Mobility Investment Priorities Project

Economic & Congestion Benefit Evaluation

December 2013

mobility
INVESTMENT PRIORITIES

Texas A&M Transportation Institute

Establishing Mobility Investment Priorities Under TxDOT Rider 42:

Economic and Congestion Benefit Evaluation

Prepared for
Texas Transportation Commission
And
83rd Texas Legislature

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PURPOSE AND REPORT ORGANIZATION

As part of the Mobility Investment Priorities (MIP) project (officially authorized under the General Appropriations Act, 82nd Texas Legislature), lawmakers tasked the Texas A&M Transportation Institute (TTI) with estimating the benefits and costs of high-priority congestion-reducing transportation projects. Traffic congestion has been a significant problem in Texas' major metropolitan regions for many years, directly affecting the state's economic growth and quality of life. Developing an economic assessment of the benefits is an important practice that ensures public investments are spent wisely.

Therefore, this report provides an overview of benefits that result from transportation mobility improvements, offers a comparison of those benefits with the preliminary project cost estimates, and summarizes the benefit calculation methodology. Results for five congestion-reducing projects are presented in an executive summary format. Additional information on the calculation process used to determine congestion reduction, total economic benefits, and how those are compared to the preliminary costs are provided in Appendices A–H. Four of the five projects are in some phase of study, with many details yet to be determined, analysis continuing, and public comments still being solicited and analyzed—nothing in this report should be read as dictating conclusions or describing final designs. This report may provide additional information to those deliberations about project scale and about the various projects and programs that might provide significant economic returns.

With several key project and analysis elements not yet determined, it also seems appropriate to maintain a very conservative set of assumptions. In several cases either a conservative value was used or several assumptions were tested to identify how sensitive the results were to the assumptions. Most of these decisions affect the estimated benefits; only high-level planning cost estimates are available for most projects. This is an appropriate decision at this early stage of development, but readers should realize that the benefit values and the benefit/cost comparisons will change. Consider this report as part of the dialogue, not an end of the discussion.

BENEFITS RESULTING FROM MOBILITY IMPROVEMENTS

Infrastructure spending usually results in economic and social benefits to an economy. The design and function of a transportation project can determine the magnitude of the effect on the local and regional economy after it is constructed. The type of industrial, commercial and employment markets in the metropolitan area also affects the type and amount of benefit from a project. The following are the five major benefits from transportation infrastructure investment that were evaluated in this report:

- **Traveler Benefits (Out-of-Pocket):** More spending on transportation infrastructure can result in direct personal benefits to Texans. These include cost savings resulting from a reduction in travel time for personal and business vehicle drivers. Improving the speed of travel and reducing stop-and-go traffic result in fuel savings due to more efficient fuel burn, which means vehicle operating cost savings for personal and commercial travel. *Travelers must buy more fuel when they travel in congestion.*
- **Traveler Benefits (Not Out-of-Pocket):** Traveler benefits that do not affect out-of-pocket expenses include the value of personal time and travel time reliability. Value of personal time and reliability are associated with the amount of time a driver spends on the road rather than attending important family functions or spending time accomplishing personal activities. All

travelers place a value on their travel time—and that value changes according to what the trip purpose is, how important the trip is, and how late the traveler might be at the end of the trip. Rather than sitting idle in traffic, drivers could be meeting with clients, at home with their families, or otherwise using their time more productively. Some of these alternative trips do not have a direct monetary effect on the U.S. gross domestic product, but they clearly have a value for the individual traveler. *Travel time is valuable—ask someone who is late to a social function or a parent who misses a ballgame or a recital.*

- **Shipper/Logistics Cost Savings:** Reducing the travel time and shipping costs for industries that produce or consume the freight shipped on trucks traveling in congested corridors can have a positive effect on the economy. The consumer costs are decreased and the economic competitiveness of businesses is improved if serious congestion is eliminated. *Longer travel times mean drivers and trucks can make fewer trips during a day, plumbers and electricians make fewer service calls, and distribution centers are able to serve fewer stores or manufacturing operations.*
- **Economic Benefits:** An improved transportation network can mean increased business output, value added, more jobs and increased wage income, and can produce positive impacts to Texas businesses. Conversely, traffic congestion can constrain the ability for goods and services to be shipped and delivered efficiently. Reducing traffic congestion can allow for the more efficient shipment of goods and services. *Lower congestion levels expand the area that can be reached—by an employee and employers. Residents can have their choice of more jobs, employers can find workers with the right skills, and producers have access to more potential sales markets.*
- **Societal and Environmental Cost Savings:** Reducing traffic congestion can also result in environmental cost savings and societal benefits. *Environmental benefits, such as improvement in air quality from the reduction of stop-and-go traffic and the increase in time for civic engagement and family time, provide net positive social and financial impacts for the Texas economy.*

Taken together, these five major transportation infrastructure investment benefit categories can be used to estimate the total economic and societal benefit to all Texans.

MOBILITY IMPROVEMENT COSTS

While mobility improvements can provide significant economic value to the Texas economy, major projects also require significant capital investment to build and maintain.

- *Mobility improvement costs* in this report refer to construction costs (e.g., acquiring land to construct a new highway and the actual construction of the facility).
- *Operation and maintenance costs* refer to general roadway and right of way maintenance and, where applicable, expenses related to collecting tolls.

These costs are phased in over a three- to four-year construction period and subsequent annual expenses and aggregated over a period of 30 years.

Constantly changing factors such as increases in construction material prices, labor, land, and raw materials mean that costs for mobility projects can be difficult to predict. Therefore, it is important to note that the costs presented in this report are only preliminary estimates and are subject to change. In some cases, the project is in the conceptual stage, and the public is still being consulted; this happens to be an ideal stage for a benefit estimate, but it also means that the values will change as the public is engaged and project designs evolve. A project with total benefits of $1 billion and total costs of $600 million could be worthwhile to pursue. However, a two-fold increase in project costs could change the viability of the project.

REVENUE ESTIMATES

The funding and financing ideas offered in this report use familiar concepts as comparisons. The major sources of Texas state-level transportation funding come from the 18.4 cent per gallon federal motor fuel tax, the 20 cent per gallon state motor fuel tax, and the $50 average vehicle registration fee.[1] Values in this report for these sources are used as a "how much more than I pay now" type of comparison—they are not recommendations, advice, or suggestions of public consent. Other, less familiar sources and the estimation techniques are described below.

Tax Increment Financing

Property values were available for the Houston projects through the Harris County Appraisal District facet maps.[2] Properties within a conservative distance of approximately ½ mile of the roadway were used as the area that would likely experience growth in value due to the proposed improvement. Taking the total property value for the project corridor, the research team determined a value per mile by dividing the property value by the length of the project. For the Austin and San Antonio projects, we multiplied Houston's value per mile by the length of the project to determine a total property value for the tax increment financing zones of each project. Tax exempt properties such as Fort Sam Houston in San Antonio and the University of Texas in Austin were subtracted from the estimated value. Keeping our estimates conservative, a 2 percent increase in value was then applied each year to the property values. We then calculated the property tax revenue resulting from the 2 percent increase using the tax rates for each project's area. There are a variety of tax increment zones in place; the 2 percent annual value can be thought of as an estimate of the end result of negotiations over apportioning the significant benefits that will occur in the corridors due to the substantial transportation improvements.

Managed Lane Revenue

All of the project discussions in the studied corridors have managed lanes—facilities where users pay a toll for high speed and reliable travel times. In most cases, transit buses travel for free in these lanes, and in some locations carpools are also free. In most cases, the lanes have a variable toll rate that rises as congestion worsens; the toll rate ensures that just enough vehicles use the lanes to fill up the capacity but not overload the lane. This premium service is used by those who place a high value on a particular trip—typically these are workers who can make one or two more service calls during the day if they are not delayed by congestion; parents late for daycare pick-up; or others who are late for meetings, a plane flight, or a social or family event.[3]

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[1] http://mobility.tamu.edu/mip/rpm.php
[2] Harris County Appraisal District Index Map. http://www.hcad.org/maps/default.asp
[3] http://mobility.tamu.edu/mip/strategies_pdfs/added-capacity/executive-summary/managed-hov-hot-1-pg.pdf

The research team calculated toll rates using a range of cents per mile. The lowest rate ($0.17/mile) represents the 2015 rate posted by the North Texas Tollway Authority (NTTA); the highest rate ($0.50/mile) is similar to those seen on the Houston Katy Freeway (IH 10 West) during peak travel times.

The percent of trips using the managed lanes was also calculated using a range. A preliminary estimate by the Central Texas Regional Mobility Authority (CTRMA) showed the managed lane revenue for Austin's Loop 1 (MoPac) project could pay for 60 percent of the project's total cost. The median percent of annual trips estimated to use the managed lanes on Loop 1 was established by assuming a median toll rate of $0.30/mile and total revenue equal to 60 percent of the project's total cost. Using Loop 1 as a baseline, we applied the calculated median percentage of trips proportionally to the remaining projects. The percent of trips in the managed lanes varied from 30 percent lower to 30 percent higher for the revenue calculations.

Bond Values

In calculating bond values and payments, we assumed a 4 percent interest rate along with a 2 percent issuance cost and a 1.2 debt coverage ratio. We estimated both 15- and 30-year bonds backed by the full faith and credit of the State of Texas. Any costs associated with financing the project, such as interest or bond issuance costs, are not included in the benefit/cost analysis.

PROJECT FINDINGS

Benefit/Cost Comparison

An analysis of the benefits and costs was performed for five projects located in Austin, Houston, and San Antonio. Exhibit 1 illustrates the benefit/cost ratios for each project. The costs of the US 290 project are being funded from a variety of sources, and construction has begun on several sections; the other projects are in early planning stages, and the costs shown are estimates based on design options being studied. The benefit/cost ratio in Exhibit 1 includes the total cost of constructing and operating the project (and does not include any financing costs).

Exhibit 1: Benefits and Costs Summary

Metro Area	Project	Total Benefits ($Million)	Total Costs ($Million)	Benefit/ Cost Ratio
Austin	IH 35	$9,490	$1,800	5.3:1
Austin	Loop 1	$1,320	$270	5.0:1
Houston	IH 45	$10,330	$2,170	4.8:1
San Antonio	IH 35	$6,470	$2,160	3.0:1
Houston	US 290	$5,990	$890	6.8:1

The five projects examined in this report have a combined benefit/cost ratio of greater than 4.6 to 1, returning $33 billion in estimated benefits as a result of the initial $7 billion capital investment. Further, of the $33 billion in benefits that Texans will see from the projects, over $20 billion in benefits result directly from the mobility improvements in the form of savings in travel time, fuel, shipping and logistics costs, and the associated economic benefits that result.

Paying for the Projects

The project costs are substantial, but so are the benefits. The Mobility Investment Priorities project was tasked with identifying funding options for the projects; more detailed explanations of a variety of strategies are included in the project summaries that follow. All the strategies assume that the costs will be paid for by the residents and travelers in the region. These may be from a local option fee, an allocation from a statewide fund, or some other source. It could be from a newly enacted or increased fee or tax, or it could be from repurposing an existing tax or fee. A summary is presented below.

Traditional Approaches

Traditionally, projects have been paid for using State Highway Fund resources consisting mainly of revenue from motor fuel taxes and vehicle registration fees. Exhibit 2 shows the increase in statewide fuel tax or vehicle registration fees needed to pay for each project using a pay-as-you-go approach or a 30-year bond.

Exhibit 2: Paying for the Project Using Traditional Statewide Funding Sources

			Paying for the Project over a 3- or 4-Year Construction Period		Paying for the Project with a 30-Year Bond	
Metro Area	Project	Total Costs ($ Million)	Fuel Tax Increase (₵/Gallon)	Vehicle Registration Fee Increase ($/Vehicle)	Fuel Tax Increase (₵/Gallon)	Vehicle Registration Fee Increase ($/Vehicle)
Austin	IH 35	$1,800	4₵	$18	1.3₵	$8
Austin	Loop 1	$270	1₵	$3	0.2₵	$1
Houston	IH 45	$2,170	6₵	$32	1.5₵	$9
San Antonio	IH 35	$2,160	5₵	$22	1.5₵	$9
Statewide Total		**$6,390**	**16₵**	**$75**	**4.5₵**	**$27**

Another funding strategy (should the Texas Legislature authorize it) could include local motor fuel taxes and/or vehicle registration fees (either by legislation or by voter approval). Exhibit 3 shows the local tax or fee increase needed to fund each project using a pay-as-you-go approach or a 30-year bond. This is the local area allocation in cents per gallon or dollars per vehicle needed to fund the project if the fee were paid only by local residents or travelers.

Exhibit 3: Paying for the Project Using Traditional Funding Sources Applied Locally

			Paying for the Project over a 3- or 4-Year Construction Period		Paying for the Project with a 30-Year Bond	
Metro Area	Project	Total Costs ($Million)	Local Fuel Tax Increase (₵/Gallon)	Local Vehicle Registration Fee Increase ($/Vehicle)	Local Fuel Tax Increase (₵/Gallon)	Local Vehicle Registration Fee Increase ($/Vehicle)
Austin	IH 35	$1,800	55₵	$230	16.0₵	$74
Austin	Loop 1	$270	8₵	$35	2.5₵	$11
Houston	IH 45	$2,170	26₵	$145	5.5₵	$31
San Antonio	IH 35	$2,160	55₵	$255	16.0₵	$79

A "Multi-payer" Solution

Several examples of possible ways to finance the projects are also presented in this report. As an example, Exhibit 4 shows the amount of bond debt that could be issued using the listed revenue streams to service the debt for 30 years. For example, bond debt could be issued for the total cost of the IH 35 project in Austin assuming a median value for the expected managed lanes revenue stream, revenue from tax increment financing zones, and revenue received from an allocation equivalent to $63 per Austin registered vehicle.

Exhibit 4: Paying for the Project Now Summary

	Bonding Capacity (to Fund the Project Cost)			
Revenue Source	**Austin IH 35 ($1,800 Million)**	**Austin Loop 1 ($270 Million)**	**Houston IH 45 ($2,170 Million)**	**San Antonio IH 35 ($2,150 Million)**
Managed Lane Revenue	$42 to $268	$71 to $353	$282 to $1,525	$127 to $720
Tax Increment Financing Revenue	$105	$37	$25	$134
Total Bond Value	***$299 to $1,250***	***$108 to $390***	***$308 to $1,550***	***$261 to $855***
Local Vehicle Registration Fee Revenue*	$1,553*	$25*	$1,297*	$1,610*
Additional Bond Value	***$1,553***	***$25***	***$1,297***	***$1,610***
Total Bond Value	***$1,701 to $1,927***	***$133 to $415***	***$1,605 to $2,847***	***$1,871 to $2,465***

**Local vehicle registration fees (assuming median value of managed lane revenue):*
Austin IH 35: $63, Austin Loop 1: $1, Houston IH 45: $18, San Antonio IH 35: $59

A New Idea

A new, blended financing arrangement presented in this report uses state and local strategies in order to take advantage of certain attributes of each government level. Under this funding strategy the state could issue a bond (backed by the credit of the state) to cover the cost of the project, thus obtaining a lower interest rate than a local agency could. The state and local authorities would then agree to a repayment schedule that would benefit both parties.

For example, Exhibit 5 illustrates the possible resulting funding shares if the state and local governments each pay half of the project cost and the local governments pay all of the interest costs on a 30-year bond. For IH 35 in Austin, the state would owe $30 million annually. This payment could be made, for example, using funds from oil and gas fees should the constitutional amendment be approved in the November 2014 election.[4] The remaining $74 million would be owed by the local government. This annual payment could possibly be made using managed lane revenue, proceeds from a tax increment financing zone, and revenue received from an allocation equivalent to $30 per Austin registered vehicle. For Loop 1 (MoPac), depending on the toll rate and managed lane volume, the locally owed portion of the payment could be made entirely from the estimated managed lane revenue. This strategy could

[4] The Texas Legislature recently passed a proposed constitutional amendment that would transfer up to $1.2 billion in revenues from oil and gas severance tax to the State Highway Fund. This amendment will be on the ballot in the November 2014 general election.

also be implemented using a bond with a shorter term, thereby reducing the amount of interest owed by the local government over the term of the loan.

