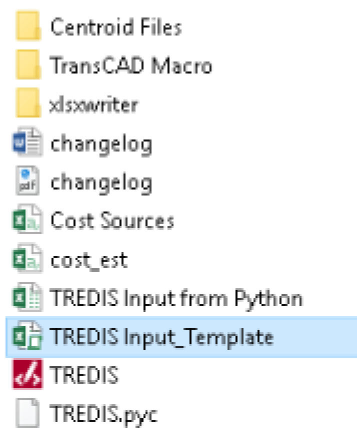
Follow the same steps as for the previous matrix file to add indices for “Centroids_7k_8k”. Instead of using Centroids_48k_49k for the second set of indices, Centroids_20k_25k should be selected. It should look as shown in the screenshot below once the indices have been added.



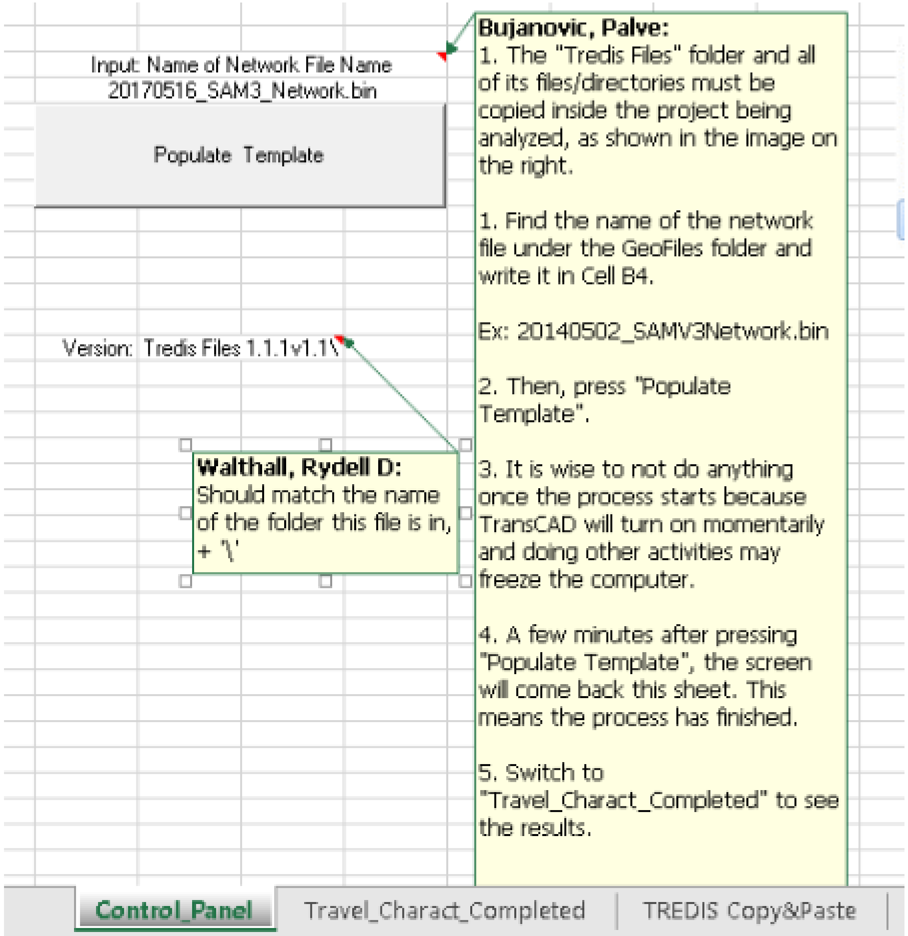
All the files in TransCAD can now be closed. **TransCAD should be exited before proceeding.**

C.4 Run the Processing Code

Open “TREDIS Input_Template.xlsm” from the “Tredis Files 1.1.1v1.1” directory within the SAM simulation directory. **It might be necessary to enable macros in Microsoft Excel if they are disabled by default.**



Go to the first sheet in the workbook, “Control_Panel”. Click the “Populate Template” button.



The automated code should now generate the necessary inputs for TREDIS. This process takes several minutes, during which using Excel or TransCAD could disrupt the results.

C.5 Interpreting the Results

Once the code finishes, the “Travel_Charact_Completed” sheet (sheet two) should be filled in with the results of the SAM simulation. This includes annual vehicle-trips, annual VMT, annual VHT, fraction congested (percentage of travel along links with a V/C ratio greater than 0.8), and internal/external fractions for each mode.

The “TREDIS Copy&Paste” sheet (sheet three) contains the same information without formatting to make it easier to copy and paste the numbers into TREDIS.

The “Costs” sheet (sheet six) contains the costs for the SAM projects in the simulation. If modifications were made to the network but were not reflected in the SAM projects, those projects’ costs will not be reflected in this sheet. The other sheets contain information from the base cases developed by the CTR team and sheets for internal calculations.

C.6 Version Compatibility

When a new version of SAM is released, substantial changes to the processing code will likely be necessary for it to produce correct outputs from the simulation.

Appendix D. List of SAM Roadway Functional Classes

Functional Classification	Description
01	Rural Interstate
02	Rural Principal Arterial
06	Rural Minor Arterial
07	Rural Major Collector
08	Rural Minor Collector
09	Rural Local
11	Urban Interstate
12	Urban Freeway & Expressway
14	Other Urban Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

Appendix E. Detailed Safety and Operations Analysis

E.1 Crash Rates for Detailed Analysis

Crash rates vary by type of facility. Per unit distance, there are more crashes along small local roadways than on large controlled-access highways. The study team estimated separate crash rates for each type of facility in Texas based on accidents in the CRIS database, using data from 2016. Table shows the crash rates used for analysis for fatal, injury-causing, and property-damage-only (PDO) crashes.

The database did not have sufficient data to estimate crash rates for rural or urban local roadways (functional classes 9 and 19 respectively). In order to estimate those rates, the study team extrapolated figures based on data from the Massachusetts DOT[23], which had calculated crash rates for all facilities in Massachusetts. Specifically, the study team applied the ratio of local-road crashes to all other crashes in order to arrive at local road crash rates for Texas.

Table E1. Crash Rates for Different Roadway Facilities in the SAM

Functional Classification	Description	Fatalities	Injuries	PDO Accidents
01	Rural Interstate	0.18	11.44	28.38
02	Rural Principal Arterial	0.33	21.46	53.21
06	Rural Minor Arterial	0.39	25.75	63.86
07	Rural Major Collector	0.61	39.48	97.91
08	Rural Minor Collector	1.01	65.80	163.19
09	Rural Local	0.53	34.33	85.14
11	Urban Interstate	0.27	17.45	43.28
12	Urban Freeway & Expressway	0.36	23.75	58.89
14	Other Urban Principal Arterial	1.44	94.13	233.43
16	Urban Minor Arterial	1.59	103.85	257.55
17	Urban Collector	1.59	103.57	256.85
19	Urban Local	0.97	63.23	156.80

E.2 Operating Costs for Detailed Analysis

Along controlled-access facilities, vehicles are able to operate at relatively continuous speeds. Along smaller roadways, vehicles have to constantly accelerate as they start and stop. Additionally, lower functional class roadways receive less maintenance and can cause more wear-and-tear to the vehicles traversing them.