Exhibit 5: State and Local Cost Sharing Summary for Innovative Bonding Strategy

Paying for the Project Using State and Local Cost Sharing (30 Years) ($Million)				
	Austin		Houston	San Antonio
Revenue Source	**IH 35**	**Loop 1**	**IH 45**	**IH 35**
Annual State-Owed Debt Service	$30	$4	$36	$36
Annual Locally Owed Debt Service	$74	$11	$89	$89
Total Annual Debt Service	***$104***	***$15***	***$125***	***$125***
Voter-Approved (Nov. 2014) Funds from Oil and Gas Fees	$30	$4	$36	$36
Total Annual State Revenue	***$30***	***$4***	***$36***	***$36***
Managed Lane Revenue	$3 to $19	$5 to $25	$20 to $108	$9 to $51
Tax Increment Financing	$7 to $33	$3 to $12	$2 to $31	$10 to $42
Local Vehicle Registration Fee Revenue*	$57*	$0*	$25*	$49*
Total Annual Local Revenue	***$68 to $109***	***$7 to $38***	***$47 to $164***	***$68 to $142***
Total Revenue	***$98 to $139***	***$12 to $41***	***$83 to $200***	***$104 to $178***

**Local vehicle registration fees (assuming median value of managed lane and tax increment zone revenue): Austin IH 35: $30, Houston IH 45: $5, San Antonio IH 35: $24*

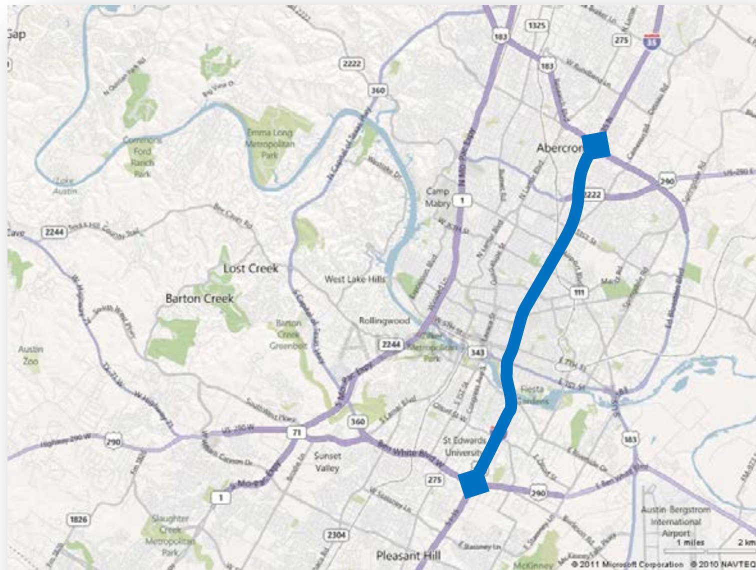
A state and local cost sharing approach opens the project sooner, providing early congestion relief. In return for these earlier benefits to local travelers, the local funding pays for the state's borrowing costs, allowing state funds to be spent on other congestion relief and roadway repair projects.

IH 35 Austin

US 183 to SH 71 (Ben White Blvd)

Current Conditions and Proposed Project

The 10.2-mile section of Austin's central IH 35 has three distinct general designs. Between US 183 and Airport Boulevard, IH 35 operates with four lanes in each direction. From there, IH 35 has an upper deck/lower deck configuration, with two lanes in each direction on each deck between Airport and Martin Luther King, Jr. Boulevard (MLK). South of MLK, IH 35 has three main freeway lanes in each direction.



While discussions about the project are continuing, one possible design could include adding two managed lanes to the existing Austin IH 35 freeway as well as other cross street and frontage road improvements (http://www.mobility35.org/). The project construction cost is estimated at $1.7 billion and will require an estimated $9.6 million annually in operating and maintenance (O&M) costs.

Congestion Reduction Benefits

The IH 35 managed lanes project will result in several benefits directly to users. The following benefits on IH 35 are likely to result:

- From SH 71 to US 183, average peak-period speed is estimated to increase from 37 mph to 44 mph; from US 183 to Howard Lane, average peak-period speed is estimated to increase from 51 mph to 59 mph; from SH 71 to RM 150, average peak-period speed is estimated to increase from 58 mph to 64 mph.
- From SH 71 to US 183, congestion levels are estimated to decrease from 41 percent to 28 percent; from US 183 to Howard Lane, congestion levels are estimated to decrease from 13 percent to 8 percent; from SH 71 to RM 150, congestion levels are estimated to decrease from 8 percent to 4 percent.

Economic Impact Analysis Results

These congestion reduction benefits also manifest as economic benefits for the state. Overall, this analysis estimated the benefit/cost ratio for this project to be **5.3** to **1** (Exhibit 1). This economic impact analysis (EIA) compares the capital construction and operation costs needed to maintain the new facility to the quantifiable benefits of the project for 30 years following construction.[5] This project will result in several direct benefits to users. Vehicle operating cost reduction benefits, travel time reduction, and the value of personal time will improve as a result of congestion reduction. Shippers and receivers will be more productive because they will be able to efficiently deliver their products where they need to go. Local wage income in the Greater Austin region will

[5] Please refer to Appendix B for more information on the calculation process used.

increase as construction jobs are created to build the managed lanes project. Finally, the reduction in bumper-to-bumper traffic will generate environmental impacts.

Exhibit 1: Economic Impact Analysis Summary

Benefits and Costs	Present Value (2013 $Million)
Vehicle Operating Cost Benefits	$578
Reduction in Travel Time	$1,414
Value of Personal Time	$780
Logistics/Freight Costs	$134
Value Added	$2,687
Economic Effect of Wage Income	$3,886
Environmental Factors	$8
Total Benefits	***$9,487***
Capital Costs	$1,627
Maintenance Costs	$176
Total Costs	***$1,803***
Benefit/Cost Ratio	***5.3***

Note: Present value calculated using 3% discount rate.

Method and Sources of Finance

If the IH 35 expansion includes managed lanes, the toll revenue can provide one source of project funding. But very few managed lanes projects in the United States pay for all the project costs; detailed studies of operating scenarios and revenue are needed to determine realistic estimates. This study developed an annual revenue estimate of between $17 and $91 million if the managed lanes were open in 2013. If the managed lanes revenue cannot cover all the costs, there are several options for funding the remaining need.

Major improvements on the state roadway network are typically funded from a combination of federal and state tax sources. Historically, the major source of federal funds has been in the form of partial reimbursement to the state of the 18.4 cent per gallon federal fuel tax on gasoline and the 24.4 cent per gallon federal fuel tax on diesel fuel paid by Texans and visitors on fuel purchased in the state.

Major sources of state revenue for roadway improvement are derived from the 20 cent per gallon state tax on gasoline and diesel fuel purchased in Texas and the revenue received from annual vehicle registration fees.[6] The vehicle registration fee for most personal vehicles is $50.75 per year. The vehicle registration fee for heavy vehicles ranges from $110 per year for a vehicle weighing 10,000 pounds to $840 per year for an 80,000-pound vehicle.

As an example, if the IH 35 improvements were funded entirely from state funds, the project would require the equivalent of 4 cents of state motor fuel taxes or $18 in vehicle registration fees for four years.

Local participation by cities, counties, toll authorities, or special districts in funding major transportation projects on the state roadway network has become more prevalent in recent years. This participation can take many forms including, but not limited to, managed lane revenue, direct contributions, and loans.

Below are several different strategies for funding the IH 35 improvements. These strategies are meant to serve only as examples and as an illustration of a few alternatives that can be used alone or in combination as a means to fund the improvement.

Local Strategies

There are also a number of opportunities for local revenue to be developed. Tax increment financing serves as a means to capture the increase in property tax revenue that would be received as a result of the incremental increase in property values in a corridor that results from the transportation improvement. The difference between the property tax revenue received prior to the IH 35 improvement versus the property

[6] The Texas Constitution dedicates ¾ of the revenue from the motor fuel tax to transportation and ¼ of the revenue to public education.

tax revenue received after the IH 35 improvement could be used to help fund the project.

In the IH 35 corridor between SH 71 and US 183, the combined taxable values of the properties within ½ mile of the project are estimated to be $3.1 billion. Assuming a 2 percent increase in property values per year and assuming that property tax rates are kept constant, it is estimated that a tax increment financing strategy could yield approximately $816 million over 30 years. If the past is any indication of what will happen in the IH 35 corridor, however, new development is likely to add more than a 2 percent annual increase, thereby producing more than $816 million in revenue.

Another local funding strategy (should the legislature authorize it) could include additional local motor fuel taxes and/or vehicle registration fees (either by legislation or by voter approval). These fees could then be used to fund the improvement.

Unfortunately, the pay-as-you-go strategy requires many years to build up sufficient funds. As an example, to pay for the project within a four-year construction time period, an estimated regional motor fuel tax of 55 cents per gallon or an estimated local vehicle registration fee of $230 per vehicle would be required.

Using a combination of these pay-now strategies also does not seem feasible. Revenue received from an allocation equivalent to $222 per Austin registered vehicle in addition to revenue from tax increment financing would be needed to construct the improvements with an estimated cost of $1.8 billion (Exhibit 2).

Exhibit 2: Paying for the Project in Four Years

Paying for the Project in 4 Years	($Million)
Tax Increment Financing	$39
Local Vehicle Registration Fee Revenue ($222/Vehicle)	$1,769
Total Revenue	***$1,808***

A more viable strategy is to use the revenue streams from the local funding sources outlined above to secure debt in order to construct the improvement. In that case, revenue from a tax increment financing mechanism would secure approximately $105 million in bond debt, while a revenue stream from managed lanes could secure an estimated $42 million to $268 million in bond debt, depending on traffic volumes and toll rates. Again, taken together, the funding strategy in Exhibit 3 could be constructed.

Exhibit 3: Paying for the Project Now

Paying for the Project Using 30-Year Bonds	($Million)
Managed Lane Revenue	$42 to $268
Tax Increment Financing	$105
Local Vehicle Registration Fee Revenue ($44/Vehicle)	$1,553
Total Revenue	***$1,701 to $1,927***

A New, Blended Financing Arrangement
Analysts and policy experts familiar with the Texas transportation system have concluded that the most likely funding scenarios involve a mix of options.[7] During the Mobility Investment Priorities project, a plan that uses several state and local strategies was developed to take advantage of certain attributes of each government level. Under this funding strategy the state could issue a bond backed by the credit of the state to cover the cost of the project, thus potentially obtaining a lower interest rate than a local agency could. The state and local authorities would then agree to a repayment schedule that would benefit both parties.

For example, Exhibit 4 illustrates the resulting funding shares if the state and local governments each pay half of the project cost and the local governments pay all of the interest costs. This

[7] House Committee on Transportation Funding, Bill Analysis, Tex. H.B. 1, 83rd Leg., 3d C.S. (2013).

approach recognizes the benefit of the state's borrowing power to obtain a low interest rate, and the advantages to commuters and freight shippers from the early implementation of improvements.

Exhibit 4: State and Local Cost Sharing Payments

State and Local Cost Sharing Annual Payment (30 Years)	($Million)
Annual State-Owed Debt Service (50% of Principal)	$30
Annual Locally Owed Debt Service (50% of Principal + 100% of Interest)	$74
Total Annual Debt Service	***$104***

The state's share of the annual payment could come from the oil and gas fee funding that will be voted on in November 2014. The local share could come from a variety of revenue sources including tax increment financing, revenue from the new managed lanes, and revenue from an allocation equivalent to an increase in the vehicle registration fee (Exhibit 5).

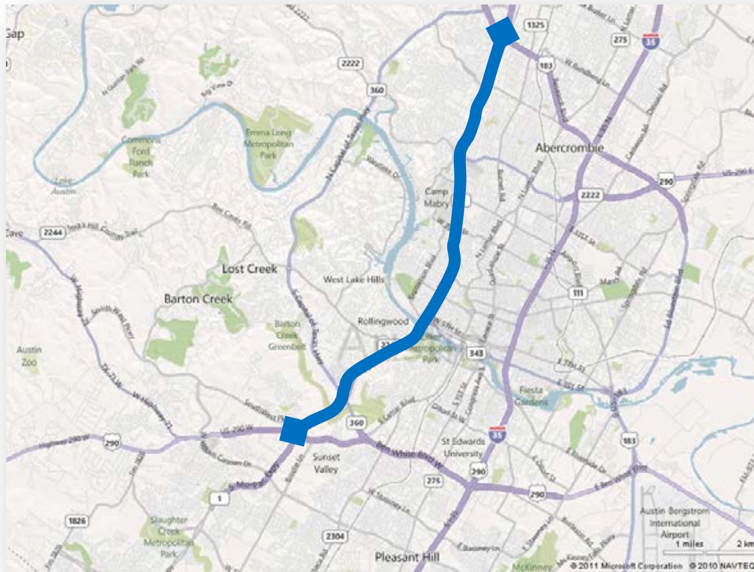
Exhibit 5: State and Local Cost Sharing Sources

Paying for the Project Now Using State and Local Cost Sharing (30 Years)	($Million)
Voter-Approved (Nov. 2014) Funds from Oil and Gas Fees	$30
Total Annual State Revenue	***$30***
Managed Lane Revenue	$3 to $19
Tax Increment Financing	$7 to $33
Local Vehicle Registration Fee Revenue ($30/Vehicle)	$57
Total Annual Local Revenue	***$68 to $109***
Total Revenue	***$98 to $139***

NOTE: The funding ideas presented here are for discussion purposes only. They should not be taken as specific recommendations.

Loop 1 (MoPac) Austin

US 183 North to US 290 West



Current Conditions and Proposed Project

From US 183 to US 290, MoPac operates primarily with six lanes, three northbound and three southbound. While there is access to the highway throughout the stretch, the majority of parallel arterials run through residential areas and become congested during peak periods. Due to the residential and commercial development parallel to MoPac, the potential for future road widening is limited. Construction has begun on the addition of a pair of managed lanes from Cesar Chavez to Parmer Lane (http://www.mopacexpress.com/). They are expected to begin operating in 2015. Rider 42 funds were allocated to conduct the environmental impact study in the south portion of the corridor from Cesar Chavez to Slaughter Lane. The primary south section build option being studied is a continuation of the north section managed lanes.

While discussions about the project are continuing, one possible design could include adding two managed lanes to the existing Loop 1 as well as other cross street and frontage road improvements. The project construction cost is estimated at $250 million and will require an estimated $1.4 million annually in O&M costs.

Congestion Reduction Benefits

The Loop 1/MoPac managed lanes project will result in several benefits directly to users:

- From Cesar Chavez to SH 71, average mainlane peak-period speed is estimated to increase from 45 mph to 50 mph; from US 183 to Cesar Chavez, average peak-period speed is estimated to increase from 45 mph to 50 mph; from US 183 to FM 734, average peak-period speed is estimated to increase from 56 mph to 57 mph.
- From Cesar Chavez to SH 71, congestion levels are estimated to decrease from 8 percent to 6 percent; from US 183 to Cesar Chavez, congestion levels are estimated to decrease from 12 percent to 10 percent.

Economic Impact Analysis Results

This analysis estimated the benefit/cost ratio for this project to be **5.0** to **1** (Exhibit 1). This EIA compares the capital construction and operation costs needed to maintain the new facility to the benefits of the project for 30 years following construction.[8] This savings will result in several direct benefits to users. Vehicle operating cost reduction benefits, travel time reduction, and the value of personal time will improve as a result of congestion reduction. Shippers and receivers will be more productive because they will be

[8] Please refer to Appendix C for more information on the calculation process used.

able to efficiently deliver their products where they need to go. Local wage income in the Greater Austin region will increase as construction jobs are created to build the managed lanes project. Finally, congestion reduction will create environmental benefits.

Exhibit 1: Economic Impact Analysis Summary

Benefits and Costs	Present Value (2013 $Million)
Vehicle Operating Cost Benefits	$29
Reduction in Travel Time	$209
Value of Personal Time	$144
Logistics/Freight Costs	$7
Value Added	$381
Economic Effect of Wage Income	$555
Environmental Factors	$0.1
Total Benefits	***$1,324***
Capital Costs	$239
Maintenance Costs	$26
Total Costs	***$265***
Benefit/Cost Ratio	***5.0***

Note: Present value calculated using 3% discount rate.

Method and Sources of Finance

One outcome of the environmental impact process could be a pair of managed lanes that will be operated by the Central Texas Regional Mobility Authority, similar to the northern end of the corridor. An initial revenue analysis indicated that the managed lane revenue might cover the construction and debt financing project costs; this will be examined in more detail in the environmental study. If the managed lane revenue cannot cover all the costs, there are several options for funding the remaining need.

Major improvements on the state roadway network are typically funded from a combination of federal and state tax sources. Historically, the major source of federal funds has been in the form of partial reimbursement to the state of the 18.4 cent per gallon federal fuel tax on gasoline and the 24.4 cent per gallon federal fuel tax on diesel fuel paid by Texans and visitors on fuel purchased in the state.

Major sources of state revenue for roadway improvement are derived from the 20 cent per gallon state tax on gasoline and diesel fuel purchased in Texas and the revenue received from annual vehicle registration fees.[9] The vehicle registration fee for most personal vehicles is $50.75 per year. The vehicle registration fee for heavy vehicles ranges from $110 per year for a vehicle weighing 10,000 pounds to $840 per year for an 80,000-pound vehicle.

As an example, if the Loop 1 improvements were funded entirely from state funds, the project would require the equivalent of 0.75 cents of state motor fuel taxes or $2.75 in vehicle registration fees for four years.