One estimate from the Victoria Transport Policy Institute places the increase in maintenance costs associated with poor-quality maintenance at 17%[24]. To get an idea of various fuel consumption rates, the study team examined the city and highway fuel mileage of various popular vehicle models. Table E1

[23] Crash Rates by Roadway Functional Classification. Massachusetts Department of Transportation Highway Division. 2018. Accessed at: https://www.mass.gov/service-details/intersection-and-roadway-crash-rate-data-for-analysis

[24] Litman, Todd. “Transportation Cost and Benefit Analysis II – Vehicle Costs.” Victoria Transport Policy Institute. Accessed at: https://www.vtpi.org/tca/tca0501.pdf

shows the two most popular cars, SUVs, and personal trucks from 2018, and their average city and highway mileage ratings[25, 26].

Table E1. City versus Highway Fuel Mileage for Six Popular Vehicle Models

Model	City Mileage (mpg)	Highway Mileage (mpg)	% increase
Car – Toyota Camry	29	41	41%
Car – Honda Civic	31	40	29%
SUV – Toyota RAV4	23	29	26%
SUV – Nissan Rogue	25	32	28%
Truck – Ford F-Series	22	30	36%
Truck – Chevrolet Silverado	18	24	33%

This is not an extensive list of the vehicles that will be considered within the simulation, but it can give an idea of the extent to which driving conditions (e.g., city driving versus highway driving) affect vehicle fuel mileage. The effects of the six vehicle models in Table E1 range from 26% to 41%.

As a conservative estimate of the fuel and maintenance savings, the study team limited the benefits to 20%. In the simulation, the highest functional class roadways have operating costs reduced by 10% and the lowest functional class facilities have 10% higher costs, as shown in Table E2.

Table E2. Changes in Vehicle Operating Costs by Functional Class for the Detailed Analysis

Functional Class	Vehicle Operating Cost Fractions
FC1, 11, 12, & 111	0.9
FC2 & 14	0.95
FC6 & 16	1
FC7, 8, 9, 17, & 19	1.1

E.3 Effect of Detailed Analysis on the Economic Results

Most of the scenarios the study team analyzed involve highway improvements. These scenarios tend to cause traffic to divert from lower functional class roadways to the improved highways. When this is the case, the detailed analysis tends to report higher benefits than the normal analysis because the normal analysis ignores any benefits from the type of roadway travelers use.

Some scenarios simulate projects to expand or improve existing highways (e.g., the Clear Lanes Projects discussed in Section 3.9) while other scenarios simulate full facility upgrades (e.g., the IH-69 Upgrade discussed in Section 3.2). Scenarios involving facility upgrades tend to return the highest benefits from the detailed analysis because they result in benefits from diverted travel (as all scenarios do in the detailed analysis) in addition to benefits from the travelers already using the facility. For example, when a segment of the IH-69 corridor is upgraded to interstate standards, the drivers already using the segment will now be

[25] Macesich, Mark. "Most-popular SUV's, trucks, cars in America right now." Santander Consumer USA. 29 April 2019. Accessed at: https://santanderconsumerusa.com/blog/most-popular-suvs-trucks-cars-in-america-right-now

[26] Office of Energy Efficiency and Renewable Energy. "www.fueleconomy.gov". United States Department of Energy and United States Environmental Protection Agency. Accessed at: https://www.fueleconomy.gov/feg/findacar.shtml

driving on a higher functional class facility with a lower crash rate. For a scenario such as Clear Lanes, many of the projects occur along roadways that are already of the highest functional class. In such a case, the detailed analysis reports the benefits of travelers diverting onto the better facilities, but there are fewer benefits for the travelers already on the facility.

E.4 Drawback of Detailed Analysis

Roadway functional class is only a proxy for driving style and pavement quality. It is possible to have start-stop motion and potholes on freeways, and it is possible for a minor roadway to be freshly repaved and have long stretches without a stop. While such cases are unlikely, the detailed analysis process outlined in this section will tend to overestimate benefits if a higher functional class roadway operates like a lower functional class facility.

Additionally, there is a great deal of uncertainty in the change in operating costs to assign for each facility type. The study team has attempted to keep the operating cost changes conservative so that the actual vehicle operating cost benefits for a scenario will likely be higher than the amount stated in the detailed analysis.

Appendix F. I-10 within Texas Triangle Project Details

Table F1. SAM Project along I-10 within the Texas Triangle

Project ID	Project Type	Year	Modified or not	Modification
HOU-12769	Widen to 8 Lanes	3000	yes	Changed the project year to 2040
TXDOT-76	Widen to 10 Lanes	3000	yes	Changed the project year to 2040
HOU-12780	Widen to 8 Lanes	3000	yes	Changed the project year to 2040
HOU-11561	Widen to 8 Lanes	3000	yes	Changed the project year to 2040
HOU-12652	Widen to 10 Lanes	3000	yes	Changed the project year to 2040
HOU-9693	New HOV	3000	yes	Changed the project year to 2040
HOU-7434	New Managed Lane	3000	yes	Changed the project year to 2040
TXDOT-68	New Managed Lane	3000	yes	Changed the project year to 2040
HOU-10334	New Managed Lane	3000	yes	Changed the project year to 2040
HOU-6056	New Managed Lane	3000	yes	Changed the project year to 2040
HOU-12614	Widen to 8 Lanes	3000	yes	Changed the project year to 2040
HOU-916	New Managed Lane	3000	yes	Changed the project year to 2040
TXDOT-62	Widen to 6 Lanes	3000	yes	Changed the project year to 2040
GRN-500000089	Widen to 6 Lanes	3000	yes	Changed the project year to 2040
TXDOT-120	Widen to 6 Lanes	3000	yes	Changed the project year to 2040
HOU-14203	New Managed Lane	3000	yes	Changed the project year to 2040
TXDOT-120	Widen to 6 Lanes	3000	yes	Changed the project year to 2040
TXDOT-110	Widen to 6 Lanes	3000	yes	Changed the project year to 2040
SAN-3824.0	Widen to 8 Lanes	3000	yes	Changed the project year to 2040
SAN-3007.0	New Managed Lane	2023	no	Project year is already before 2040
SAN-3774.0	New Managed Lane	2023	no	Project year is already before 2040
TXDOT-104	Widen to 6 Lanes	3000	yes	Changed the project year to 2040

Table F2. ODP Project along I-10 within the Texas Triangle

Control Section Job	Project Year	Project Description	Construction Cost	Project Length	Limits From	Limits To	Modified or not	Modification
27106117	2026	RECONFIGURE TO REMOVE DIAMOND LANES AND ADD 4 MANAGED LANES	$17,300,000	10.193	FORT BEND COUNTY LINE	SH 6	no	Already included in SAM projects
27105025	2026	WIDEN TO 6 MAIN LANES WITH 4 MANAGED LANES; RECONSTRUCT 2-3	$35,000,000	2.18	WALLER-FORT BEND COUNTY LINE	FORT BEND-HARRIS COUNTY LINE	no	Already included in SAM projects
27104070	2026	WIDEN TO 6 MAIN LANES WITH 4 MANAGED LANES AND RECONSTRUCT	$111,500,000	5.775	FM 359	WALLER-FORT BEND C/L	no	Already included in SAM projects
27102049	2020	ADD LANES FOR 6-LANE FACILITY	$113,781,000	8.917	COLORADO C/L	FM 3538	no	Already included in SAM projects
27101066	2020	ADD LANES FOR 6-LANE FACILITY	$174,940,000	13.718	COLORADO RIVER BRIDGE	AUSTIN C/L	no	Already included in SAM projects
53508072	2020	ADD LANES FOR 6-LANE FACILITY	$28,964,000	2.724	SH 71	COLORADO RIVER BRIDGE	no	Already included in SAM projects
53501074	2024	EXPAND FROM 4 LANE TO 6 LANE EXPRESSWAYS	$200,000,000	10.843	US 90A	SH 130	no	Already included in SAM projects
2503097	2029	EXPAND FROM 4 LANE TO 6 LANE EXPRESSWAYS	$229,000,000	9.151	BEXAR/GUADALUPE COUNTY LINE	US 90A	no	Already included in SAM projects
2502215	2029	EXPAND FROM 4 LANE TO 6 LANE EXPRESSWAYS	$171,000,000	6.86	LOOP 1604	GUADALUPE/ BEXAR COUNTY LINE	no	Already included in SAM projects
2502193	2025	CONSTRUCT NEW ENTRANCE AND EXIT RAMPS	$30,000,000	2.021	AT PRESA STREET	AT PRESA STREET	no	Already Connected
7207075	2029	EXPAND FROM 4 TO 8 LANE EXPRESSWAY-2 NEW GENERAL PURPOSE & 2	$107,000,000	5.324	KENDALL/BEXAR COUNTY LINE	FM 3351	yes	Changed number of lanes from 2 to 4 in each direction