Local participation by cities, counties, toll authorities, or special districts in funding major transportation projects on the state roadway network has become more prevalent in recent years. This participation can take many forms including, but not limited to, managed lane revenue, direct contributions, and loans.

Below are several different strategies for funding the Loop 1 improvements. These strategies are meant to serve as examples only and as a means to illustrate a few alternatives that can be used alone or in combination as a means to fund the improvement.

Local Strategies

There are also a number of opportunities for local revenue to be developed. Tax increment financing serves as a means to capture the increase in property tax revenue that would be received as a result of the incremental increase in property values in a corridor that results from the transportation improvement. The difference

[9] The Texas Constitution dedicates ¾ of the revenue from the motor fuel tax to transportation and ¼ of the revenue to public education.

between the property tax revenue received prior to the Loop 1 improvement versus the property tax revenue received after the Loop 1 improvement could be used to help fund the project.

In the Loop 1 corridor between US 183 and US 290, the combined taxable values of the properties within ½ mile of the project are estimated to be $1.1 billion. Assuming a 2 percent increase in property values per year and assuming that property tax rates are kept constant, it is estimated that a tax increment financing strategy could yield approximately $288 million over 30 years. If the desired increase in development due to the improved mobility occurs, this value could grow.

Another local funding strategy (should the legislature authorize it) could include local motor fuel taxes and/or vehicle registration fees (either by legislation or by voter approval). These fees could then be used to fund the improvement.

Unfortunately, the pay-as-you-go strategy requires many years to build up sufficient funds. As an example, to pay for the project within a four-year construction time period, an estimated regional motor fuel tax of 8 cents per gallon or an estimated local vehicle registration fee of $35 per vehicle would be required.

Revenue from an allocation equivalent to $35 per Austin registered vehicle in addition to revenue from tax increment financing would be needed to construct the improvements with an estimated cost of $265 million (Exhibit 2).

Exhibit 2: Paying for the Project in Four Years

Paying for the Project in 4 Years	($ Million)
Tax Increment Financing	$14
Local Vehicle Registration Fee Revenue ($35/Vehicle)	$256
Total Revenue	***$269***

Another viable strategy is to use the revenue streams from the local funding sources outlined above to secure debt in order to construct the improvement. In that case, revenue from a tax increment financing mechanism would secure approximately $37 million in bond debt, while a revenue stream from managed lanes could secure an estimated $71 million to $353 million in bond debt, depending on traffic volumes and toll rates. Again, taken together the funding strategy in Exhibit 3 could be constructed.

Exhibit 3: Pay Now Using 30-Year Bonds

Paying for the Project Using 30-Year Bonds	($Million)
Managed Lane Revenue	$71 to $353
Tax Increment Financing	$37
Local Vehicle Registration Fee Revenue ($1/Vehicle)	$25
Total Revenue	***$336 to $1,563***

A New, Blended Financing Arrangement

Analysts and policy experts familiar with the Texas transportation system have concluded that the most likely funding scenarios involve a mix of options.[10] During the Mobility Investment Priorities project, a plan that uses several state and local strategies was developed to take advantage of certain attributes of each government level. Under this funding strategy the state could issue a bond backed by the credit of the state to cover the cost of the project, thus potentially obtaining a lower interest rate than a local agency could. The state and local authorities would then agree to a repayment schedule that would benefit both parties.

For example, Exhibit 4 illustrates the resulting funding shares if the state and local governments each pay half of the project cost and the local governments pay all of the interest costs. This approach recognizes the benefit of the state's

[10] House Committee on Transportation Funding, Bill Analysis, Tex. H.B. 1, 83rd Leg., 3d C.S. (2013).

borrowing power to obtain a low interest rate, and the advantages to commuters and freight shippers from the early implementation of improvements.

Exhibit 4: State and Local Cost Sharing Payments

State and Local Cost Sharing Annual Payment (30 Years)	($Million)
Annual State-Owed Debt Service (50% of Principal)	$4
Annual Locally Owed Debt Service (50% of Principal + 100% of Interest)	$11
Total Annual Debt Service	***$15***

The state's share of the annual payment could come from the oil and gas fee funding that will be voted on in November 2014. The local share could come from a variety of revenue sources including tax increment financing, revenue from the new managed lanes, and revenue from an allocation equivalent to an increase in the vehicle registration fee (Exhibit 5).

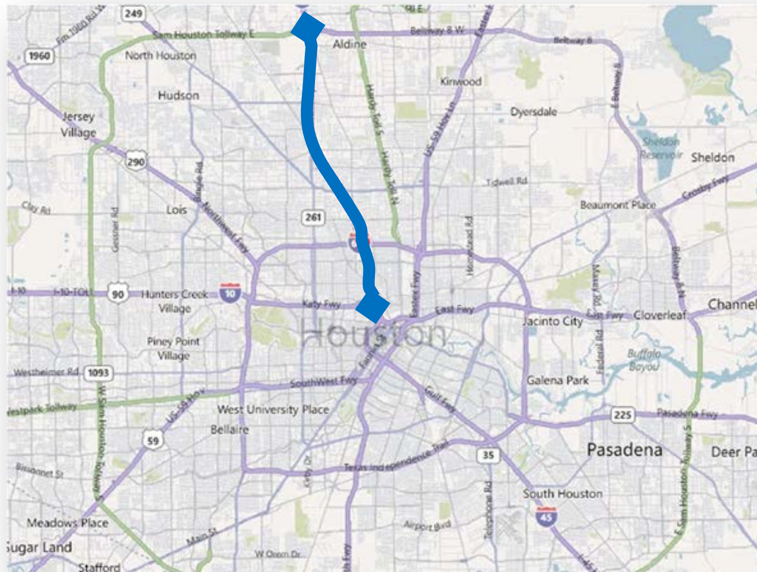
Exhibit 5: State and Local Cost Sharing Sources

Paying for the Project Now Using State and Local Cost Sharing (30 Years)	($ Million)
Voter-Approved (Nov. 2014) Funds from Oil and Gas Fees	$4
Total Annual State Revenue	***$4***
Managed Lane Revenue	$5 to $25
Tax Increment Financing	$3 to $12
Local Vehicle Registration Fee Revenue	$0
Total Annual Local Revenue	***$7 to $36***
Total Revenue	***$12 to $41***

NOTE: The funding ideas presented here are for discussion purposes only. They should not be taken as specific recommendations.

IH 45 North Houston

SL 8 (Sam Houston Tollway) **to IH 10** (Katy Freeway)



Current Conditions and Proposed Project

From Beltway 8 (Sam Houston Tollway) to IH 10 (Katy Freeway), IH 45 is a 9-lane section, four general-purpose lanes in each direction and a one-lane reversible high-occupancy vehicle (HOV) lane in the middle. Traffic on IH 45 loosely follows a traditional inbound/morning and outbound/evening congestion pattern, though both directions experience significant slowdowns during the evening peak period.

One design under consideration adds four managed lanes to the IH 45 Freeway (http://www.ih45northandmore.com/). The project construction cost for this option is estimated at $2.0 billion and will require an estimated $11.4 million annually in operating and maintenance costs for 30 years. Once the project is constructed, it is estimated that up to 33 percent of total person trips on this segment of IH 45 will be on the managed lanes.

Congestion Reduction Benefits

The IH 45 managed lanes, if constructed, are estimated to result in several congestion reduction benefits directly to users:

- On IH 45 average peak-period speed is expected to increase from 47 to 50 mph.
- On IH 10 average peak-period speed is expected to increase from 44 to 46 mph.
- From SL 8 (Beltway 8) to IH 610, congestion levels are expected to decrease from 35 to 21 percent; from IH 10 to IH 610, congestion levels are expected to decrease from 26 to 17 percent; from IH 45 to US 59, congestion levels are expected to decrease from 20 to 15 percent; from IH 10 to IH 610S, congestion levels are expected to decrease from 32 to 22 percent.

Economic Impact Analysis Results

This analysis estimated the benefit/cost ratio for this project to be **4.8** to **1** (Exhibit 1). This EIA compares the capital construction and operation costs needed to maintain the new facility to the benefits of the project for 30 years following construction.[11] This project will result in several direct benefits to users. Vehicle operating cost reduction benefits, travel time reduction, and the value of personal time will improve as a result of congestion reduction. Shippers and receivers will be more productive because they will be able to efficiently deliver their products where they need to go. Local wage income in the Greater Houston region will increase as construction jobs are created to build the managed lanes project. Finally, congestion reduction will create environmental benefits.

[11] Please refer to Appendix D for more information on the calculation process used.

Exhibit 1: Economic Impact Analysis Summary

Benefits and Costs	Present Value (2013 $Million)
Vehicle Operating Cost Benefits	$6,449
Reduction in Travel Time	$1,231
Value of Personal Time	$737
Logistics/Freight Costs	$75
Value Added	$3,101
Economic Effect of Wage Income	$4,727
Environmental Factors	$5
Total Benefits	***$10,326***
Capital Costs	$1,952
Maintenance Costs	$215
Total Costs	***$2,167***
Benefit/Cost Ratio	***4.8***

Note: Present value calculated using 3% discount rate.

Method and Sources of Finance

If managed lane revenue cannot cover all the costs, there are several options for funding the remaining need. Major improvements on the state roadway network are typically funded from a combination of federal and state tax sources. Historically, the major source of federal funds has been in the form of partial reimbursement to the state of the 18.4 cent per gallon federal fuel tax on gasoline and the 24.4 cent per gallon federal fuel tax on diesel fuel paid by Texans and visitors on fuel purchased in the state.

Major sources of state revenue for roadway improvement are derived from the 20 cent per gallon state tax on gasoline and diesel fuel purchased in Texas and revenue received from annual vehicle registration fees.[12] The vehicle registration fee for most personal vehicles is $50.75 per year. The vehicle registration fee for heavy vehicles ranges from $110 per year for a vehicle weighing 10,000 pounds to $840 per year for an 80,000-pound vehicle.

As an example, if the IH 45 improvements were funded entirely from state funds, the project would require the equivalent of 6 cents of state motor fuel taxes or $32 in vehicle registration fees for four years.

Local participation by cities, counties, toll authorities, or special districts in funding major transportation projects on the state roadway network has become more prevalent in recent years. This participation can take many forms including, but not limited to, managed lane revenue, direct contributions, and loans.

Below are several different strategies for funding the IH 45 improvements. These strategies are meant to only serve as examples and as a means to illustrate a few alternatives that can be used alone or in combination as a means to fund the improvement.

Local Strategies

There are also a number of opportunities for local revenue to be developed. Tax increment financing serves as a means to capture the increase in property tax revenue that would be received as a result of the incremental increase in property values in a corridor that results from the transportation improvement. The difference between the property tax revenue received prior to the IH 45 improvement versus the property tax revenue received after the IH 45 improvement could be used to help fund the project.

In the IH 45 corridor between SL 8 and IH 610, the combined taxable values of the properties within ½ mile of the project are estimated to be $2.6 billion. Assuming a 2 percent increase in property values per year and assuming that current property tax rates are kept constant, it is estimated that a tax increment financing strategy could yield approximately $1 billion over 30 years. If the desired increase in development due to the improved mobility occurs, this value could grow.

[12] The Texas Constitution dedicates ¾ of the revenue from the motor fuel tax to transportation and ¼ of the revenue to public education.

Another local funding strategy (should the legislature authorize it) could include the imposition of local motor fuel taxes and/or vehicle registration fees. These fees could then be used to fund the improvement.

Unfortunately, the pay-as-you-go strategy requires many years to build up sufficient funds. As an example, to pay for the project within a three-year construction time period, an estimated regional motor fuel tax of 26 cents per gallon or an estimated local vehicle registration fee of $145 per vehicle would be required.

Using a combination of these pay-now strategies also does not seem feasible. Revenue from an allocation equivalent to $141 per Houston registered vehicle in addition to revenue from tax increment financing would be needed to construct the improvements with an estimated cost of $2,167 million (Exhibit 2).

Exhibit 2: Paying for the Project in Three Years

Paying for the Project in 3 Years	($ Million)
Tax Increment Financing	$11
Local Vehicle Registration Fee Revenue ($141/Vehicle)	$2,160
Total Revenue	***$2,171***

A more viable strategy is to use the revenue streams from the local funding sources outlined above to secure debt in order to construct the improvement. In that case, revenue from a tax increment financing mechanism would secure approximately $25 million in bond debt, while a revenue stream from managed lanes could secure an estimated $282 million to $1.5 billion in bond debt depending on traffic volumes and toll rates. Again, taken together the funding strategy in Exhibit 3 could be constructed.

Exhibit 3: Paying for the Project Now

Paying for the Project Using 30-Year Bonds	($ Million)
Managed Lane Revenue	$282 to $1,525
Tax Increment Financing	$25
Local Vehicle Registration Fee Revenue ($18/Vehicle)	$1,297
Total Revenue	***$1,605 to $2,847***

A New, Blended Financing Arrangement
Analysts and policy experts familiar with the Texas transportation system have concluded that the most likely funding scenarios involve a mix of options.[13] During the Mobility Investment Priorities project, a plan that uses several state and local strategies was developed to take advantage of certain attributes of each government level. Under this funding strategy the state could issue a bond backed by the credit of the state to cover the cost of the project, thus potentially obtaining a lower interest rate than a local agency could. The state and local authorities would then agree to a repayment schedule that would benefit both parties.

For example, Exhibit 4 illustrates the resulting funding shares if the state and local governments each pay half of the project cost and the local governments pay all of the interest costs. This approach recognizes the benefit of the state's borrowing power to obtain a low interest rate, and the advantages to commuters and freight shippers from the early implementation of improvements.

[13] House Committee on Transportation Funding, Tex. H.B. 1, 83rd Leg., 3d C.S. (2013).

Exhibit 4: State and Local Cost Sharing Payments

State and Local Cost Sharing Annual Payment (30 Years)	($ Million)
Annual State-Owed Debt Service (50% of Principal)	$36
Annual Locally Owed Debt Service (50% of Principal + 100% of Interest)	$89
Total Annual Debt Service	***$125***

The state's share of the annual payment could come from the oil and gas fee funding that will be voted on in November 2014. The local share could come from a variety of revenue sources including tax increment financing, revenue from the new managed lanes, and revenue from an allocation equivalent to an increase in the vehicle registration fee (Exhibit 5).

Exhibit 5: State and Local Cost Sharing Sources

Paying for the Project Now Using State and Local Cost Sharing (30 Years)	($ Million)
Voter-Approved (Nov. 2014) Funds from Oil and Gas Fees	$36
Total Annual State Revenue	***$36***
Managed Lane Revenue	$20 to $108
Tax Increment Financing	$2 to $31
Local Vehicle Registration Fee Revenue ($5/Vehicle)	$25
Total Annual Local Revenue	***$47 to $164***
Total Revenue	***$83 to $200***

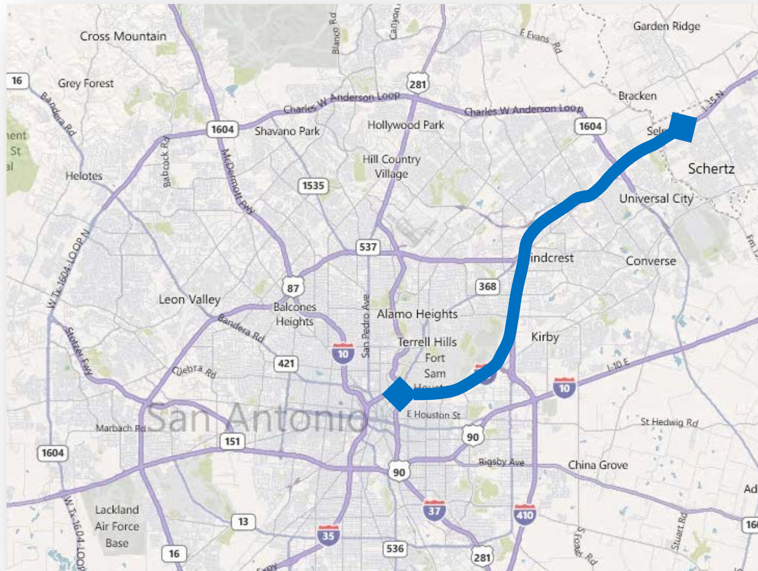
NOTE: The funding ideas presented here are for discussion purposes only. They should not be taken as specific recommendations.

IH 35 North San Antonio

US 281 to Schertz Parkway

Current Conditions and Proposed Project

IH 35, a major interstate freeway and international trade corridor, passes through the city of San Antonio from northeast to southwest. From US 281 to Schertz Parkway, IH 35 has three or four general-purpose lanes in each direction. An environmental impact study is examining a build option that includes adding two managed lanes in each direction to the existing IH 35 freeway from US 281 to Schertz Parkway (http://www.drivefor35.com/).



The early estimate for the project construction cost is $2.0 billion and will require an estimated $11.5 million annually in operating and maintenance costs. If the project is constructed, an early planning-level estimate is that approximately 18 percent of total person trips on this segment of IH 35 would be on the managed lanes.