Appendix G. I-35 within Texas Triangle Project Details

Table G1. SAM Projects along I-35 within the Texas Triangle

ID	Project Type	Year	Modified or not	Modification
DFW-17-A	Widen	2030	no	
DFW-17-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-17-B	Widen	2030	no	
DFW-17-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-17-C	Widen	2030	no	
DFW-17-C-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-18-A	Widen	2040	no	
DFW-18-B	Widen	2040	no	
DFW-19-A	Widen	2020	no	
DFW-19-B	Widen	2020	no	
DFW-1-A	Widen	2030	no	
DFW-1-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-1-C	Widen	2040	no	
DFW-1-C-HOV	New HOV	3000	yes	
DFW-2013-17A	New Managed Lanes	2030	no	
DFW-2013-17B	New Managed Lanes	2030	no	
DFW-2013-17B-remove	HOV Replacement	2003	no	
DFW-2013-17C	New Managed Lanes	2030	no	
DFW-2013-1A	New Managed Lanes	2030	no	
DFW-2013-1A-remove	HOV Replacement	1900	no	
DFW-2013-3A	New Managed Lanes	2015	no	
DFW-2013-4A	New Managed Lanes	2030	no	
DFW-2013-4A-remove	HOV Replacement	2011	no	
DFW-2013-4B	New Managed Lanes	2030	no	
DFW-2013-4C	New Managed Lanes	2030	no	
DFW-2013-4D	New Managed Lanes	2030	no	

ID	Project Type	Year	Modified or not	Modification
DFW-2013-4E	New Managed Lanes	2030	no	
DFW-2013-4F	New Managed Lanes	2020	no	
DFW-2013-8C	New Managed Lanes	2020	no	
DFW-2013-8C-remove	HOV Replacement	1900	no	
DFW-20-A	Widen	2030	no	
DFW-20-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-20-B	Widen	2040	no	
DFW-20-B-HOV	New Managed Lanes	3000	yes	Change the project year to 2040
DFW-21	Widen	3000	yes	Change the project year to 2040
DFW-27-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-A	Widen	2030	no	
DFW-29-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-B	Widen	2030	no	
DFW-29-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-C	Widen	2030	no	
DFW-29-C-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-D	Widen	2030	no	
DFW-29-D-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-B	Widen	2040	no	
DFW-2-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-C	Widen	2040	no	
DFW-2-C-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-D-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-33-C	Widen	2020	no	
DFW-33-C-HOV	New Managed Lanes	3000	yes	Change the project year to 2040
GRN-001416268	Widen	3000	yes	Change the project year to 2040
GRN-004809029	Widen	3000	yes	Change the project year to 2040
GRN-019603269	Widen	3000	yes	

ID	Project Type	Year	Modified or not	Modification
GRN-044202088	not in Project file		no	
GRN-044202088M	not in Project file		no	
GRN-044202159	not in Project file		no	
KTB-T15-06a	Widen	2020	no	
KTB-T15-06b	Widen	3000	yes	Change the project year to 2040
KTB-T15-06c	Widen	2010	no	
KTB-T15-06d	Widen	2020	no	
SAN-3477.0	New Managed Lanes	2020	no	
SAN-3514.0	New Managed Lanes	2020	no	
SAN-61.2	New Managed Lanes	2020	no	
TXDOT-105	Widen	3000	yes	Change the project year to 2040
TXDOT-106	Widen	3000	yes	Change the project year to 2040
TXDOT-12	not in Project file		no	
TXDOT-127	Widen	3000	yes	Change the project year to 2040
TXDOT-128	Widen	3000	yes	Change the project year to 2040
TXDOT-133	Widen	3000	yes	Change the project year to 2040
TXDOT-134	Widen	3000	yes	Change the project year to 2040
TXDOT-14	not in Project file		no	
TXDOT-15	not in Project file		no	
TXDOT-17	not in Project file		no	
TXDOT-18	not in Project file		no	
TXDOT-19	not in Project file		no	
TXDOT-20	not in Project file		no	
TXDOT-21	Widen	3000	yes	Change the project year to 2040
TXDOT-23	not in Project file		no	
TXDOT-43	Widen	3000	yes	
TXDOT-43B	not in Project file		no	
TXDOT-46	not in Project file		no	
TXDOT-47	Widen	3000	yes	Change the project year to 2040

ID	Project Type	Year	Modified or not	Modification
TXDOT-7	Widen	3000	yes	Change the project year to 2040
TXDOT-8	Widen	3000	yes	Change the project year to 2040
TXDOT-9	Widen	3000	yes	Change the project year to 2040
WAC-S-022	Widen	2015	no	

Table G2. ODP Projects along I-35 within the Texas Triangle

Control Section Job	Year	Description	Cost ($)	Length (mile)	Overlap with SAM Project	Limits From	Limits To
1606047	2020	Add 2 GP and 2 Managed Ln each Direction	$259,546,500	3.253		BEXAR/GUADALUPE COUNTY LINE	GUADALUPE/COMAL COUNTY LINE
1510062	2025	Add 1 Managed Ln each Direction	$856,400,000	3.8		SH 45N	FM 1825
1416268	2030	Widen to 4 GP Ln each Direction	$350,000,000	6.495	DFW-29D	I-30	I-820
1710168	2020	Add 2 Managed Ln each Direction	$568,530,500	3.949	SAN 61.2	I-410 S	I-410 N
1513077	2025	Add 1 Managed Ln each Direction	$195,584,400	6.34		RIVERSIDE DR	LP 275-SLAUGHTER LANE
1607113	2020	Add 2 Managed Ln each Direction	$617,968,000	6.778	SAN 3477.0	I-410 N	GUADALUPE/BEXAR COUNTY LINE
1513389	2025	Add 1 Managed Ln each Direction	$212,150,000	7.097		FM 1825	US 183
1501171	2018	Widen to 4 Ln each Direction	$396,000,000	7.436	TXDOT-133	S LP 340	N LP 340
8112041	2035	Add 1 GP Ln and 2 Managed Ln each Direction	$270,380,540	7.201	DFW-29A, DFW-2013-4A	US 81/287 SPLIT	DENTON COUNTY LINE
4809029	2019	Add 1 GP Ln each Direction	$100,000,000	7.887	TXDOT-127	I-35W	ELLIS CO LINE
1402050	2027	Add 1 GP Ln each Direction	$482,000,000	6.613	DFW-21, TXDOT-47	I-20	SH 174
19601108	2026	Widen to 4 GP Ln w/ 2 Managed Ln each Direction	$388,006,067	8.257	DFW-17-C-HOV, DFW-17C	TURBEVILLE RD	US 77