Congestion Reduction Benefits

The IH 35 managed lanes project would result in several congestion reduction benefits directly to users:

- On IH 35 from US 281 to IH 410 North, average peak-period speed is estimated to increase from 55 mph to 61 mph; in the downtown area from US 281 to IH 10, average peak-period speed is estimated to increase from 49 mph to 51 mph; from IH 410 North to SL 1604, average peak-period speed is estimated to increase from 51 mph to 58 mph; from SL 1604 to FM 3009, average peak-period speed is estimated to increase from 48 mph to 50 mph.
- On US 281 from IH 35 to IH 410 North, average peak-period speed is estimated to increase from 55 mph to 56 mph; from IH 35 to IH 10 East, average peak-period speed is estimated to increase from 58 mph to 59 mph.
- On IH 35 from US 281 to IH 410, congestion levels are estimated to decrease from 8 percent to 4 percent; from US 281 to IH 10, congestion levels are estimated to decrease from 12 to 10 percent; from IH 410 North to SL 1604, congestion levels are estimated to decrease from 16 to 8 percent; from SL 1604 to FM 3009, congestion levels are estimated to decrease from 28 to 26 percent.
- Congested hours are not expected to change significantly on US 281.

Economic Impact Analysis Results

This analysis estimated the benefit/cost ratio for this project to be **3.0** to **1**. This EIA compares the capital construction and operation costs needed to maintain the new facility to the benefits of the project for 30 years following construction.[14] This project will result in several direct benefits to users (Exhibit 1). Vehicle operating cost reduction benefits, travel time reduction, and the value of personal time will improve as a result of congestion reduction. Shippers and receivers, particularly important in this North American Free Trade Agreement corridor, will be more productive because they will be able to efficiently deliver their products where they need to go. Local wage income in the Greater San Antonio region will increase as construction jobs are created to build the managed lanes project. Finally, congestion reduction will create environmental benefits.

Exhibit 1: Economic Impact Analysis Summary

Benefits and Costs	Present Value (2013 $Million)
Vehicle Operating Cost Benefits	$192
Reduction in Travel Time	$511
Value of Personal Time	$292
Logistics/Freight Costs	$79
Value Added	$2,170
Economic Effect of Wage Income	$3,224
Environmental Factors	$3
Total Benefits	***$6,471***
Capital Costs	$1,948
Maintenance Costs	$210
Total Costs	***$2,159***
Benefit/Cost Ratio	***3.0***

Note: Present value calculated using 3% discount rate.

[14] Please refer to Appendix E for more information on the calculation process used.

Method and Sources of Finance

Revenue from four managed lanes will financially support some of the construction of the expansion, but it may not be sufficient to fund the entire project. Major improvements on the state roadway network are typically funded from a combination of federal and state tax sources. Historically, the major source of federal funds has been in the form of partial reimbursement to the state of the 18.4 cent per gallon federal fuel tax on gasoline and the 24.4 cent per gallon federal fuel tax on diesel fuel paid by Texans and visitors on fuel purchased in the state.

Major sources of state revenue for roadway improvement are derived from the 20 cent per gallon state tax on gasoline and diesel fuel purchased in Texas and revenue received from annual vehicle registration fees.[15] The vehicle registration fee for most personal vehicles is $50.75 per year. The vehicle registration fee for heavy vehicles ranges from $110 per year for a vehicle weighing 10,000 pounds to $840 per year for an 80,000-pound vehicle.

As an example, if the IH 35 improvements were funded entirely from state funds, the project would require the equivalent of 4.5 cents of state motor fuel taxes or $21.50 in vehicle registration fees for four years.

Local participation by cities, counties, toll authorities, or special districts in funding major transportation projects on the state roadway network has become more prevalent in recent years. This participation can take many forms including, but not limited to, managed lane revenue, direct contributions, and loans.

[15] The Texas Constitution dedicates ¾ of the revenue from the motor fuel tax to transportation and ¼ of the revenue to public education.

Below are several different strategies for funding the IH 35 improvements. These strategies are meant to only serve as examples and to illustrate a few alternatives that can be used alone or in combination as a means to fund the improvement.

Local Strategies

There are also a number of opportunities for local revenue to be developed. Tax increment financing serves as a means to capture the increase in property tax revenue that would be received as a result of the incremental increase in property values in a corridor that results from the transportation improvement. The difference between the property tax revenue received prior to the IH 35 improvement versus the property tax revenue received after the IH 35 improvement could be used to help fund the project.

In the IH 35 corridor between US 281 and SL 1604, the combined taxable values of the properties within ½ mile of the project are estimated to be $3.3 billion. Assuming a 2 percent increase in property values per year and assuming that current property tax rates are kept constant, it is estimated that a tax increment financing strategy could yield approximately $1 billion over 30 years. If the desired increase in development due to the improved mobility occurs, this value could grow.

Another local funding strategy (should the legislature authorize it) could include the imposition of local motor fuel taxes and/or vehicle registration fees. These fees could then be used to fund the improvement.

Unfortunately, the pay-as-you-go strategy requires many years to build up sufficient funds. As an example, to pay for the project within a four-year construction time period, an estimated regional motor fuel tax of 55 cents per gallon or an estimated local vehicle registration fee of $255 per vehicle would be required.

A combination of these pay-now strategies also does not seem feasible. Revenue from an allocation equivalent to $264 per San Antonio registered vehicle in addition to revenue from tax increment financing would be needed to construct the improvements with an estimated cost of $2.2 billion (Exhibit 2).

Exhibit 2: Paying for the Project in Four Years

Paying for the Project in 4 Years	($Million)
Tax Increment Financing	$50
Local Vehicle Registration Fee Revenue ($264/Vehicle)	$2,107
Total Revenue	***$2,158***

A more viable strategy is to use the revenue streams from the local funding sources outlined above to secure debt in order to construct the improvement. In that case, revenue from a tax increment financing mechanism would secure approximately $134 million in bond debt, while a revenue stream from managed lanes could secure an estimated $127 million to $720 million in bond debt, depending on traffic volumes and toll rates. Again, taken together the funding strategy in Exhibit 3 could be constructed.

Exhibit 3: Paying for the Project Now

Paying for the Project Using 30-Year Bonds	($Million)
Managed Lane Revenue	$127 to $720
Tax Increment Financing	$134
Local Vehicle Registration Fee Revenue ($42/Vehicle)	$1,610
Total Revenue	***$1,871 to $2,465***

A New, Blended Financing Arrangement

Analysts and policy experts familiar with the Texas transportation system have concluded that the most likely funding scenarios involve a mix of options.[16] During the Mobility Investment Priorities project, a plan that uses several state and local strategies was developed to take advantage of certain attributes of each government level. Under this funding strategy the state could issue a bond backed by the credit of the state to cover the cost of the project, thus potentially obtaining a lower interest rate than a local agency could. The state and local authorities would then agree to a repayment schedule that would benefit both parties.

For example, Exhibit 4 illustrates the resulting funding shares if the state and local governments each pay half of the project cost and the local governments pay all of the interest costs. This approach recognizes the benefit of the state's borrowing power to obtain a low interest rate, and the advantages to commuters and freight shippers from the early implementation of improvements.

Exhibit 4: State and Local Cost Sharing Payments

State and Local Cost Sharing Annual Payment (30 Years)	($Million)
Annual State-Owed Debt Service (50% of Principal)	$36
Annual Locally Owed Debt Service (50% of Principal + 100% of Interest)	$89
Total Annual Debt Service	***$125***

The state's share of the annual payment could come from the oil and gas fee funding that will be voted on in November 2014. The local share could come from a variety of revenue sources including tax increment financing, revenue from the new managed lanes, and revenue from an allocation equivalent to an increase in the vehicle registration fee (Exhibit 5).

Exhibit 5: State and Local Cost Sharing Sources

Paying for the Project Now Using State and Local Cost Sharing (30 Years)	($Million)
Voter-Approved (Nov. 2014) Funds from Oil and Gas Fees	$36
Total Annual State Revenue	***$36***
Managed Lane Revenue	$9 to $51
Tax Increment Financing	$10 to $42
Local Vehicle Registration Fee Revenue ($24/Vehicle)	$49
Total Annual Local Revenue	***$68 to $142***
Total Revenue	***$104 to $178***

NOTE: The funding ideas presented here are for discussion purposes only. They should not be taken as specific recommendations.

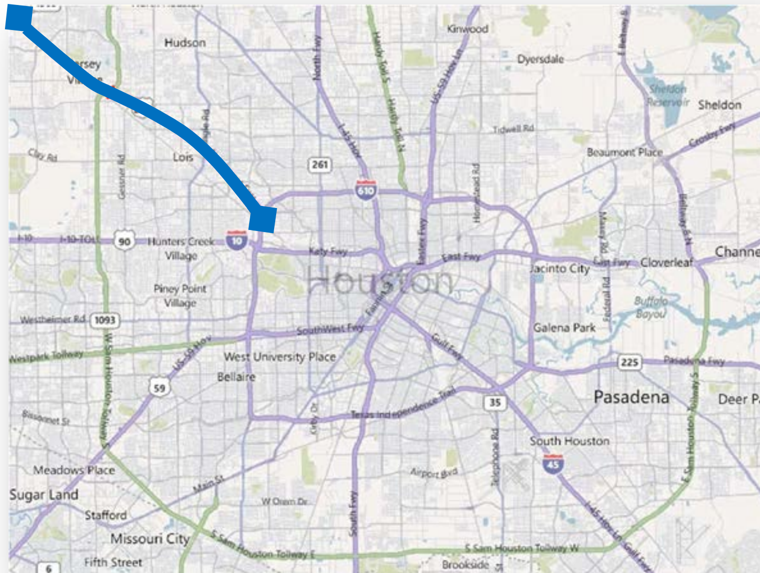
[16] House Committee on Transportation Funding, Bill Analysis, Tex. H.B. 1, 83rd Leg., 3d C.S. (2013).

US 290 (Northwest Fwy) Houston

IH 610 to FM 1960

Current Conditions and Proposed Project

From IH 610 to FM 1960, US 290 has three or four general-purpose lanes in each direction and a one-way reversible high occupancy vehicle (HOV) lane in the middle. Construction has begun on a project to add three managed lanes and two mainlanes, as well as rebuild much of the existing freeway and frontage roads. Once the project is constructed, it is estimated that up to 27 percent of total person trips on this segment of US 290 will be on the managed lanes. The widened and rebuilt freeway will be completed between IH 610 and FM 1960 by 2016. US 290 had experienced heavy slowdowns inbound during the morning hours and outbound during the evening hours—following a traditional commute pattern. In addition, midday and weekend congestion was also a frequent occurrence.



The project construction cost for these segments is estimated at $824 million and will require an estimated $4.7 million annually in operating and maintenance costs. The project cost for the Interim Phased Plan with Managed Lanes from IH 610 to Grand Parkway (SH 99) is estimated at $1.8 billion. Project funding is from several sources:

- $400 million from Harris County.
- $168 million from Rider 42/Prop 12.
- $332 million from other Prop 12 funds.
- $105 million from Prop 14.
- $315 from other state funds.
- $480 million from federal funds.

This combination of funding sources was estimated to allow the US 290 improvements to be completed **20 years ahead of the normal schedule** (http://www.my290.com/).

Congestion Reduction Benefits

The US 290 managed lanes project will result in several congestion reduction benefits directly to users:

- On US 290 from FM 529 to IH 610, average peak-period speed is estimated to increase from 43 mph to 52 mph; from FM 1960 to FM 529, average peak-period speed is estimated to increase from 48 mph to 58 mph; from FM 1960 to Business 290 (Hempstead), average peak-period speed is estimated to increase from 62 mph to 63 mph.
- On IH 610 from IH 45 to IH 10, average peak-period speed is estimated to increase from 42 mph to 45 mph.
- On US 290 from FM 529 to IH 610, congestion levels are estimated to decrease from 27 percent to 15 percent; from FM 1960 to FM 529, congestion levels are estimated to decrease from 16 to 9 percent.

- On IH 610 from IH 45 to IH 10, congestion levels are estimated to decrease from 26 to 23 percent.

Economic Impact Analysis Results

This analysis estimated the benefit/cost ratio for this project to be **6.8** to **1** (Exhibit 1). This EIA compares the capital construction and operation costs needed to maintain the new facility to the benefits of the project for 30 years following construction.[17] This project will result in several direct benefits to users. Vehicle operating cost reduction benefits, travel time reduction, and the value of personal time will improve as a result of congestion reduction. While substantially a commuter and personal travel route, shippers and receivers will be more productive because they will be able to efficiently truck their products where they need to go. Local wage income in the Greater Houston region will increase as construction jobs are created to build the managed lanes project. Finally, congestion reduction will create environmental benefits.

Exhibit 1: Economic Impact Analysis Summary

Benefits and Costs	Present Value (2013 $Million)
Vehicle Operating Cost Benefits	$310
Reduction in Travel Time	$902
Value of Personal Time	$548
Logistics/Freight Costs	$71
Value Added	$1,661
Economic Effect of Wage Income	$2,496
Environmental Factors	$3
Total Benefits	***$5,992***
Capital Costs	$800
Maintenance Costs	$89
Total Costs	***$888***
Benefit/Cost Ratio	***6.8***

Note: Present value calculated using 3% discount rate.

[17] Please refer to Appendix F for more information on the calculation process used.

EXPLANATION OF APPENDICES

- **Appendix A: Key TREDIS Assumptions and Methodology.** Appendix A explains the calculations and the benefit/cost analysis results of the projects as well as several assumptions and operating practices that were used with the Transportation Economic Development Impact System (TREDIS). This appendix is the "how-to" and "why" methodology for the resulting data in the following appendices.
- **Appendix B through F: Corridor Project Summaries.** These appendices summarize the TREDIS calculations used to forecast the economic impact resulting from the corridor improvement projects for IH 35 and Loop 1 in Austin, IH 45 North and US 290 in Houston, and IH 35 in San Antonio. Exhibits included are project assumptions, congestion reduction results, impacts on travel characteristics, a benefit/cost analysis, the present value of benefit stream, project net benefits, economic impacts, economic impacts by industry, and tax impacts as a result of the possible future improvement projects.
- **Appendix G: Congestion Reduction Methodology.** The Future Improvement Examination Technique (FIXiT) spreadsheet is a transparent analysis tool that uses analyst-specified factors, an extensive database of congestion reduction strategies, and available data to estimate the effect of improvement projects and programs.
- **Appendix H: Congestion Reduction Results.** Appendix H presents the estimated before-and-after conditions for each of the roadways and some of the surrounding road segments in the project corridors. The congestion analysis of five projects in Austin, Houston, and San Antonio estimated a reduction in daily peak-period delay between 500,000 and 1.6 million person-hours, representing an improvement of between 21 percent and 35 percent.

APPENDIX A: KEY TREDIS ASSUMPTIONS AND METHODOLOGY

There are several assumptions and operating practices that were used with the Transportation Economic Development Impact System (TREDIS) to develop the benefit/cost calculations computed for the five large Texas projects. This "how-to" and "why" appendix explains the calculations and the benefit/cost analysis results.

The analysis begins by examining two scenarios: the no-build or Current Design, and the build or Possible Future. The term "no-build" refers to the fact that no substantial capacity is added to the roadway being analyzed; there may be improvements to other roads, which could affect the subject road. Traveler, user, and societal benefits are then compared for the two scenarios while also evaluating the economic development impacts of the Possible Future Scenario. The initial parameters of the project include:

- Construction period.
- Operation period (30 years).
- Construction cost.
- Operation and maintenance cost per year.
- Travel growth rate per year.
- Constant dollar year used.

Travel Conditions

Travel conditions are input into the TREDIS model for both scenarios based on analyses of the project parameters. These can be obtained from any source; for this appendix and for the report, the estimates were obtained using the FIXiT spreadsheet developed as part of the Mobility Investment Priorities project. Input factors include:

- Annual vehicle trips—trips along the project segment for the given time period.
- Annual vehicle-miles traveled (VMT)—miles traveled along the project segment for the given time period.
- Annual vehicle-hours of travel (VHT)—hours traveled along the project segment for the given time period.
- Fraction of all trips that are congested—portion of trips that are subject to traffic congestion along the project segment.
- Buffer time in hours per trip—measures travel time reliability by representing time travelers add to their trips along the project segment to allow for congestion.
- Number of freight tons per vehicle—measurement of weight by freight trucks along the project corridor.
- Fraction of trips internal—all trips that are internal to the region.