Control Section Job	Year	Description	Cost ($)	Length (mile)	Overlap with SAM Project	Limits From	Limits To
19602124	2026	Widen to 4 GP Ln w/ 2 Managed Ln each Direction	$720,605,307	7.612	DFW-17-C-HOV, DFW-17C	DALLAS COUNTY LINE	FM 407
19603274	2026	Widen to 4 GP Ln w/ 2 Managed Ln each Direction	$494,847,135	6.397	DFW-17-C-HOV, DFW-17C	I-635	DENTON COUNTY LINE
19602125	2026	Widen to 4 GP Ln w/ 2 Managed Ln each Direction	$499,217,637	2.339	DFW-17-C-HOV, DFW-17C	FM 407	TURBEVILLE ROAD
1501243	2018	Widen to 4 Ln each Direction	$278,000,000	4.58	TXDOT-133	12TH STREET	N LP 340

Appendix H. Clear Lanes Projects Details

Table H1. Clear Lanes Projects

CSJ	Highway Number	Description	Cost	Modeling Method	Existing # of Lanes
0015-09-196	I-35	Reconstruct ramps, frontage roads improvements, add aux lanes and improve freight movement	$240,000,000	Added one lane in each direction (8 total). Activated SAM project TXDOT-7	3
0015-10-069	I-35	Reconstruct ramps, frontage road improvements, add aux lanes and improve freight movements	$140,000,000	Added one lane in each direction (8 total). Activated SAM project TXDOT-8	3
0015-13-408	I-35	Reconstruct ramps, frontage road improvements, add aux lanes and improve freight movements	$320,000,000	Added one lane in each direction (8 total). Activated SAM project TXDOT-8	3
0015-13-409	I-35	Reconstruct ramps, frontage road improvements, add aux lanes and improve freight movements	$380,000,000	Added one lane in each direction (8 to 10 total). Activated SAM project TXDOT-8	3 to 4
0015-13-410	I-35	Reconstruct ramps, frontage road improvements, add aux lanes and improve freight movements	$200,000,000	Added one lane in each direction (8 total). Activated SAM project TXDOT-8	3
0016-01-126	I-35	Reconstruct ramps, frontage road improvements, add aux lanes and improve freight movements	$160,000,000	Added one lane in each direction (8 total). Activated SAM project TXDOT-8	3
0025-02-160	I-10	Expand from 4 to 6 lane expressway	$101,350,891	Made all links 3 lanes in each direction. Activated SAM project TXDOT-110	2 to 3
0027-13-200	I-69	Reconstruct and widen to 12 main lanes and reconstruct IH69/ SH 288 interchange	$173,500,000	Already has 16 lanes; functional class changed to 11 to capture the effects of the interchange upgrade	8
0027-13-201	I-69	Reconstruct to 10 main lanes	$192,000,000	Changed to 5 lanes in each direction	3 or 4
0027-13-221	I-69	Construct 3 bridges	$55,800,000	Not modeled[27]	8
0151-05-113	US 183	Widen from 3 to 4 general purpose lanes	$60,000,000	Expanded to 4 lanes in each direction	2

[27] The three roadways being bridged-over are not included in the current SAM network.

CSJ	Highway Number	Description	Cost	Modeling Method	Existing # of Lanes
0151-06-142	US 183	Widen from 3 to 4 general purpose lanes	$60,000,000	Widened to 4 lanes in each direction	3
0253-04-138	US 281	Expand to 6-lane expressway with frontage roads: 4 general purpose & 2 HOV lanes	$182,000,000	Activated SAM projects GRN-025304138 and GRN-025304138M; The northernmost link of the segment is manually changed from FC6 to FC2; and made six lanes in each direction	2 to 6
0271-16-140	I-610	Reconstruct mainlanes, frontage road and construct overpass at Cambridge street/Almeda road/Uprr	$75,000,000	Almeda RD intersecting links upgraded one step to FC 12 to represent the overpass construction; other minor roads are not part of the network and cannot be modelled	3 to 5
0364-01-147	SH 121	Construct I-635 and FM 2499 deferred connections	$351,300,000	Upgraded functional class to 11	4 to 5
0500-03-599	I-45	Reconstruct interchange including I-10 express lanes (non-tolled)	$721,400,000	Already highest functional class	4 to 5 (1 express lane)
0500-03-601	I-45	Reconstruct interchange including I-45 & I-69 mainlanes	$856,500,000	Link 2180623 changed to FC11	4 to 8
0500-08-001	I-45	Reconstruct interchange including I-45, I-10 & I-69 mainlanes and I-10 express lanes (non-tolled)	$873,200,000	Link 3352769 changed to FC11	2 to 4 (1 express lane)
0521-04-204	I-410	Expand from 8 to 10 lane expressway	$50,000,000	Expanded to 5 lanes in each direction	3
0521-04-275	I-410	Reconstruct interchange—phase 2	$40,000,000	Upgraded interchange links to FC11	2 to 3
0521-04-279	I-410	Expand from 6-lane to 8-lane expressway	$10,000,000	Expanded to 4 lanes in each direction - note that overlap with 0521-04-275 means this link was already upgraded to FC11	3
0521-06-138	I-410	Construct direct connectors; phase 1-priority connectors	$100,000,000	Unclear which interchange this refers to, but the eastern one currently has a cloverleaf instead of direct connectors - upgraded link 1252566 to FC11, other links	2 to 3

CSJ	Highway Number	Description	Cost	Modeling Method	Existing # of Lanes
				were already highest functional class	
2374-01-137	I-635	Widen 8 to 10 general purpose lanes and reconstruct 4/6 discontinuous to 4/6 continuous frontage roads	$244,507,250	Existing roadway already has highest functional class and 10GP lanes; Activated SAM project GRN-237401137M	5
2374-01-183	I-635	Widen 8 to 10 general purpose lanes and reconstruct 4/6 discontinuous to 4/6 continuous frontage roads	$404,101,375	Existing roadway already has highest functional class and 10GP lanes	5
2452-03-112	SL 1604	Expand from 4-lane divided to 4-lane expressway	$40,000,000	Upgraded to FC11	2

Appendix I. Top 20 Overall Congested Locations Project Details

Table I1. The Top 20 Congested Locations in Texas in 2018

2018 Rank	County	Road Name	From	To	Segment Length
1	102 Harris	W Loop Fwy / I-610	Katy Fwy / IH10/ US90	Southwest Fwy / US 59 / I-69	3.62
2	102 Harris	Southwest Fwy / I-69 / US 59	W Loop Fwy / I-610	South Fwy / SH 288	5.44
3	227 Travis	I-35	US 290 N / SS69	Ben White Blvd / SH71	7.92
4	057 Dallas	Woodall Rodgers Fwy / SS 366	US 75	N Beckley Ave	1.44
5	102 Harris	Eastex Fwy / I-69 / US 59	SH 288	I-10	3.03
6	220 Tarrant	North Fwy / I-35W / US 287	SH 183	I-30	3.36
7	102 Harris	Katy Fwy / IH10 / US90	N Eldridge Pkwy	Sam Houston Tollway W	3.28
8	057 Dallas	Stemmons Fwy / I-35E/ US 77	John W. Carpenter / SH 183	Tom Landry Fwy / I-30	5.43
9	057 Dallas	US 75	Lyndon B Johnson / I-635	Woodall Rodgers Freeway / SS 366	9.19
10	102 Harris	North Fwy / I-45	Sam Houston Tollway N	N Loop Fwy / I-610	9.26
11	102 Harris	Gulf Fwy/ I-45	IH10 / US 90	S Loop E Fwy/ I-610	7.89
12	102 Harris	South Fwy / SH 288	Gulf Fwy/ I-45	S Loop W Fwy / I-610	4.8
13	102 Harris	Katy Fwy / IH10 / US90	Sam Houston Tollway W	W Loop N Fwy/ IH610	6.62
14	057 Dallas	US 75	President George Bush Turnpike Toll Rd / SH 190	Lyndon B Johnson / I-635	6.56
15	015 Bexar	McAllister Fwy / US 281	Stone Oak Pkwy	Charles West Anderson Loop N / SL 1604	2.94
16	102 Harris	IH10 / US90	North Fwy / I-45	Eastex Fwy / US 59	1.57
17	102 Harris	Katy Fwy / IH10 / US90	W Loop N Fwy/ IH610	North Fwy / I-45	5.65
18	102 Harris	N Loop W Fwy / I-610	North Fwy / I-45	Katy Fwy/ IH10/ US90	6.22
19	227 Travis	I-35	Ben White Blvd / SH71	Slaughter Ln	3.99
20	102 Harris	North Fwy / I-45	N Loop Fwy / I-610	IH10 / US 90	3.11