Travel Cost Savings

The TREDIS model uses the estimated travel conditions to calculate traveler costs. For each of these costs a portion is derived from the study region, and the rest occurs in the area directly adjacent to the study region. The savings associated with each traveler cost are calculated by subtracting the travel costs of the project scenario from the travel costs of the base scenario. After the traveler cost savings have been estimated, they are distributed among the following five categories (A–E):

A. Out-of-Pocket Traveler Benefits

Traveler benefits from out-of-pocket expenses include:

- Vehicle operating costs—Vehicle operating costs are calculated with either (1) an equation using cost per hour when traffic is idling or (2) an equation for cost per mile in congested or free-flow traffic (see Exhibit A-1 and A-2).
- Travel time costs—Passenger time costs are calculated by multiplying the vehicle-hours traveled for each mode in each scenario by the number of passengers per vehicle and the passenger cost per hour.
- Reliability costs—Reliability costs are based on the variability of travel times caused by congestion. If travel times are highly variable, each trip will have to budget extra time in order to reach the destination on schedule. The extra buffer time can cost businesses and passengers by interfering with work schedules and personal activities. TREDIS calculated the average buffer time needed per trip by first finding the Buffer Time Index (BTI) using the percentage of congested hours. The BTI is then multiplied by the average time per trip. The cost of this extra or buffer time is determined by multiplying the congested trips by the average buffer hours per trip and the average cost per hour of buffer time.

B. Not Out-of-Pocket Traveler Benefits

Traveler benefits that do not affect out-of-pocket expenses include value of personal time and reliability. Value of personal time and reliability are associated with the amount of non-compensated time a driver spends on the road in traffic and congestion rather than attending important family functions and spending time accomplishing personal activities. Our personal time has value (see Exhibit A-3), and TREDIS captures that value in this section.

C. Shipper/Logistics Costs

Shipper/logistics costs represent the time and shipping cost savings due to time savings for industries that produce or consume the freight goods on the trucks traveling in the project corridor.

- Crew time costs are calculated by multiplying the vehicle-hours traveled for each mode in each scenario by the number of crew members per vehicle and the crew cost per hour factor.
- Freight time costs are related to handling and storage costs, lost sales and late penalties, and costs associated with keeping extra inventory or materials on hand. This is calculated as the vehicle-hours traveled multiplied by the weighted average of cost per vehicle hour. The weighting is based on the commodity mix for the area. Since each commodity has a different cost associated with transporting it, applying the commodity mix for the area allows a more accurate average cost per vehicle to be used.

D. Economic Benefits

TREDIS calculates the following scenarios by combining an interregional input/output model with both regional and statewide trade flows. In this application the input/output model calculates aggregate economic impacts by measuring the effect that changes in travel conditions have across all sectors of the local economy. The model reports these impacts for each year during the construction phase, each year during the operation phase, and the total economic impact over the analysis period.

- Business output—increased productivity per worker.
- Value added—the measure of regional income growth calculated as business output minus the cost of materials used.
- Jobs—calculated as net gain in employment.
- Wage income—income from jobs gained.
- Economic benefit of wage income—calculated by reducing the wage income by the percent withheld for federal income taxes, Social Security, and Medicare. The remaining wage income is then further reduced by the average savings rate. The remainder is then multiplied by the regions' income multiplier to estimate the increase in economic activity due to the increase in wages.

E. Societal and Environmental Costs

The model estimates environmental costs using only the cost of emissions. These costs are estimated the same way vehicle operating costs are calculated in that the vehicle-hours traveled or vehicle-miles traveled is multiplied by a cost per hour for each mode.

Calculations

Vehicle Operating Costs

If the VMT change is zero, the following equation is applied using per-hour costs:

1. *Vehicle Operating Cost = Vehicle-Hours Traveled (VHT) * Cost per Hour Factor for Each Mode (passenger on the clock, passenger commute, passenger personal, and truck freight) in Each Scenario (Base and Project) (see Exhibit A-1).*

However, if the vehicle-miles traveled change is nonzero, the following equation is applied using a per-mile cost:

2. *Vehicle Operating Cost = Vehicle-Miles Traveled for Each Mode in Each Scenario * [(Congested Cost per Mile for Each Mode * Fraction Congested for Each Mode) + (Congested Cost per Mile for Each Mode * (1 − Fraction Congested for Each Mode in Each Scenario))] (see Exhibit A-1).*

Travel Time Costs (see Exhibits A-1 and A-2)

Exhibit A-1: Per-Vehicle Cost Factors

Per-Vehicle Cost Factors		
Free-Flow Conditions ($/Hour)	**Current Design**	**Possible Future**
Passenger Car: Business	$0.48	$0.48
Passenger Car: Commute	$0.48	$0.48
Passenger Car: Personal	$0.48	$0.48
All Trucks: Freight	$1	$1
Congested Conditions ($/Hour)		
Passenger Car: Business	$0.59	$0.59
Passenger Car: Commute	$0.59	$0.59
Passenger Car: Personal	$0.59	$0.59
All Trucks: Freight	$2	$2
Congested/Idle Conditions ($/Hour)		
Passenger Car: Business	$2	$2
Passenger Car: Commute	$2	$2
Passenger Car: Personal	$2	$2
All Trucks: Freight	$5	$5

3. *Travel Time Cost = Vehicle-Hours Traveled * Passengers per Vehicle * Passenger Cost per Hour.*

Exhibit A-2: Travel Conditions

Travel Conditions		
Avg. Crew Members per Vehicle	**Current Design**	**Possible Future**
All Trucks: Freight	1	1
Avg. Vehicle Occupancy		
Passenger Car: Business	2	2
Passenger Car: Commute	2	2
Passenger Car: Personal	2	2
Freight Tons per Vehicle		
Passenger Car: Business	0	0
Passenger Car: Commute	0	0
Passenger Car: Personal	0	0
All Trucks: Freight	24	24
Fraction of Trips Internal		
Passenger Car: Business	0.85	0.85
Passenger Car: Commute	0.85	0.85
Passenger Car: Personal	0.85	0.85
All Trucks: Freight	0.85	0.85

Where Average Buffer Hours per Trip is calculated as (see Exhibit 3 in Appendix B through F):

4. *Average Buffer Hours per Trip = Buffer Time Index (Fraction Congested) * (Vehicle-Hours Traveled / Vehicle Trips).*

(The Buffer Time Index (BTI) is calculated as a function of Fraction Congested.)

Reliability Costs (see Exhibit A-3)

5. *Reliability Costs = Trips * Average Buffer Hours per Trip * Average Cost per Hour of Buffer Time (from Exhibit A-3).*

Exhibit A-3: Value of Time

Value of Time		
Cost per Passenger ($/Hour)	**Current Design**	**Possible Future**
Passenger Car: Business	$31	$31
Passenger Car: Commute	$24	$24
Passenger Car: Personal	$12	$12
All Trucks: Freight	$0	$0
Buffer Time Cost ($/Hour)		
Passenger Car: Business	$31	$31
Passenger Car: Commute	$24	$24
Passenger Car: Personal	$12	$12
All Trucks: Freight	$62	$62
Cost per Crew ($/Hour)		
Passenger Car: Business	$0	$0
Passenger Car: Commute	$0	$0
Passenger Car: Personal	$0	$0
All Trucks: Freight	$27	$27

Crew Time Costs (see Exhibit A-3)

6. *Crew Time Costs = Vehicle-Hours Traveled * Number of Crew Members per Vehicle * Crew Cost per Hour.*

Freight Time Costs (see Exhibit A-3)

7. *Freight Time Costs = Freight Vehicle-Hours Traveled * Average Cost per Freight Vehicle.*

Economic Benefit of Wage Income (see Exhibit 13, Appendix B through F)

8. *Economic Benefit of Wage Income = Wage Income * (Federal Income Tax Rate + Social Security Tax Rate + Medicate Tax Rate) * Average Savings Rate * Regional Income Multiplier.*

Where Regional Income Multiplier is calculated by summing the total of the following calculation for each industry category:[18]

9. *Regional Income Multiplier = National Income Multiplier for Industry Category * (Employment for Industry Category / Total Employment for Region).*[19]

[18] Regional Multipliers calculated using TRACER2 data from the Texas Workforce Commission's Quarterly Employment and Wages (QCEW) dataset.
[19] National Income Multiplier is derived from statistical data produced by the Bureau of Economic Analysis.

Environmental Costs (see Exhibit A-4)

10. *Environmental Costs = Vehicle-Hours Traveled * Average Environmental Cost per Hour.*

Exhibit A-4: Societal and Environmental Cost

Environmental Cost		
Free-Flow Conditions ($/Hour)	**Current Design**	**Possible Future**
Passenger Car: Business	$0.03	$0.03
Passenger Car: Commute	$0.03	$0.03
Passenger Car: Personal	$0.03	$0.03
All Trucks: Freight	$0.05	$0.05
Congested Conditions ($/Hour)		
Passenger Car: Business	$0.03	$0.03
Passenger Car: Commute	$0.03	$0.03
Passenger Car: Personal	$0.03	$0.03
All Trucks: Freight	$0.07	$0.07
Congested/Idle Conditions ($/Hour)		
Passenger Car: Business	$0.09	$0.09
Passenger Car: Commute	$0.09	$0.09
Passenger Car: Personal	$0.09	$0.09
All Trucks: Freight	$0.21	$0.21

Present Value of Benefit Stream

The present value of the benefit stream is calculated for each of the five categories of benefits (see TREDIS categories A through E above) over the expected life of the project.

- The MIP project analysis used a project life of 30 years for all major construction projects based on the typical pavement design parameters.
- The present value of the cost stream includes construction costs and annual operation and maintenance costs.
- The model produces benefit/cost ratios for each of the five categories using a discount rate in calculating the net present value of benefit, impacts, and costs.

There are six types of benefit/cost calculations:

- The Traveler Benefit/Cost Ratio (Exhibit 12, Appendix B through F) compares traveler benefits that affect out-of-pocket expenses and traveler benefits that do not affect out-of-pocket expenses (see columns A and B in Exhibit 10, Appendix B through F) to the net total cost (Exhibit 11, Appendix B through F).
- The Full User Benefit/Cost Ratio compares the traveler benefits that affect out-of-pocket expenses, traveler benefits that do not affect out-of-pocket expenses, and shipper and logistics costs (see columns A, B, and C in Exhibit 10, Appendix B through F) to the total net cost (Exhibit 11, Appendix B through F).
- The Total Societal Benefit/Cost Ratio compares all five of the categories of benefits (see columns A, B, C, D, and E in Exhibit 10, Appendix B through F) to the total net cost (Exhibit 11, Appendix B through F).

Discount Rate

To calculate the various benefit/cost ratios, the total present value of the benefit stream (derived from reduced costs) is divided by the total project cost (that is, construction, operation, and maintenance costs). A benefit/cost ratio of 1.0 would indicate that benefits equal the cost. If a project has a benefit/cost ratio greater than 1.0, the benefits are greater than the cost (positive net benefits). This calculation was done using three discount rates. Discounting relates to the opportunity cost of time and is based on the premise that benefits received in the future are not as valuable as the same benefits received now. According to the Federal Highway Administration (FHWA) the appropriate opportunity cost for project analysis is about 3 to 5 percent per year.[20] A sensitivity analysis was conducted by using a 3 percent and 7 percent discount rate to examine a range of possible project values.

[20] *Life-Cycle Cost Analysis Primer,* U.S. Department of Transportation, Federal Highway Administration, Office of Asset Management, August 2002.

APPENDIX B: AUSTIN IH 35 RESULTS

This appendix summarizes the TREDIS calculations to compute and forecast the economic impact resulting from the Austin IH 35 corridor project. Exhibits included are:

- Project assumptions—project parameters including project time period, startup costs, operation and maintenance costs, and travel conditions.
- Congestion reduction—measures the reduction in traffic congestion along the project corridor by calculating average daily and peak period vehicle-miles traveled, average free-flow and current peak period speed, peak period proposed speed, current hours of congestion, and proposed hours of congestion.
- Impacts on travel characteristics—measured in vehicle-hours traveled and vehicle-miles traveled.
- Present value of benefit stream—establishes the economic efficiency of transportation investments; the dollar value of net gain to the project users and non-users.
- Project net benefits—measures the cost effectiveness of a project; the overall benefits of the possible project minus the costs.
- Benefit/cost analysis—a cost effectiveness measure; the dollar value of net gain to the project segment users and non-users compared to the project costs.
- Economic impacts—impacts measured in the dollar value of the business output, value added, jobs, wage income, and economic benefit of wage income.
- Economic impacts by industry—impacts on the specific industries measured in business output, value added, jobs, wage income, and economic benefit of wage income.
- Tax impacts—measures taxes and fees paid to the federal government and state and local governments by households and businesses around the project segment.

Project-Specific TREDIS Assumptions

Exhibit B-1 shows the Austin IH 35 project-specific assumptions on dates, travel growth rate, constant dollar year, and cost used for TREDIS assumptions and further calculations.

Exhibit B-1: Project Assumptions

Project Assumptions	
Construction Start	2017
Construction End	2020
Operation Start	2021
Operation End	2051
Analysis Year	2031
Travel Growth Rate	0.022
Constant Dollar Year	2013
Total Project Cost	$1.8 Billion

Operation and Maintenance Cost

Annual maintenance costs were estimated by assuming the total cost would be 17 percent of the startup (construction) cost and dividing by the 30-year life of the roadway (Exhibit B-2).[21] The project is assumed to use Portland cement concrete (PCC) pavement. We assume that for every original $100 cost the project will incur $17 of maintenance expenses over the lifetime of the roadway (30 years). These costs are distributed as follows:

- $1 to reseal after 7 years,
- $2 to patch and reseal after 14 years,
- $3 to patch and reseal after 21 years,
- $5 to patch and reseal after 28 years, followed by
- $6 to overlay.

Exhibit B-2: Operation and Maintenance Costs

Operation & Maintenance Costs ($Million)		
Road Element	**Current Design**	**Possible Future**
Operation & Maintenance	$0	$298

Travel Conditions

Travel conditions shown in Exhibit B-3 include estimates of annual vehicle-miles traveled, annual vehicle-hours traveled, fraction congested, and buffer time. These were estimated with the FIXiT spreadsheet and are used by TREDIS in the benefit estimation process.

Congestion Reduction

Exhibit B-4 shows the results of the congestion analysis performed with the FIXiT program. The key outputs that describe the proposed project enhancements are shown, along with the before conditions.

[21] Texas A&M Transportation Institute, Pavement Division, email dated June 20, 2013.

Exhibit B-3: Travel Conditions

Travel Conditions		
Annual Vehicle Trips	**Current Design**	**Possible Future**
Passenger Car: Business	39,645,436	39,645,436
Passenger Car: Commute	118,936,309	118,936,309
Passenger Car: Personal	39,645,436	39,645,436
All Trucks: Freight	22,025,242	22,025,242
Annual Vehicle-Miles Traveled		
Passenger Car: Business	363,548,651	363,548,651
Passenger Car: Commute	1,090,645,952	1,090,645,952
Passenger Car: Personal	363,548,651	363,548,651
All Trucks: Freight	201,971,473	201,971,473
Annual Vehicle-Hours Traveled		
Passenger Car: Business	6,456,796	6,041,689
Passenger Car: Commute	19,370,387	18,125,068
Passenger Car: Personal	6,456,796	6,041,689
All Trucks: Freight	3,587,109	3,356,494
Fraction Congested		
Passenger Car: Business	0.32	0.20
Passenger Car: Commute	0.32	0.20
Passenger Car: Personal	0.32	0.20
All Trucks: Freight	0.32	0.20
Average Buffer Time (Hours/Trip)		
Passenger Car: Business	0.02	0.01
Passenger Car: Commute	0.02	0.01
Passenger Car: Personal	0.02	0.01
All Trucks: Freight	0.02	0.01

Exhibit B-4: Congestion Results

To	From	Avg Daily VMT	Avg Daily Peak Period VMT	Avg Free-Flow Speed	Current Peak Period Avg Speed	Best Estimate for Proposed Avg Peak Period Speed	Current Congested Level (% VMT)	Proposed Congested Hours (% VMT)
SH 71	US 183	1,555,078	777,539	62	37	44	41	28
US 183	Howard Ln	696,679	348,340	65	51	59	13	8
SL 275	FM 3406	1,168,181	584,091	65	53	60	14	8
RM 150	SH 71	2,113,527	1,056,764	65	58	64	8	4
Total		**5,533,465**	**2,766,734**	**64**	**50**	**57**	**32**	**20**

Travel Characteristics

Exhibit B-5 shows the difference in the travel characteristics between the current roadway design and the possible future design. The output is based on results from TREDIS assumptions and calculations.

Exhibit B-5: Difference between Travel Characteristics (Current Design–Possible Future)

	Vehicles			Passenger			Freight Tons		
Year[22]	Trips	Miles	Hours	Trips	Miles	Hours	Trips	Miles	Hours
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	-1,855,147	0	0	-2,504,448	0	0	-4,461,631
5	0	0	-1,895,960	0	0	-2,559,545	0	0	-4,559,787
6	0	0	-1,937,671	0	0	-2,615,855	0	0	-4,660,102
7	0	0	-1,980,300	0	0	-2,673,404	0	0	-4,762,625
8	0	0	-2,023,866	0	0	-2,732,219	0	0	-4,867,402
9	0	0	-2,068,391	0	0	-2,792,328	0	0	-4,974,485
10	0	0	-2,113,896	0	0	-2,853,759	0	0	-5,083,924
11	0	0	-2,160,402	0	0	-2,916,542	0	0	-5,195,770
12	0	0	-2,207,930	0	0	-2,980,706	0	0	-5,310,077
13	0	0	-2,256,505	0	0	-3,046,281	0	0	-5,426,899
14	0	0	-2,306,148	0	0	-3,113,300	0	0	-5,546,291
15	0	0	-2,356,883	0	0	-3,181,792	0	0	-5,668,309
16	0	0	-2,408,735	0	0	-3,251,792	0	0	-5,793,012
17	0	0	-2,461,727	0	0	-3,323,331	0	0	-5,920,458
18	0	0	-2,515,885	0	0	-3,396,444	0	0	-6,050,708
19	0	0	-2,571,234	0	0	-3,471,166	0	0	-6,183,824
20	0	0	-2,627,801	0	0	-3,547,532	0	0	-6,319,868
21	0	0	-2,685,613	0	0	-3,625,577	0	0	-6,458,905
22	0	0	-2,744,697	0	0	-3,705,340	0	0	-6,601,001
23	0	0	-2,805,080	0	0	-3,786,858	0	0	-6,746,223
24	0	0	-2,866,792	0	0	-3,870,168	0	0	-6,894,640
25	0	0	-2,929,861	0	0	-3,955,312	0	0	-7,046,322
26	0	0	-2,994,318	0	0	-4,042,329	0	0	-7,201,341
27	0	0	-3,060,193	0	0	-4,131,260	0	0	-7,359,771
28	0	0	-3,127,518	0	0	-4,222,147	0	0	-7,521,686
29	0	0	-3,196,323	0	0	-4,315,035	0	0	-7,687,163
30	0	0	-3,266,642	0	0	-4,409,966	0	0	-7,856,280
31	0	0	-3,338,508	0	0	-4,506,985	0	0	-8,029,118
32	0	0	-3,411,955	0	0	-4,606,138	0	0	-8,205,759
33	0	0	-3,487,018	0	0	-4,707,473	0	0	-8,386,286
34	0	0	-3,563,733	0	0	-4,811,038	0	0	-8,570,784

[22] Project estimated to begin construction in 2017 (year zero).

Benefit Stream

Shown in Exhibit B-6 are the five benefits (A through E) calculated for the IH 35 project segment. These include traveler benefits consisting of vehicle operating costs, travel time and reliability, traveler benefits consisting of value of personal time and reliability, shipper/logistics cost, economic benefits, and social and environmental benefits.

Exhibit B-6: Present Value Benefit Stream ($Million Constant Dollars)[23]

		(A) Traveler Benefits[25]		(B) Traveler Benefits[26]				
Year[24]	3% Discount Rate	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0	1.00	$0	$0	$0	$0	$814	$0	$814
1	0.97	$0	$0	$0	$0	$790	$0	$790
2	0.94	$0	$0	$0	$0	$767	$0	$767
3	0.92	$0	$0	$0	$0	$745	$0	$745
4	0.89	$21	$52	$28	$5	$132	$0.3	$238
5	0.86	$21	$51	$28	$5	$130	$0.3	$236
6	0.84	$21	$51	$28	$5	$129	$0.3	$233
7	0.81	$21	$50	$28	$5	$127	$0.3	$231
8	0.79	$20	$50	$28	$5	$126	$0.3	$229
9	0.77	$20	$50	$27	$5	$124	$0.3	$226
10	0.74	$20	$49	$27	$5	$123	$0.3	$224
11	0.72	$20	$49	$27	$5	$122	$0.3	$222
12	0.70	$20	$48	$27	$5	$120	$0.3	$220
13	0.68	$20	$48	$26	$5	$119	$0.3	$218
14	0.66	$20	$48	$26	$4	$118	$0.3	$216
15	0.64	$19	$47	$26	$4	$116	$0.3	$214
16	0.62	$19	$47	$26	$4	$115	$0.2	$212
17	0.61	$19	$47	$26	$4	$114	$0.2	$210
18	0.59	$19	$46	$25	$4	$113	$0.2	$208
19	0.57	$19	$46	$25	$4	$111	$0.3	$206
20	0.55	$19	$45	$25	$4	$110	$0.3	$204
21	0.54	$18	$45	$25	$4	$109	$0.3	$202
22	0.52	$18	$45	$25	$4	$108	$0.3	$200
23	0.51	$18	$44	$24	$4	$107	$0.3	$198
24	0.49	$18	$44	$24	$4	$106	$0.2	$197
25	0.48	$18	$44	$24	$4	$104	$0.2	$194
26	0.46	$18	$43	$24	$4	$103	$0.2	$191
27	0.45	$17	$43	$23	$4	$101	$0.2	$189
28	0.44	$17	$42	$23	$4	$100	$0.2	$186

[23] All benefits and costs are estimated at a 3 percent discount rate.
[24] Project estimated to begin construction in 2017 (year zero).
[25] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[26] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit B-6: Present Value Benefit Stream ($Million Constant Dollars)[27] Cont.

Year	3% Discount Rate	(A)Traveler Benefits		(B)Traveler Benefits	(C) Shipper/ Logistics Cost	(D)Economic Benefits	(E) Social/ Environ.	Total Benefits
		Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
29	0.42	$17	$41	$23	$4	$98	$0.2	$184
30	0.41	$17	$41	$23	$4	$97	$0.2	$182
31	0.40	$17	$41	$22	$4	$96	$0.2	$179
32	0.39	$16	$40	$22	$4	$94	$0.2	$177
33	0.38	$16	$40	$22	$4	$93	$0.2	$175
34	0.37	$16	$39	$22	$4	$92	$0.2	$172
Total		**$578**	**$1,414**	**$780**	**$134**	**$6,573**	**$8**	**$9,487**

Exhibit B-7: Benefit Summary ($Million)

Discount Rate	(A) Traveler Benefits[28]		(B) Traveler Benefits[29]	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
0%	$1,027	$2,514	$1,386	$238	$9,361	$14	$14,541
3%	$578	$1,414	$780	$134	$6,573	$8	$9,487
7%	$305	$745	$411	$70	$4,787	$4	$6,322

Project Net Benefits

Exhibit B-8 illustrates the net benefits of the proposed IH 35 project using a 3 percent discount rate. The startup, operation, and maintenance costs are subtracted from the benefits to calculate the net benefits. All of the net benefit values are positive.

[27] All benefits and costs are estimated at a 3 percent discount rate.
[28] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[29] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit B-8: Project's Net Benefits ($Million Constant Dollars)[30]

Year[31]	3% Discount Rate	Construction Costs	Operation & Maintenance Cost	Total Cost	Total Benefits	Project Net Benefits
0	1.00	$425	$0	$425	$814	$389
1	0.97	$413	$0	$413	$790	$377
2	0.94	$401	$0	$401	$767	$366
3	0.92	$389	$0	$389	$745	$356
4	0.89	$0	$9	$9	$238	$229
5	0.86	$0	$8	$8	$236	$227
6	0.84	$0	$8	$8	$233	$225
7	0.81	$0	$8	$8	$231	$223
8	0.79	$0	$8	$8	$229	$221
9	0.77	$0	$7	$7	$226	$219
10	0.74	$0	$7	$7	$224	$217
11	0.72	$0	$7	$7	$222	$215
12	0.70	$0	$7	$7	$220	$213
13	0.68	$0	$7	$7	$218	$211
14	0.66	$0	$6	$6	$216	$209
15	0.64	$0	$6	$6	$214	$208
16	0.62	$0	$6	$6	$212	$206
17	0.61	$0	$6	$6	$210	$204
18	0.59	$0	$6	$6	$208	$202
19	0.57	$0	$5	$5	$206	$200
20	0.55	$0	$5	$5	$204	$199
21	0.54	$0	$5	$5	$202	$197
22	0.52	$0	$5	$5	$200	$195
23	0.51	$0	$5	$5	$198	$193
24	0.49	$0	$5	$5	$197	$192
25	0.48	$0	$5	$5	$194	$189
26	0.46	$0	$4	$4	$191	$187
27	0.45	$0	$4	$4	$189	$185
28	0.44	$0	$4	$4	$186	$182
29	0.42	$0	$4	$4	$184	$180
30	0.41	$0	$4	$4	$182	$178
31	0.40	$0	$4	$4	$179	$175
32	0.39	$0	$4	$4	$177	$173
33	0.38	$0	$4	$4	$175	$171
34	0.37	$0	$4	$4	$172	$169
Total		**$1,627**	**$176**	**$1,803**	**$9,487**	**$7,684**

[30] All benefits and costs are estimated at a 3 percent discount rate.
[31] Project estimated to begin construction in 2017 (year zero).

Exhibit B-9: Project Net Benefits Summary ($Million)

Discount Rate	Construction Costs	Operation & Maintenance Costs	Total Costs	Total Benefits	Project Net Benefits
0%	$1,700	$298	$1,998	$14,541	$12,543
3%	$1,627	$176	$1,803	$9,487	$7,684
7%	$1,540	$98	$1,639	$6,322	$4,683

Benefit/Cost Analysis

Exhibits B-10 through B-12 summarize the benefit stream for the Austin IH 35 project in 2013 constant dollars. There are five types of benefit calculations shown (A through E, Exhibit B-10). The total cost stream including facility type, startup costs, annual operation and maintenance costs, and net total costs is also shown (Exhibit B-11). Traditionally, the ratio of traveler benefits (A and B), shipper/logistics cost savings (C), and social/environmental cost savings (E) to the net total cost is used for benefit/cost ratio purposes that do not include economic impacts.

Exhibit B-10: Present Value of Benefit Stream Summary ($Million)

Mode	(A) Traveler Benefits[32]		(B) Traveler Benefits[33]			
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.
Passenger Car – On the Job	$80	$527	$0	$0	No Separate Estimate	No Separate Estimate
Passenger Car – Commute	$240	$611	$585	$0		
Passenger Car – Pers/Rec	$80	$0	$195	$0		
All Trucks – Freight	$178	$276	$0	$134		
Total	**$578**	**$1,414**	**$780**	**$134**	**$6,573**	**$8**

Exhibit B-11: Present Value of Cost Stream ($Million)

Facility Type	Construction Costs	Sum of Annual Operation & Maintenance Costs	Net Total Costs
Road	$1,627	$176	$1,803

32 Benefit (A) Traveler Benefits describe *out-of-pocket.*

33 Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit B-12: Efficiency Measures ($Million)

Benefit Measure	Benefit Definition[34]	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits – Costs)	Benefit/ Cost Ratio
Traveler Benefit	A+B	$2,772	$1,803	$969	1.54
Full User Benefit	A+B+C	$2,905	$1,803	$1,103	1.61
Total Societal Benefit	A+B+C+D+E	$9,487	$1,803	$7,684	5.26

Economic Impacts

Exhibit B-13 shows the economic impacts of the project during construction and operation periods. Economic impacts calculated include business output, value added, jobs, wage income, and economic impact of wage income along the project segment. The assumptions used to calculate "economic benefit of wage income ($Million)" are as follows: 14.4 percent average tax rate, 6.2 percent Social Security rate, and 1.45 percent[35] Medicare rate for a total of 22.1 percent;[36] also included is a 3.2 percent savings rate and 2.44 income multiplier.

[34] From Exhibit B-10.

[35] Average tax rate, Social Security rate, and Medicare rate were retrieved from the *Congressional Budget Office* http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/57xx/doc5746/08-13-effectivefedtaxrates.pdf.

[36] Total 22.1 percent retrieved from the *Bureau of Economic Analysis* http://www.bea.gov/newsreleases/national/pi/pinewsrelease.htm.

Exhibit B-13: Economic Impacts[37]

Year[38]	3% Discount Rate	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)	Economic Benefit of Wage Income ($Million)
0	1.00	$589	$328	4568	$264	$486
1	0.97	$572	$319	4568	$256	$471
2	0.94	$555	$309	4568	$249	$458
3	0.92	$539	$300	4568	$241	$444
4	0.89	$101	$54	1077	$42	$78
5	0.86	$100	$53	1096	$42	$77
6	0.84	$99	$53	1116	$41	$76
7	0.81	$98	$52	1136	$41	$75
8	0.79	$97	$52	1156	$40	$74
9	0.77	$96	$51	1177	$40	$73
10	0.74	$95	$51	1198	$39	$72
11	0.72	$94	$50	1220	$39	$72
12	0.70	$93	$50	1242	$38	$71
13	0.68	$92	$49	1265	$38	$70
14	0.66	$91	$49	1288	$38	$69
15	0.64	$90	$48	1312	$37	$68
16	0.62	$89	$48	1336	$37	$68
17	0.61	$88	$47	1361	$36	$67
18	0.59	$87	$47	1386	$36	$66
19	0.57	$86	$46	1412	$35	$65
20	0.55	$85	$46	1438	$35	$65
21	0.54	$84	$45	1465	$35	$64
22	0.52	$83	$45	1493	$34	$63
23	0.51	$83	$44	1521	$34	$62
24	0.49	$82	$44	1550	$34	$62
25	0.48	$81	$43	1574	$33	$61
26	0.46	$80	$43	1598	$33	$60
27	0.45	$78	$42	1622	$32	$59
28	0.44	$77	$42	1647	$32	$58
29	0.42	$76	$41	1672	$31	$57
30	0.41	$75	$40	1697	$31	$57
31	0.40	$74	$40	1723	$30	$56
32	0.39	$73	$39	1750	$30	$55
33	0.38	$72	$39	1776	$29	$54
34	0.37	$71	$38	1803	$29	$53
Total		**$4,925**	**$2,687**		**$2,111**	**$3,886**

[37] All benefits and costs are estimated at a 3 percent discount rate.
[38] Project estimated to begin construction in 2017 (year zero).

Exhibit B-14: Economic Impact Summary ($Million)

Discount Rate	Business Output	Value Added	Wage Income	Economic Benefit of Wage Income
0%	$7,074	$3,843	$2,997	$5,518
3%	$4,925	$2,687	$2,111	$3,886
7%	$3,552	$1,948	$1,542	$2,838

Economic Impact by Industry

The economic impact for individual industries is examined for 2031, 10 years following the beginning of operation. Exhibit B-15 illustrates the industries that are affected as a result of the economic impact contributed from the completion of the Austin IH 35 corridor project.

Exhibit B-15: Economic Impact by Industry for 2031 (in 2013 Dollars)

NAICS[39]	Industry	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)
111–115, 211–213	Agriculture, Forestry, Mining, Oil & Gas Extraction	$4	$2	79	$1
221	Utilities	$2	$1	3	$0
230	Construction	$4	$2	33	$2
311–339	Manufacturing	$17	$5	48	$3
420	Wholesale Trade	$4	$4	23	$2
441–454	Retail Trade	$7	$4	104	$3
481–488	Transportation	$16	$6	202	$8
491–493	Postal Service & Warehousing	$1	$1	17	$1
511–519	Media and Information	$7	$4	23	$2
521–525, 531–533	Finance, Insurance, & Real Estate	$19	$9	82	$3
541, 551, 561–562	Business Support Services (Prof., Mgmt., & Admin.)	$25	$17	271	$15
611, 621–624	Educational, Health Care, & Social Services	$17	$11	178	$10
711–713, 721–722, 811–814	Arts, Entertainment, Accommodation, Food, & Household Services	$13	$7	223	$6
920	Government	$0	$0	2	$0
	Total	**$137**	**$73**	**1288**	**$57**

39 North American Industry Classification System.

Tax Impacts

Taxes collected by the federal, state, and local governments were calculated for households and businesses surrounding the project segment (Exhibit B-16).

Exhibit B-16: Tax Impacts for 2031 (in 2013 Dollars)

Tax/Fee Collector	Tax/Fee Description	Taxes/Fees ($Million) Paid by: Households	Taxes/Fees ($Million) Paid by: Businesses	Total ($Million)
Federal Government	Motor Fuel Tax	-$1	-$1	-$2
	Income Profits	$0	$0	$0
	Social Insurance Tax (FICA)	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
	Total Federal Government	**-$1**	**-$1**	**-$2**
State and Local Government	Motor Fuel Tax	-$1	-$1	-$2
	Motor Vehicle License Fees	$0	$0	$0
	Income/Profits	$0	$0	$0
	Sales Tax	not available	not available	$0
	Property Tax	$0	$0	$0
	Social Insurance Tax	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
	Total State and Local Government	**-$1**	**-$1**	**-$2**
	Grand Totals for Federal, State, and Local	**-$2**	**-$3**	**-$5**

Findings

The Austin IH 35 project proves cost effective in several ways. It provides a present value benefit stream of $9.5 billion and will create over 4,500 jobs each year of construction and 1,000 to 1,800 jobs each year of operation.