Table I2. SAM Projects along the 2018 Top 20 Congested Locations

Project ID	Project Type	year	Modified or not	Modification
HOU-335	Widen	2040	Yes	Change Project Year to 2040
TXDOT-8	Widen	2040	Yes	Change Project Year to 2040
HOU-7428	New Managed Lanes	2040	Yes	Change Project Year to 2040
DFW-53-C	Widen	4000	No, modification lower than current standard	Change Project Year to 4000
DFW-29-D-HOV	New HOV	2040	Yes	Change Project Year to 2040
GRN-001416268	Widen	2040	Yes	Change Project Year to 2040
TXDOT-43	Widen	2040	Yes	Change Project Year to 2040
HOU-7431	New Managed Lanes	2040	Yes	Change Project Year to 2040
GRN-019603269	New Managed Lanes	2040	Yes	Change Project Year to 2040
DFW-33-C-HOV	New Managed Lanes	2040	Yes	Change Project Year to 2040
TXDOT-66	New Managed Lanes	2040	Yes	Change Project Year to 2040
TXDOT-29B	New Managed Lanes	2040	Yes	Change Project Year to 2040
SAN-3781.0	New Managed Lanes	2040	Yes	Change Project Year to 2040
HOU-7434	New Managed Lanes	2040	Yes	Change Project Year to 2040
TXDOT-78	New Managed Lanes	2040	Yes	Change Project Year to 2040

Table I3. ODP Projects along the 2018 Top 20 Congested Locations

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
1513077	2025	ADD NB & SB EXPR LNS	$ 710,000,000	6.34	RIVERSIDE DR	LP 275- SLAUGHTER LANE	Create 1 express lane each direction
1513388	2024	ADD NB & SB EXPR LNS	$ 786,200,000	6.792	US 183	RIVERSIDE DR	Create 1 express lane each direction
2713200	2021	RECONSTRUCT AND WIDEN TO 12 MAIN LANES AND RECONSTRUCT IH69/ SH 288 INTERCHANGE	$ 173,500,000	1	I-45	SH 288	Widen to 6 GP lanes each direction
1416268	2035	WIDEN 4/6/8 TO 8 GP LANES W/COLLECTOR DISTRIBUTOR AUXILIARY LANES AND FR RDS CONNECTIONS INCLUDING SH 121 INTERCHANGE	$ 700,000,000	6.495	I-30	I-820	Widen to 4 GP lanes each direction
19603199	2030	8/10/12 LANES WITH AUXILIARY LANES AND TWO-LANE REVERSIBLE HOV/M LANE WITH 4/6 FRONTAGE ROADS	$ 846,801,984	2.178	I-30	NORTH OF OAK LAWN AVE	Widen to 4 GP lanes each direction
11006132	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$ 260,550,000	1.987	SOUTH OF WEST ROAD	N OF BW 8	Create 2 express lanes each direction
11006139	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$ 392,850,000	2.705	SOUTH OF SHEPHERD DRIVE	SOUTH OF WEST ROAD	Create 2 express lanes each direction
50003446	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT	$ 348,300,000	2.516	TIDWELL ROAD	SOUTH OF SHEPHERD DRIVE	Create 2 express lanes each direction

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
		4 ADDITIONAL MANAGED LANES					
50003596	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$ 348,300,000	2.433	I-610	TIDWELL	Create 2 express lanes each direction
50003560	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$ 238,800,000	3.132	I-10	I-610	Widen to 4 GP lanes each direction
17809018	2025	CONSTRUCT 8-LANE ROADWAY ON NEW LOCATION	$ 72,000,000	2.2	I-45	GRIGGS RD	Widen to 4 GP lanes each direction
17809016	2030	CONSTRUCT 6-LANE TOLLWAY WITH 2 2-LANE FRONTAGE ROADS ON NEW LOCATION	$ 110,000,000	3.3	BELLFORT TO	NORTH OF ALMEDA-GENOA	Widen to 3 express lanes and 1 GP lane each direction
4707219	2030	WIDEN FREEWAY AND ADD MANAGED LANES	$ 405,488,000	5.21	I-635	COLLIN COUNTY LINE	Add 1 GP lane and 1 express lane each direction
4707232	2019	CONSTRUCT OLIVER STREET BRIDGE & WIDEN EASBOUND FRONTAGE RD	$ 1,770,000	0.205	AT OLIVER STREET	.	Add 1 GP lane each direction
4706158	2026	CONSTRUCT INTERCHANGE WITH MANAGED LANES AND DC'S WITH TWO 2-LANE FRONTAGE ROADS	$ 136,199,445	0.95	W OF MANGUM/18T H ST ON HEMPSTEAD	S OF OLD KATY RD ON I-610 (SEG 1)	Create 2 express lanes each direction
27117162	2022	CONSTRUCT 4 EXPRESS LANES	$ 310,000,000	4.815	I-69	I-10(W)	Create 2 express lanes each direction

Appendix J. Top 25 Trucking Congested Locations Project Details

Table J1. The 2017[28] Top 25 Trucking Congested Locations in Texas

2017 Rank - Truck Delay	2017 Rank - All Delay	County	Road Name	From	To	Segment Length
1	2	227 Travis	IH 35	US 290 N / SS69	Ben White Blvd / SH71	7.92
2	1	102 Harris	W Loop Fwy / IH 610	Katy Fwy / IH10/ US90	Southwest Fwy / US 59 / IH 69	3.62
3	5	102 Harris	Eastex Fwy / IH 69 / US 59	SH 288	IH 10	3.03
4	3	102 Harris	Southwest Fwy / IH 69 / US 59	W Loop Fwy / IH 610	South Fwy / SH 288	5.45
5	22	057 Dallas	IH 345 / US 75 _ IH 45	US 75	S.M. Wright Fwy / US 175	2.35
6	6	057 Dallas	Stemmons Fwy / IH 35E/ US 77	John W. Carpenter / SH 183	Tom Landry Fwy / IH 30	5.43
7	15	227 Travis	IH 35	Ben White Blvd / SH71	Slaughter Ln	3.99
8	17	102 Harris	Katy Fwy / IH10 / US90	W Loop N Fwy/ IH610	North Fwy / IH 45	5.67
9	7	102 Harris	Katy Fwy / IH10 / US90	N Eldridge Pkwy	Sam Houston Tollway W	3.29
10	8	102 Harris	Gulf Fwy/ IH 45	IH10 / US 90	S Loop E Fwy/ IH 610	7.91
11	20	057 Dallas	Lyndon B Johnson / IH 635	US 75	Garland Ave / SH 78	6.92
12	14	102 Harris	Katy Fwy / IH10 / US90	Sam Houston Tollway W	W Loop N Fwy/ IH610	6.64
13	24	220 Tarrant	North Fwy / IH 35W / US 287	SH 183	IH 30	3.37
14	39	102 Harris	IH10 / US90	North Fwy / IH 45	Eastex Fwy / US 59	1.58
15	12	102 Harris	North Fwy / IH 45	N Loop Fwy / IH 610	IH10 / US 90	3.11
16	9	102 Harris	North Fwy / IH 45	Sam Houston Tollway N	N Loop Fwy / IH 610	9.27
17	31	015 Bexar	N PanAm Expy / IH 35	Connally Loop NE / IH 410	Connally Loop E / IH 410	3.75
18	36	015 Bexar	PanAm Expy / IH 35 / IH10	Staff Sergeant William J. Bordelon Fwy / IH 37 / US 281	Cleto Rodriguez Fwy / US 90	4.15
19	19	061 Denton	IH 35 E / US 77	BS 121 H	Lyndon B Johnson / IH 635	10.55