APPENDIX C: AUSTIN LOOP 1 RESULTS

This appendix summarizes the TREDIS calculations to compute and forecast the economic impact resulting from the Austin Loop 1 corridor project. Exhibits included are:

- Project assumptions—project parameters including project time period, startup costs, operation and maintenance costs, and travel conditions.
- Congestion reduction—measures the reduction in traffic congestion along the project corridor by calculating average daily and peak period vehicle-miles traveled, average free-flow and current peak period speed, peak period proposed speed, current hours of congestion, and proposed hours of congestion.
- Impacts on travel characteristics—measured in vehicle-hours traveled and vehicle-miles traveled.
- Present value of benefit stream—establishes the economic efficiency of transportation investments; the dollar value of net gain to the project users and non-users.
- Project net benefits—measures the cost effectiveness of a project; the overall benefits of the possible project minus the costs.
- Benefit/cost analysis—a cost effectiveness measure; the dollar value of net gain to the project segment users and non-users compared to the project costs.
- Economic impacts—impacts measured in the dollar value of the business output, value added, jobs, wage income, and economic benefit of wage income.
- Economic impacts by industry—impacts on the specific industries measured in business output, value added, jobs, wage income, and economic benefit of wage income.
- Tax impacts—measures taxes and fees paid to the federal government and state and local governments by households and businesses around the project segment.

Project-Specific TREDIS Assumptions

Exhibit C-1 shows the Austin Loop 1 project-specific assumptions on dates, travel growth rate, constant dollar year, and cost used for TREDIS assumptions and further calculations.

Exhibit C-1: Project Assumptions

Project Assumptions	
Construction Start	2014
Construction End	2017
Operation Start	2018
Operation End	2048
Analysis Year	2028
Travel Growth Rate	0.022
Constant Dollar Year	2013
Total Project Cost	$265 Million

Operation and Maintenance Cost

Annual maintenance costs were estimated by assuming the total cost would be 17 percent of the startup (construction) cost and dividing by the 30-year life of the roadway (Exhibit C-2).[40] The project is assumed to use Portland cement concrete (PCC) pavement. We assume that for every original $100 cost the project will incur $17 of maintenance expenses over the lifetime of the roadway (30 years). These costs are distributed as follows:

- $1 to reseal after 7 years,
- $2 to patch and reseal after 14 years,
- $3 to patch and reseal after 21 years,
- $5 to patch and reseal after 28 years, followed by
- $6 to overlay.

Exhibit C-2: Operation and Maintenance Costs

Operation and Maintenance Costs ($Million)		
Road Element	**Current Design**	**Possible Future**
Operation & Maintenance	$0	$43

Travel Conditions

Travel conditions shown in Exhibit C-3 include estimates of annual vehicle-miles traveled, annual vehicle-hours traveled, fraction congested, and buffer time. These were estimated with the FIXiT spreadsheet and are used by TREDIS in the benefit estimation process.

Congestion Reduction

Exhibit C-4 shows the results of the congestion analysis performed with the FIXiT program. The key outputs that describe the proposed project enhancements are shown, along with the before conditions.

[40] Texas A&M Transportation Institute, Pavement Division, email dated June 20, 2013.

Exhibit C-3: Travel Conditions

Travel Conditions		
Annual Vehicle Trips	**Current Design**	**Possible Future**
Passenger Car: Business	31,566,762	31,566,762
Passenger Car: Commute	94,700,287	94,700,287
Passenger Car: Personal	31,566,762	31,566,762
All Trucks: Freight	3,221,098	3,221,098
Annual Vehicle-Miles Traveled		
Passenger Car: Business	154,677,135	154,677,135
Passenger Car: Commute	464,031,404	464,031,404
Passenger Car: Personal	154,677,135	154,677,135
All Trucks: Freight	15,783,381	15,783,381
Annual Vehicle-Hours Traveled		
Passenger Car: Business	2,810,268	2,694,958
Passenger Car: Commute	8,430,804	8,084,874
Passenger Car: Personal	2,810,268	2,694,958
All Trucks: Freight	286,762	274,996
Fraction Congested		
Passenger Car: Business	0.1	0.1
Passenger Car: Commute	0.1	0.1
Passenger Car: Personal	0.1	0.1
All Trucks: Freight	0.1	0.1
Average Buffer Time (Hours/Trip)		
Passenger Car: Business	0.003	0.003
Passenger Car: Commute	0.003	0.003
Passenger Car: Personal	0.003	0.003
All Trucks: Freight	0.003	0.003

Exhibit C-4: Congestion Results

To	From	Avg Daily VMT	Avg Daily Peak Period VMT	Avg Free-Flow Speed	Current Peak Period Avg Speed	Best Estimate for Proposed Avg Peak Period Speed	Current Congested Levels (%VMT)	Proposed Congested (%VMT)
Cesar Chavez	SH 71	619,089	309,545	64	45	50	8	6
US 183	Cesar Chavez	890,884	445,442	64	45	50	12	10
US 183	FM 734	340,601	170,301	65	56	57	4	4
US 290/SH 71	SH 45	311,533	155,767	65	54	55	5	5
Total		**2,162,10**	**1,081,055**	**65**	**48**	**52**	**10**	**8**

Travel Characteristics

Exhibit C-5 shows the difference in the travel characteristics between the current roadway design and the possible future design. The output is based on results from TREDIS assumptions and calculations.

Exhibit C-5: Difference between Travel Characteristics (Current Design–Possible Future)

	Vehicles			Passenger			Freight Tons		
Year[41]	Trips	Miles	Hours	Trips	Miles	Hours	Trips	Miles	Hours
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	-473,262	0	0	-695,696	0	0	-227,633
5	0	0	-483,674	0	0	-711,001	0	0	-232,641
6	0	0	-494,315	0	0	-726,643	0	0	-237,759
7	0	0	-505,190	0	0	-742,629	0	0	-242,990
8	0	0	-516,304	0	0	-758,967	0	0	-248,335
9	0	0	-527,662	0	0	-775,664	0	0	-253,799
10	0	0	-539,271	0	0	-792,729	0	0	-259,382
11	0	0	-551,135	0	0	-810,169	0	0	-265,089
12	0	0	-563,260	0	0	-827,993	0	0	-270,921
13	0	0	-575,652	0	0	-846,208	0	0	-276,881
14	0	0	-588,316	0	0	-864,825	0	0	-282,972
15	0	0	-601,259	0	0	-883,851	0	0	-289,198
16	0	0	-614,487	0	0	-903,296	0	0	-295,560
17	0	0	-628,005	0	0	-923,168	0	0	-302,062
18	0	0	-641,821	0	0	-943,478	0	0	-308,708
19	0	0	-655,942	0	0	-964,235	0	0	-315,499
20	0	0	-670,372	0	0	-985,448	0	0	-322,440
21	0	0	-685,120	0	0	-1,007,128	0	0	-329,534
22	0	0	-700,193	0	0	-1,029,284	0	0	-336,784
23	0	0	-715,597	0	0	-1,051,929	0	0	-344,193
24	0	0	-731,340	0	0	-1,075,071	0	0	-351,765
25	0	0	-747,429	0	0	-1,098,723	0	0	-359,504
26	0	0	-763,873	0	0	-1,122,894	0	0	-367,413
27	0	0	-780,678	0	0	-1,147,598	0	0	-375,496
28	0	0	-797,853	0	0	-1,172,845	0	0	-383,757
29	0	0	-815,406	0	0	-1,198,648	0	0	-392,200
30	0	0	-833,345	0	0	-1,225,018	0	0	-400,828
31	0	0	-851,678	0	0	-1,251,969	0	0	-409,646
32	0	0	-870,415	0	0	-1,279,512	0	0	-418,658
33	0	0	-889,564	0	0	-1,307,661	0	0	-427,869
34	0	0	-909,135	0	0	-1,336,430	0	0	-437,282

[41] Project estimated to begin construction in 2014 (year zero).

Benefit Stream

Exhibit C-6 shows the five benefits (A through E) calculated for the Loop 1 project segment. These include traveler benefits consisting of vehicle operating costs, travel time and reliability, traveler benefits consisting of value of personal time and reliability, shipper/logistics cost, economic benefits, and social and environmental benefits.

Exhibit C-6: Present Value Benefit Stream ($Million Constant Dollars)[42]

Year[43]	3% Discount Rate	(A) Traveler Benefits[44] Vehicle Operating Costs	(A) Traveler Benefits[44] Time & Reliability Costs	(B) Traveler Benefits[45] Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0	1.00	$0	$0	$0	$0	$120	$0	$120
1	0.97	$0	$0	$0	$0	$116	$0	$116
2	0.94	$0	$0	$0	$0	$113	$0	$113
3	0.92	$0	$0	$0	$0	$109	$0	$109
4	0.89	$1	$8	$5	$0.3	$18	$0.0	$32
5	0.86	$1	$8	$5	$0.3	$18	$0.0	$32
6	0.84	$1	$7	$5	$0.3	$18	$0.0	$32
7	0.81	$1	$7	$5	$0.2	$18	$0.0	$31
8	0.79	$1	$7	$5	$0.2	$17	$0.0	$31
9	0.77	$1	$7	$5	$0.2	$17	$0.0	$31
10	0.74	$1	$7	$5	$0.2	$17	$0.0	$31
11	0.72	$1	$7	$5	$0.2	$17	$0.0	$30
12	0.70	$1	$7	$5	$0.2	$17	$0.0	$30
13	0.68	$1	$7	$5	$0.2	$16	$0.0	$30
14	0.66	$1	$7	$5	$0.2	$16	$0.0	$29
15	0.64	$1	$7	$5	$0.3	$16	$0.0	$29
16	0.62	$1	$7	$5	$0.2	$16	$0.0	$29
17	0.61	$1	$7	$5	$0.2	$16	$0.0	$29
18	0.59	$1	$7	$5	$0.2	$16	$0.0	$28
19	0.57	$1	$7	$5	$0.2	$15	$0.0	$28
20	0.55	$1	$7	$5	$0.2	$15	$0.0	$28
21	0.54	$1	$7	$5	$0.2	$15	$0.0	$27
22	0.52	$1	$7	$5	$0.2	$15	$0.0	$27
23	0.51	$1	$7	$5	$0.2	$15	$0.0	$27
24	0.49	$1	$6	$4	$0.2	$15	$0.0	$27
25	0.48	$1	$6	$4	$0.2	$14	$0.0	$26
26	0.46	$1	$6	$4	$0.2	$14	$0.0	$26
27	0.45	$1	$6	$4	$0.2	$14	$0.0	$26
28	0.44	$1	$6	$4	$0.2	$14	$0.0	$25

[42] All benefits and costs are estimated at a 3 percent discount rate.
[43] Project estimated to begin construction in 2014 (year zero).
[44] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[45] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit C-6: Present Value Benefit Stream ($Million Constant Dollars)[46] Cont.

Year	3% Discount Rate	(A)Traveler Benefits		(B)Traveler Benefits	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
		Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
29	0.42	$1	$6	$4	$0.2	$14	$0.0	$25
30	0.41	$1	$6	$4	$0.2	$13	$0.0	$25
31	0.40	$1	$6	$4	$0.2	$13	$0.0	$24
32	0.39	$1	$6	$4	$0.2	$13	$0.0	$24
33	0.38	$1	$6	$4	$0.2	$13	$0.0	$24
34	0.37	$1	$6	$4	$0.2	$13	$0.0	$23
Total		**$29**	**$209**	**$144**	**$7**	**$936**	**$0.1**	**$1,324**

Exhibit C-7: Benefit Summary ($Million)

Discount Rate	(A) Traveler Benefits[47]		(B) Traveler Benefits[48]	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
0%	$51	$371	$256	$12	$1,322	$0.2	$2,011
3%	$29	$209	$144	$7	$936	$0.1	$1,324
7%	$15	$110	$76	$4	$688	$0.1	$892

Project Net Benefits

Exhibit C-8 illustrates the net benefits of the proposed Loop 1 project. The startup, operation, and maintenance costs are subtracted from the benefits to calculate the net benefits. All of the net benefit values are positive.

[46] All benefits and costs are estimated at a 3 percent discount rate.
[47] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[48] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit C-8: Project's Net Benefits ($Million Constant Dollars)[49]

Year[50]	3% Discount Rate	Construction Costs	Operation & Maintenance Cost	Total Cost	Total Benefits	Project Net Benefits
0	1.00	$63	$0	$63	$120	$57
1	0.97	$61	$0	$61	$116	$55
2	0.94	$59	$0	$59	$113	$54
3	0.92	$57	$0	$57	$109	$52
4	0.89	$0	$1	$1	$32	$31
5	0.86	$0	$1	$1	$32	$31
6	0.84	$0	$1	$1	$32	$31
7	0.81	$0	$1	$1	$31	$30
8	0.79	$0	$1	$1	$31	$30
9	0.77	$0	$1	$1	$31	$30
10	0.74	$0	$1	$1	$31	$30
11	0.72	$0	$1	$1	$30	$29
12	0.70	$0	$1	$1	$30	$29
13	0.68	$0	$1	$1	$30	$29
14	0.66	$0	$1	$1	$29	$28
15	0.64	$0	$1	$1	$29	$28
16	0.62	$0	$1	$1	$29	$28
17	0.61	$0	$1	$1	$29	$28
18	0.59	$0	$1	$1	$28	$27
19	0.57	$0	$1	$1	$28	$27
20	0.55	$0	$1	$1	$28	$27
21	0.54	$0	$1	$1	$27	$27
22	0.52	$0	$1	$1	$27	$27
23	0.51	$0	$1	$1	$27	$26
24	0.49	$0	$1	$1	$27	$26
25	0.48	$0	$1	$1	$26	$26
26	0.46	$0	$1	$1	$26	$25
27	0.45	$0	$1	$1	$26	$25
28	0.44	$0	$1	$1	$25	$25
29	0.42	$0	$1	$1	$25	$24
30	0.41	$0	$1	$1	$25	$24
31	0.40	$0	$1	$1	$24	$24
32	0.39	$0	$1	$1	$24	$23
33	0.38	$0	$1	$1	$24	$23
34	0.37	$0	$1	$1	$23	$23
Total		**$239**	**$26**	**$265**	**$1,324**	**$1,059**

[49] All benefits and costs are estimated at a 3 percent discount rate.
[50] Project estimated to begin construction in 2014 (year zero).

Exhibit C-9: Project Net Benefits Summary ($Million)

Discount Rate	Construction Costs	Operation & Maintenance Costs	Total Costs	Total Benefits	Project Net Benefits
0%	$250	$43	$293	$2,011	$1,718
3%	$239	$26	$265	$1,324	$1,059
7%	$227	$14	$241	$892	$652

Benefit/Cost Analysis

Exhibits C-10 through C-12 summarize the benefit stream for the Loop 1 project in 2013 constant dollars. There are five types of benefit calculations shown (A through E, Exhibit C-10). The total cost stream including facility type, startup costs, annual operation and maintenance costs, and net total costs is also shown (Exhibit C-11). Traditionally, the ratio of traveler benefits (A and B), shipper/logistics cost savings (C) and social/environmental cost savings (E) to the net total cost is used for benefit/cost ratio purposes that do not include economic impacts.

Exhibit C-10: Present Value of Benefit Stream Summary ($Million)

Mode	(A) Traveler Benefits[51]		(B) Traveler Benefits[52]	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability			
Passenger Car – On the Job	$5	$93	$0	$0	No Separate Estimate	No Separate Estimate
Passenger Car – Commute	$16	$108	$108	$0		
Passenger Car – Pers/Rec	$5	$0	$36	$0		
All Trucks – Freight	$2	$7	$0	$7		
Total	**$29**	**$209**	**$144**	**$7**	**$936**	**$0.1**

Exhibit C-11: Present Value of Cost Stream ($Million)

Facility Type	Construction Costs	Sum of Annual Operation & Maintenance Costs	Net Total Costs
Road	$239	$26	$265

[51] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[52] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit C-12: Efficiency Measures ($Million)

Benefit Measure	Benefit[53] Definition	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits – Costs)	Benefit/ Cost Ratio
Traveler Benefit	A+B	$382	$265	$117	1.44
Full User Benefit	A+B+C	$388	$265	$123	1.47
Total Societal Benefit	A+B+C+D+E	$1,324	$265	$1,059	5.00

Economic Impacts

Exhibit C-13 shows the economic impacts of the project during construction and operation periods. Economic impacts calculated include business output, value added, jobs, wage income, and economic impact of wage income along the project segment. The assumptions used to calculate "economic benefit of wage income ($Million)" are as follows: 14.4 percent average tax rate, 6.2 percent Social Security rate, and 1.45 percent[54] Medicare rate for a total of 22.1 percent;[55] also included is a 3.2 percent savings rate and 2.44 income multiplier.

[53] From Exhibit C-10.

[54] Average tax rate, Social Security rate, and Medicare rate were retrieved from the *Congressional Budget Office* http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/57xx/doc5746/08-13-effectivefedtaxrates.pdf.