[28] The Top 25 Trucking Congested Locations scenario was analyzed before the 2018 ranking was available.

2017 Rank - Truck Delay	2017 Rank - All Delay	County	Road Name	From	To	Segment Length
20	13	102 Harris	N Loop W Fwy / IH 610	North Fwy / IH 45	Katy Fwy/ IH10/ US90	6.23
21	10	057 Dallas	US 75	Lyndon B Johnson / IH 635	Woodall Rodgers Freeway / SS 366	9.19
22	32	057 Dallas	Lyndon B Johnson / IH 635	Garland Ave / SH 78	US 80	6.14
23	28	220 Tarrant	North Fwy / IH 35W / US 287	US 81 / US 287	28th St / SH 183	6.39
24	44	227 Travis	IH 35	Parmer Ln / FM 734	US 290 N / SS69	6.43
25	11	102 Harris	South Fwy / SH 288	Gulf Fwy/ IH 45	S Loop W Fwy / IH 610	4.81

Table J2. SAM Projects along the 2017 Top 25 Trucking Congested Locations[29]

SAM Project ID	Project Year	Project Type
DFW-29-D-HOV	3000	New HOV
DFW-29-B-HOV	3000	New HOV
DFW-29-C-HOV	3000	New HOV
DFW-33-C-HOV	3000	New Managed Lanes
DFW-22-C	3000	Widen
DFW-23-E	3000	Widen
DFW-23-E-HOV	3000	New HOV
HOU-7431	3000	New Managed Lanes
HOU-155	3000	New Managed Lanes
HOU-7428	3000	New Managed Lanes
HOU-7434	3000	New Managed Lanes
DFW-23-C-HOV	3000	New HOV
TXDOT-105	3000	Widen
TXDOT-106	3000	Widen
TXDOT-8	3000	Widen
TXDOT-43	3000	Widen
TXDOT-71	3000	New Managed Lanes
TXDOT-78	3000	New Managed Lanes
TXDOT-66	3000	New Managed Lanes
GRN-237401137M	3000	New Managed Lanes
DFW-23-D-HOV	3000	New HOV
GRN-001416268	3000	Widen
GRN-019603269	3000	New Managed Lanes
GRN-237402053M	3000	New Managed Lanes

[29] All projects were modified by changing the project year to 2040 to include them in the simulation.

Table J3. ODP Projects along the 2017 Top 25 Trucking Congested Locations

Control Section Job Number	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
1513077	2025	ADD NB & SB EXPR LNS	$710,000,000	6.34	RIVERSIDE DR	LP 275-SLAUGHTER LANE	Create 1 express lane in each direction
1513388	2024	ADD NB & SB EXPR LNS	$786,200,000	6.792	US 183	RIVERSIDE DR	Create 1 express lane in each direction
1513389	2025	ADD NB & SB EXPRESS LNS	$212,150,000	7.097	FM 1825	US 183	Create 1 express lane in each direction
1416268	2035	WIDEN 4/6/8 TO 8 GP LANES W/COLLECTOR DISTRIBUTOR AUXILIARY LANES AND FR RDS CONNECTIONS INCLUDING SH 121 INTERCHANGE	$700,000,000	6.495	IH 30	IH 820	Widen to 4 GP lanes in each direction
1416252	2035	WIDEN 4 TO 8 GP LANES AND ADD 2 MANAGED LANES BETWEEN IH 820 AND BASSWOOD BLVD.	$100,000,000	2.839	IH 820	US 81/287	Widen to 4 GP lanes in each direction; create 1 express lane in each direction
19602124	2025	RECON/CNVRT 2R TO 4CON MGD;6 TO 6/8 CD LNS;4/6 TO 2/6 CON FR (DAL C/L-121);RECON EX 8GP LNS;2/6 TO 2/8 CON FR(121-FM407)	$720,605,307	7.612	DALLAS COUNTY LINE	FM 407	Widen to 4 GP lanes in each direction; create 2 express lane in each direction
19603274	2026	RECON & CONVERT 2-REV TO 4-CON MGD LN;RECON 6 TO 8 GP LNS(IH 635 TO SH 121);RECON 6 TO 6/8 CD LNS (SH 121 TO DENTON C/L)	$494,847,135	6.397	IH 635	DENTON COUNTY LINE	Widen to 4 GP lanes in each direction; create 2 express lane in each direction
19603199	2030	8/10/12 LANES WITH AUXILIARY LANES AND TWO-LANE REVERSIBLE	$846,801,984	2.178	IH 30	NORTH OF OAK LAWN AVE	Widen to 6 GP lanes in each direction; create 1

Control Section Job Number	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
		HOV/M LANE WITH 4/6 FRONTAGE ROADS					express lane in each direction
27117162	2022	CONSTRUCT 4 EXPRESS LANES	$310,000,000	4.815	IH 69	IH 10(W)	Create 2 express lanes in each direction
17809016	2030	CONSTRUCT 6-LANE TOLLWAY WITH 2 2-LANE FRONTAGE ROADS ON NEW LOCATION	$110,000,000	3.3	BELLFORT TO	NORTH OF ALMEDA-GENOA	Create tollway with 3 lanes in each direction
237401183	2020	WIDEN 8 TO 10 GENERAL PURPOSE LANES AND RECONSTRUCT 4/6 DISCONTINUOUS TO 4/6 CONTINUOUS FRONTAGE ROADS	$404,101,375	3.234	EAST OF US 75	MILLER ROAD	Widen to 5 GP lanes in each direciton
237402053	2020	WIDEN 8 TO 10 GENERAL PURPOSE LANES AND RECONSTRUCT 4/6 DISCONTINUOUS TO 4/6 CONTINUOUS FRONTAGE ROADS	$437,644,207	5.222	WEST OF THE KCS RR (WEST OF SH 78)	IH 30	Widen to 5 GP lanes in each direction
2713201	2020	RECONSTRUCT TO 10 MAIN LANES	$192,000,000	1	SH 288	SP 527	Widen to 5 GP lanes in each direction
2713200	2021	RECONSTRUCT AND WIDEN TO 12 MAIN LANES AND RECONSTRUCT IH69/ SH 288 INTERCHANGE	$173,500,000	1	IH 45	SH 288	Widen to 6 GP lanes in each direction
50003560	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$238,800,000	3.132	IH 10	IH 610	Create 2 express lanes in each direction
11006132	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT	$260,550,000	1.987	SOUTH OF WEST ROAD	N OF BW 8	Create 2 express lanes in each direction

Control Section Job Number	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
		4 ADDITIONAL MANAGED LANES					
11006139	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$392,850,000	2.705	SOUTH OF SHEPHERD DRIVE	SOUTH OF WEST ROAD	Create 2 express lanes in each direction
50003596	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$348,300,000	2.433	IH 610	TIDWELL	Create 2 express lanes in each direction
237401190	2020	RECONSTRUCT AND WIDEN 2 TO 4 CONCURRENT HOV/MANAGED LANES	$65,242,375	3.234	EAST OF US 75	MILLER ROAD	Create 1 express lane in each direction
17809018	2025	CONSTRUCT 8-LANE ROADWAY ON NEW LOCATION	$72,000,000	2.2	IH 45	GRIGGS RD	Create roadway with 4 lanes in each direction
50003597	2026	RECONSTRUCT INTERCHANGE	$528,700,000	0.34	AT IH 610	.	Improve minor roadway functional classification
50003446	2026	RECONSTRUCT MAIN LANES, FRONTAGE LANES AND CONSTRUCT 4 ADDITIONAL MANAGED LANES	$348,300,000	2.516	TIDWELL ROAD	SOUTH OF SHEPHERD DRIVE	Create 2 express lanes in each direction
237401137	2020	WIDEN 8 TO 10 GENERAL PURPOSE LANES AND RECONSTRUCT 4/6 DISCONTINUOUS TO 4/6 CONTINUOUS FRONTAGE ROADS	$244,507,250	2.63	MILLER ROAD	WEST OF THE KCS RR (WEST OF SH 78)	Widen to 5 GP lanes in each direction
237402152	2020	RECONSTRUCT AND WIDEN 2 TO 4	$200,405,486	5.222	WEST OF THE KCS RR	IH 30	Create 1 express lane in each direction

Control Section Job Number	Project Year	Project Description	Construction Cost (Dollars)	Project Length (miles)	Limits From	Limits To	Modification
		CONCURRENT HOV/MANAGED LANES			(WEST OF SH 78)		
50003584	2020	REPLACE BRIDGE APPROACHES (NBI# 12102050003210)	$8,300,000	0.16	IH 45 SB MCKINNEY EXIT	AT BUFFALO BAYOU	Improve minor roadway functional classification
1513396	2019	RECONSTRUCT INTERSECTION	$22,980,714.97	2	AT PARMER LN	.	Improve minor roadway functional classification
237401191	2020	RECONSTRUCT FREEWAY AND FRONTAGE ROADS.ADD GENERAL PURPOSE MAIN LANES AND COLLECTOR-DISTRIBUTOR LANES.	$49,935,875	2.63	MILLER ROAD	WEST OF THE KCS RR (WEST OF SH 78)	Add 1 GP lane in each direction
237401171	2019	INTERCHANGE IMPROVEMENTS	$69,377,000	0.297	AT SKILLMAN / AUDELIA INTERCHANG E	.	Improve minor roadway functional classification

Appendix K. Improving I-35 and Upgrading US 281 Project Details

Table K1. SAM Project along I-35 Full Corridor

Project ID	Project Type	Year	Modified or not	Modification
DFW-1-A	Widen	2030	no	
DFW-1-B	Widen	2040	no	
DFW-1-C	Widen	2040	no	
DFW-17-D	Widen	2030	no	
DFW-2013-17C	New Managed Lanes	2030	no	
DFW-1-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-A	Widen	2040	no	
DFW-2-B	Widen	2040	no	
DFW-2-C	Widen	2040	no	
DFW-2-C-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2-D-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2013-4A	New Managed Lanes	2030	no	
DFW-2013-29A	New Managed Lanes	2030	no	Change the project year to 2040
DFW-29-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-A	Widen	2030	no	
DFW-29-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2013-4B	New Managed Lanes	2030	no	
DFW-2013-4C	New Managed Lanes	2030	no	
DFW-29-C-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-29-B	Widen	2030	no	
DFW-29-C	Widen	2030	no	
DFW-29-D-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2013-4D	New Managed Lanes	2030	no	
DFW-29-D	Widen	2030	no	
GRN-001416268	Widen	3000	yes	Change the project year to 2040
DFW-2013-4E	New Managed Lanes	2030	no	

Project ID	Project Type	Year	Modified or not	Modification
DFW-21	Widen	3000	yes	Change the project year to 2040
TXDOT-47	Widen	3000	yes	Change the project year to 2040
TXDOT-128	Widen	3000	yes	Change the project year to 2040
DFW-17-A	Widen	2030	no	
DFW-17-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2013-17A	New Managed Lanes	2030	no	
DFW-2013-17B	New Managed Lanes	2030	no	
DFW-17-B-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-17-C	Widen	2030	no	
DFW-17-C-HOV	New HOV	3000	yes	Change the project year to 2040
TXDOT-13	Widen	3000	yes	Change the project year to 2040
TXDOT-13B	New Managed Lanes	3000	yes	Change the project year to 2040
DFW-27-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-18-A	Widen	2040	no	
DFW-33-C	Widen	2020	no	
DFW-33-C-HOV	New Managed Lanes	3000	yes	Change the project year to 2040
DFW-2013-8C	New Managed Lanes	2020	no	
DFW-20-A	Widen	2030	no	
DFW-20-A-HOV	New HOV	3000	yes	Change the project year to 2040
DFW-2013-1A	New Managed Lanes	2030	no	
DFW-20-B	Widen	2040		
DFW-20-B-HOV	New Managed Lanes	3000	yes	Change the project year to 2040
DFW-19-A	Widen	2020	no	
DFW-19-B	Widen	2020	no	
TXDOT-21	Widen	3000	yes	Change the project year to 2040
GRN-004809029	Widen	3000	yes	Change the project year to 2040
TXDOT-127	Widen	3000	yes	Change the project year to 2040
TXDOT-133	Widen	3000	yes	Change the project year to 2040
KTB-T15-06d	Widen	2020	no	
TXDOT-134	Widen	3000	yes	Change the project year to 2040
KTB-T15-06a	Widen	2020	no	

Project ID	Project Type	Year	Modified or not	Modification
KTB-T15-06b	Widen	3000	yes	Change the project year to 2040
TXDOT-7	Widen	3000	yes	Change the project year to 2040
TXDOT-8	Widen	3000	yes	Change the project year to 2040
TXDOT-9	Widen	3000	yes	Change the project year to 2040
SAN-3477.0	New Managed Lanes	2020	no	
SAN-61.2	New Managed Lanes	2020	no	
TXDOT-105	Widen	3000	yes	Change the project year to 2040
TXDOT-105	Widen	3000	yes	Change the project year to 2040
TXDOT-106	Widen	3000	yes	Change the project year to 2040
SAN-3514.0	New Managed Lanes	2020	no	
TXDOT-111	Widen	3000	yes	Change the project year to 2040
TXDOT-135	Widen	3000	No	Already 3 lanes divided
TXDOT-136	Widen	3000	No	Already 4 lanes divided

Table K2. ODP Projects along I-35 Full Corridor

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length	Limits From	Limits To	Modified or not	Modification
1606047	2020	EXPAND FROM 8 LN TO 12 LN EXPY THRU FM 3009 & 6 LN TO 10 LN EXPY FROM FM 3009 TO COMAL C/L -ADD 4 NEW MANAGED LANES	$259,546,500	3.253	BEXAR/GUADALUPE COUNTY LINE	GUADALUPE/COMAL COUNTY LINE	no	Already included in SAM projects
1510062	2025	ADD NB & SB EXPRESS LNS	$856,400,000	3.8	SH 45N	FM 1825	no	Already included in SAM projects
1416268	2030	WIDEN 4/6/8 TO 8 GP LANES W/COLLECTOR DISTRIBUTOR AUXILIARY LANES AND FR RDS CONNECTIONS INCLUDING SH 121 INTERCHANGE	$350,000,000	6.495	I-30	I-820	no	Already included in SAM projects
1710168	2020	EXPAND 8 TO 12 LN EXPY -ADD 4 NEW MANAGED LANES-INCLUDING MANAGED LANE CONNS AT I-410 N & I-410 S	$568,530,500	3.949	I-410 S	I-410 N	no	Already included in SAM projects
1513077	2025	ADD NB & SB EXPR LNS	$195,584,400	6.34	RIVERSIDE DR	LP 275-SLAUGHTER LANE	no	Already included in SAM projects
1508143	2024	FUTURE TRANSPORTATION CORRIDOR	$129,100,000	4.771	SH 29	NORTH OF SH 130	yes	Add managed lanes reflect the effect of future corridor
1403088	2020	RECONSTRUCT INTERCHANGE AT FM 917 AND CONVERT FRONTAGE ROADS TO ONE WAY	$15,000,000	8.1	RICKY LN	US 67	yes	Change FC from 12 to 14 for the minor road of the intersection

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length	Limits From	Limits To	Modified or not	Modification
1607113	2020	EXPAND FROM 8 LN TO 12 LN EXPY-ADD 4 NEW MANAGED LANES INCLUDING MANAGED LANE CONNS AT LP 1604	$617,968,000	6.778	I-410 N	GUADALUPE/BEXAR COUNTY LINE	no	Already included in SAM projects
1513389	2025	ADD NB & SB EXPRESS LNS	$212,150,000	7.097	FM 1825	US 183	no	Already included in SAM projects
8112041	2035	RECONSTRUCT & WIDEN FROM 4 LANE W/4/6 FRTG RD-D TO 6 LANE W/4/6 FRTG RD-C AND 4 HOV/MANAGED-C	$270,380,540	7.201	US 81/287 SPLIT	DENTON COUNTY LINE	yes	Change number of lanes from 6 lanes to 4 lanes
4809029	2019	RECONSTRUCT AND WIDEN FROM 4 LANES TO 6 LANES, RECONSTRUCT AND REALIGN RAMPS	$100,000,000	7.887	I-35W	ELLIS CO LINE	no	Already included in SAM projects
1402050	2027	RECONSTRUCT FREEWAY MAINLANES. ADD 1 GP LANE EACH DIRECTION FOR TOTAL OF 4 GP LANES EACH DIRECTION	$482,000,000	6.613	I-20	SH 174	no	Already included in SAM projects
1509183	2023	FUTURE TRANSPORATION COORIDOR	$113,100,000	5.16	RM 1431	SH 29	yes	Add managed lanes
44203042	2021	RECONSTRUCT INTERCHANGE	$25,000,000	1.979	AT FM 664	AT FM 664	yes	Change FC from 16 and 17 to 14 for the minor road of the interchange
19601108	2026	RECONSTRUCT 6/8 TO 8 GP LANES; RECONSTRUCT AND CONVERT 2	$388,006,067	8.257	TURBEVILLE RD	US 77	no	Already included in SAM projects

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length	Limits From	Limits To	Modified or not	Modification
		REVERSIBLE TO 4 CONCURRENT MANAGED LANES						
19602124	2026	RECON/CNVRT 2R TO 4CON MGD;6 TO 6/8 CD LNS;4/6 TO 2/6 CON FR (DAL C/L-121); RECON EX 8GP LNS;2/6 TO 2/8 CON FR(121-FM407)	$720,605,307	7.612	DALLAS COUNTY LINE	FM 407	no	Already included in SAM projects
19603274	2026	RECON & CONVERT 2-REV TO 4-CON MGD LN; RECON 6 TO 8 GP LNS (I 635 TO SH 121);RECON 6 TO 6/8 CD LNS (SH 121 TO DENTON C/L)	$494,847,135	6.397	I-635	DENTON COUNTY LINE	no	Already included in SAM projects
19602125	2026	RECON EXIST 4 GP LNS (NB ONLY); WIDEN & CONVERT 2 REV TO 4 CONC MGD LNS; WIDEN 4/6 TO 4/8 LN CONTINUOUS FRONTAGE ROADS	$499,217,637	2.339	FM 407	TURBEVI LLE ROAD	no	Already included in SAM projects
1708087	2020	CONSTRUCT 2 LANE UNDIVIDED FACILITY WITH ELEVATED INTERSECT	$ 4,522,300	0.726	0.235 MI SOUTH OF RRGS AT RELIEF RT	0.235 MI NORTH OF RRGS AT RELIEF RT	Yes	Upgrade Functional Class of Adjacent Link from Functional Class 1 to Functional Class 11 and Widen from 2 to 4 lanes
19502054	2040	WIDEN 6 LANE RURAL TO 8 LANE URBAN FREEWAY	$ 72,790,000	12.436	US 77 (NORTH OF DENTON)	COOKE COUNTY LINE	Yes	Change functional class from 6 to 14
19502074	2023	RECONSTRUCT AND WIDEN 4 TO 6 LANE RURAL FREEWAY WITH RAMP MODIFICATIONS AND RECONSTRUCT 4	$ 582,280,000	11.155	US 77 (NORTH OF DENTON)	COOKE COUNTY LINE	Yes	Change number of lanes from 2 lanes to 3 lanes

Control Section Job	Project Year	Project Description	Construction Cost (Dollars)	Project Length	Limits From	Limits To	Modified or not	Modification
		LANE FRONTAGE ROADS						
19501110	2040	WIDEN TO A 8 LANE FREEWAY FACILITY	$ 30,000,000	1.688	DENTON COUNTY LINE	0.7 MILES NORTH OF FM 3002	Yes	Change number of lanes to 4 lanes
19501116	2023	WIDEN 4 TO 6 LANE RURAL FREEWAY	$ 73,770,000	1.688	DENTON COUNTY LINE	NORTH OF FM 3002	Yes	Change number of lanes from 2 lanes to 3 lanes
19501087	2030	WIDEN FROM 6 LANE TO 8 LANE FREEWAY FACILITY	$ 52,000,000	13.523	0.7 MILES NORTH OF FM 3002	0.2 MILES SOUTH OF US 82	Yes	Change number of lanes from 3 lanes to 4 lanes
19501111	2021	WIDEN TO 6 LANE FREEWAY FACILITY	$ 319,500,000	13.523	0.7 MILES NORTH OF FM 3002	0.2 MILES SOUTH OF US 82	Yes	Change number of lanes to 3 lanes
19402081	2030	WIDEN FROM 6 LANE TO 8 LANE FREEWAY FACILITY	$ 26,000,000	6.355	RED RIVER BRIDGE	0.2 MILES SOUTH OF US 82	Yes	Change number of lanes from 3 lanes to 4 lanes
19402092	2023	WIDEN TO 6 LANE FREEWAY FACILITY	$ 205,000,000	6.355	0.2 MILES SOUTH OF US 82	RED RIVER BRIDGE	Yes	Change number of lanes to 3 lanes
19401010	2023	WIDEN TO 8 LANE FREEWAY FACILITY	$ 26,200,000	0.241	ON I-35 AT THE RED RIVER BRIDGE	.	Yes	Change number of lanes to 4 lanes