[55] Total 22.1 percent retrieved from the *Bureau of Economic Analysis* http://www.bea.gov/newsreleases/national/pi/pinewsrelease.htm.

Exhibit C-13: Economic Impacts[56]

Year[57]	3% Discount Rate	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)	Economic Benefit of Wage Income ($Million)
0	1.00	$87	$48	672	$39	$71
1	0.97	$84	$47	672	$38	$69
2	0.94	$82	$45	672	$37	$67
3	0.92	$79	$44	672	$35	$65
4	0.89	$13	$7	145	$6	$11
5	0.86	$13	$7	148	$6	$11
6	0.84	$13	$7	150	$6	$11
7	0.81	$13	$7	153	$6	$10
8	0.79	$13	$7	156	$6	$10
9	0.77	$12	$7	159	$6	$10
10	0.74	$12	$7	161	$5	$10
11	0.72	$12	$7	164	$5	$10
12	0.70	$12	$7	167	$5	$10
13	0.68	$12	$7	170	$5	$10
14	0.66	$12	$7	173	$5	$10
15	0.64	$12	$7	176	$5	$9
16	0.62	$11	$7	179	$5	$9
17	0.61	$11	$6	183	$5	$9
18	0.59	$11	$6	186	$5	$9
19	0.57	$11	$6	190	$5	$9
20	0.55	$11	$6	193	$5	$9
21	0.54	$11	$6	197	$5	$9
22	0.52	$11	$6	200	$5	$9
23	0.51	$11	$6	204	$5	$9
24	0.49	$11	$6	208	$5	$9
25	0.48	$10	$6	211	$5	$8
26	0.46	$10	$6	214	$5	$8
27	0.45	$10	$6	218	$4	$8
28	0.44	$10	$6	221	$4	$8
29	0.42	$10	$6	224	$4	$8
30	0.41	$10	$6	228	$4	$8
31	0.40	$10	$5	231	$4	$8
32	0.39	$9	$5	235	$4	$8
33	0.38	$9	$5	238	$4	$7
34	0.37	$9	$5	242	$4	$7
Total		**$676**	**$381**		**$301**	**$555**

[56] All benefits and costs are estimated at a 3 percent discount rate.
[57] Project estimated to begin construction in 2014 (year zero).

Exhibit C-14: Economic Impact Summary ($Million)

Discount Rate	Business Output	Value Added	Wage Income	Economic Benefit of Wage Income
0%	$955	$540	$424	$781
3%	$676	$381	$301	$555
7%	$497	$279	$222	$409

Economic Impact by Industry

The economic impact for individual industries is examined for 2028, 10 years following the beginning of operation. Exhibit C-15 illustrates the industries that are affected as a result of the economic impact contributed from the completion of the Austin Loop 1 corridor project.

Exhibit C-15: Economic Impact by Industry for 2028 (in 2013 Dollars)

NAICS[58]	Industry	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)
111–115, 211–213	Agriculture, Forestry, Mining, Oil & Gas Extraction	$0	$0	2	$0
221	Utilities	$0	$0	0	$0
230	Construction	$1	$0	5	$0
311–339	Manufacturing	$1	$0	3	$0
420	Wholesale Trade	$1	$0	3	$0
441–454	Retail Trade	$1	$1	21	$1
481–488	Transportation	$2	$1	22	$1
491–493	Postal Service & Warehousing	$0	$0	2	$0
511–519	Media and Information	$1	$1	3	$0
521–525, 531–	Finance, Insurance, & Real Estate	$3	$1	12	$1
541, 551, 561–562	Business Support Services (Prof., Mgmt., & Admin.)	$4	$3	41	$2
611, 621–624	Educational, Health Care, & Social Services	$2	$2	25	$1
711–713, 721–722, 811–814	Arts, Entertainment, Accommodation, Food, & Household Services	$2	$1	34	$1
920	Government	$0	$0	0	$0
	Total	**$18**	**$10**	**173**	**$8**

[58] North American Industry Classification System.

Tax Impacts

Taxes collected by the federal, state, and local governments were calculated for households and businesses surrounding the project segment (Exhibit C-16).

Exhibit C-16: Tax Impacts for 2028 (in 2013 Dollars)

Tax/Fee Collector	Tax/Fee Description	Taxes/Fees ($Million) Paid by: Households	Taxes/Fees ($Million) Paid by: Businesses	Total ($Million)
Federal Government	Motor Fuel Tax	-$0.1	-$0.1	-$0.1
	Income Profits	$0.0	$0.0	$0.0
	Social Insurance Tax (FICA)	$0.0	$0.0	$0.0
	Miscellaneous Fees & Taxes	$0.0	$0.0	$0.0
	Total Federal Government	**-$0.1**	**-$0.1**	**-$0.1**
State and Local Government	Motor Fuel Tax	-$0.1	-$0.1	-$0.1
	Motor Vehicle License Fees	$0.0	$0.0	$0.0
	Income/Profits	$0.0	$0.0	$0.0
	Sales Tax	not available	not available	$0.0
	Property Tax	$0.0	$0.0	$0.0
	Social Insurance Tax	$0.0	$0.0	$0.0
	Miscellaneous Fees & Taxes	$0.0	$0.0	$0.0
Total State and Local Government		**-$0.1**	**-$0.1**	**-$0.1**
Grand Totals for Federal, State, and Local		**-$0.1**	**-$0.2**	**-$0.3**

Findings

The Austin Loop 1 project proves cost effective in several ways. It provides a present value benefit stream of almost $1.3 billion and will create over 670 jobs each year of construction and 145 to 240 jobs each year of operation.

APPENDIX D: HOUSTON IH 45 RESULTS

This appendix summarizes the TREDIS calculations to compute and forecast the economic impact resulting from the Houston IH 45 corridor project. Exhibits included are:

- Project assumptions—project parameters including project time period, startup costs, operation and maintenance costs, and travel conditions.
- Congestion reduction—measures the reduction in traffic congestion along the project corridor by calculating average daily and peak period vehicle-miles traveled, average free-flow and current peak period speed, peak period proposed speed, current hours of congestion, and proposed hours of congestion.
- Impacts on travel characteristics—measured in vehicle-hours traveled and vehicle-miles traveled.
- Present value of benefit stream—establishes the economic efficiency of transportation investments; the dollar value of net gain to the project users and non-users.
- Project net benefits—measures the cost effectiveness of a project; the overall benefits of the possible project minus the costs.
- Benefit/cost analysis—a cost effectiveness measure; the dollar value of net gain to the project segment users and non-users compared to the project costs.
- Economic impacts—impacts measured in the dollar value of the business output, value added, jobs, wage income, and economic benefit of wage income.
- Economic impacts by industry—impacts on the specific industries measured in business output, value added, jobs, wage income, and economic benefit of wage income.
- Tax impacts—measures taxes and fees paid to the federal government and state and local governments by households and businesses around the project segment.

Project-Specific TREDIS Assumptions

Exhibit D-1 shows the Houston IH 45 project-specific assumptions on dates, travel growth rate, constant dollar year, and cost used for TREDIS assumptions and further calculations.

Exhibit D-1: Project Assumptions

Project Assumptions	
Construction Start	2015
Construction End	2017
Operation Start	2018
Operation End	2048
Analysis Year	2028
Travel Growth Rate	0.022
Constant Dollar Year	2013
Total Project Cost	$2.2 Million

Operation and Maintenance Cost

Annual maintenance costs were estimated by assuming the total cost would be 17 percent of the startup (construction) cost and dividing by the 30-year life of the roadway (Exhibit D-2).[59] The project is assumed to use Portland cement concrete (PCC) pavement. We assume that for every original $100 cost the project will incur $17 of maintenance expenses over the lifetime of the roadway (30 years). These costs are distributed as follows:

- $1 to reseal after 7 years,
- $2 to patch and reseal after 14 years,
- $3 to patch and reseal after 21 years,
- $5 to patch and reseal after 28 years, followed by
- $6 to overlay.

Exhibit D-2: Operation and Maintenance Costs

Operation & Maintenance Costs ($Million)		
Road Element	**Current Design**	**Possible Future**
Operation & Maintenance	$0	$353

Travel Conditions

Travel conditions shown in Exhibit D-3 include estimates of annual vehicle-miles traveled, annual vehicle-hours traveled, fraction congested, and buffer time. These were estimated with the FIXiT spreadsheet and are used by TREDIS in the benefit estimation process.

[59] Texas A&M Transportation Institute, Pavement Division, email dated June 20, 2013.

Exhibit D-3: Travel Conditions

Travel Conditions		
Annual Vehicle Trips	**Current Design**	**Possible Future**
Passenger Car: Business	43,404,108	43,404,108
Passenger Car: Commute	130,212,323	130,212,323
Passenger Car: Personal	43,404,108	43,404,108
All Trucks: Freight	16,334,879	16,334,879
Annual Vehicle-Miles Traveled		
Passenger Car: Business	536,908,812	536,908,812
Passenger Car: Commute	1,610,726,435	1,610,726,435
Passenger Car: Personal	536,908,812	536,908,812
All Trucks: Freight	202,062,456	202,062,456
Annual Vehicle-Hours Traveled		
Passenger Car: Business	9,998,758	9,600,444
Passenger Car: Commute	29,996,274	28,801,331
Passenger Car: Personal	9,998,758	9,600,444
All Trucks: Freight	3,762,973	3,613,070
Fraction Congested		
Passenger Car: Business	0.3	0.2
Passenger Car: Commute	0.3	0.2
Passenger Car: Personal	0.3	0.2
All Trucks: Freight	0.3	0.2
Average Buffer Time (Hours/Trip)		
Passenger Car: Business	0.02	0.01
Passenger Car: Commute	0.02	0.01
Passenger Car: Personal	0.02	0.01
All Trucks: Freight	0.02	0.01

Congestion Reduction

Exhibit D-4 shows the results of the congestion analysis performed with the FIXiT program. The key outputs that describe the proposed project enhancements are shown, along with the before conditions.

Exhibit D-4: Congestion Results

To	From	Avg Daily VMT	Avg Daily Peak Period VMT	Avg Free-Flow Speed	Current Peak Period Avg Speed	Best Estimate for Proposed Avg Peak Period Speed	Current Congested Level (%VMT)	Proposed Congested Level (% VMT)
SL 8	IH 610	2,178,647	1,089,324	65	43	49	35	21
SL 8	FM 2920	2,034,158	1,017,079	65	53	55	12	11
IH 10	IH 610	717,249	358,625	63	46	48	26	17
IH 45	IH 610W	1,222,135	611,068	65	44	46	25	23
IH 45	US 59	222,332	111,166	60	42	46	20	15
IH 10	IH 610S	1,533,990	766,995	63	43	47	32	25
Total		**7,908,511**	**3,954,257**	**64**	**46**	**50**	**29**	**22**

Travel Characteristics

Exhibit D-5 shows the difference in the travel characteristics between the current roadway design and the possible future design. The output is based on results from TREDIS assumptions and calculations.

Exhibit D-5: Difference between Travel Characteristics (Current Design–Possible Future)

Year[60]	Vehicles			Passenger			Freight Tons		
	Trips	Miles	Hours	Trips	Miles	Hours	Trips	Miles	Hours
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	-1,722,677	0	0	-2,403,135	0	0	-2,900,123
4	0	0	-1,760,576	0	0	-2,456,004	0	0	-2,963,926
5	0	0	-1,799,309	0	0	-2,510,036	0	0	-3,029,132
6	0	0	-1,838,893	0	0	-2,565,256	0	0	-3,095,773
7	0	0	-1,879,349	0	0	-2,621,692	0	0	-3,163,880
8	0	0	-1,920,695	0	0	-2,679,369	0	0	-3,233,486
9	0	0	-1,962,950	0	0	-2,738,315	0	0	-3,304,622
10	0	0	-2,006,135	0	0	-2,798,558	0	0	-3,377,324
11	0	0	-2,050,270	0	0	-2,860,127	0	0	-3,451,625
12	0	0	-2,095,376	0	0	-2,923,049	0	0	-3,527,561
13	0	0	-2,141,474	0	0	-2,987,357	0	0	-3,605,167
14	0	0	-2,188,586	0	0	-3,053,078	0	0	-3,684,481
15	0	0	-2,236,735	0	0	-3,120,246	0	0	-3,765,539
16	0	0	-2,285,944	0	0	-3,188,891	0	0	-3,848,381
17	0	0	-2,336,234	0	0	-3,259,047	0	0	-3,933,046
18	0	0	-2,387,631	0	0	-3,330,746	0	0	-4,019,573
19	0	0	-2,440,159	0	0	-3,404,023	0	0	-4,108,003
20	0	0	-2,493,843	0	0	-3,478,911	0	0	-4,198,379
21	0	0	-2,548,707	0	0	-3,555,447	0	0	-4,290,744
22	0	0	-2,604,779	0	0	-3,633,667	0	0	-4,385,140
23	0	0	-2,662,084	0	0	-3,713,608	0	0	-4,481,613
24	0	0	-2,720,650	0	0	-3,795,307	0	0	-4,580,208
25	0	0	-2,780,504	0	0	-3,878,804	0	0	-4,680,973
26	0	0	-2,841,675	0	0	-3,964,138	0	0	-4,783,954
27	0	0	-2,904,192	0	0	-4,051,349	0	0	-4,889,201
28	0	0	-2,968,084	0	0	-4,140,479	0	0	-4,996,764
29	0	0	-3,033,382	0	0	-4,231,569	0	0	-5,106,693
30	0	0	-3,100,117	0	0	-4,324,664	0	0	-5,219,040
31	0	0	-3,168,319	0	0	-4,419,806	0	0	-5,333,859
32	0	0	-3,238,022	0	0	-4,517,042	0	0	-5,451,204
33	0	0	-3,309,259	0	0	-4,616,417	0	0	-5,571,130

[60] Project estimated to begin construction in 2015 (year zero).

Benefit Stream

Shown in Exhibit D-6 are the five benefits (A through E) calculated for the IH 45 project segment. These include traveler benefits consisting of vehicle operating costs, travel time and reliability, traveler benefits consisting of value of personal time and reliability, shipper/logistics cost, economic benefits, and social and environmental benefits.

Exhibit D-6: Present Value Benefit Stream ($Million Constant Dollars)[61]

Year[62]	3% Discount Rate	(A) Traveler Benefits[63] Vehicle Operating Costs	(A) Traveler Benefits[63] Time & Reliability Costs	(B) Traveler Benefits[64] Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0	1.00	$0	$0	$0	$0	$1,469	$0	$1,469
1	0.97	$0	$0	$0	$0	$1,426	$0	$1,426
2	0.94	$0	$0	$0	$0	$1,384	$0	$1,384
3	0.92	$16	$45	$27	$3	$138	$0.2	$229
4	0.89	$16	$45	$27	$3	$136	$0.2	$227
5	0.86	$16	$44	$26	$3	$134	$0.2	$224
6	0.84	$16	$44	$26	$3	$133	$0.2	$222
7	0.81	$16	$44	$26	$3	$131	$0.2	$220
8	0.79	$16	$43	$26	$3	$129	$0.2	$217
9	0.77	$16	$43	$26	$3	$128	$0.2	$215
10	0.74	$15	$42	$25	$3	$126	$0.1	$213
11	0.72	$15	$42	$25	$3	$124	$0.1	$210
12	0.70	$15	$42	$25	$3	$123	$0.1	$208
13	0.68	$15	$41	$25	$3	$121	$0.1	$206
14	0.66	$15	$41	$25	$3	$120	$0.1	$204
15	0.64	$15	$41	$24	$3	$118	$0.1	$202
16	0.62	$15	$41	$24	$3	$117	$0.1	$200
17	0.61	$15	$40	$24	$3	$116	$0.2	$198
18	0.59	$15	$40	$24	$3	$114	$0.2	$196
19	0.57	$14	$40	$24	$3	$113	$0.2	$194
20	0.55	$14	$39	$24	$3	$111	$0.2	$192
21	0.54	$14	$39	$23	$3	$110	$0.2	$190
22	0.52	$14	$39	$23	$3	$109	$0.2	$188
23	0.51	$14	$38	$23	$3	$108	$0.2	$186
24	0.49	$14	$38	$23	$1	$106	$0.2	$182
25	0.48	$14	$37	$22	$1	$104	$0.1	$179
26	0.46	$13	$37	$22	$1	$103	$0.1	$177
27	0.45	$13	$37	$22	$1	$101	$0.1	$174
28	0.44	$13	$36	$22	$1	$100	$0.1	$172
29	0.42	$13	$36	$21	$1	$98	$0.1	$170
30	0.41	$13	$35	$21	$1	$97	$0.1	$167
31	0.40	$13	$35	$21	$1	$95	$0.1	$165
32	0.39	$13	$34	$21	$1	$94	$0.1	$163
33	0.38	$12	$34	$20	$1	$93	$0.1	$160
Total		**$449**	**$1,231**	**$737**	**$75**	**$7,829**	**$5**	**$10,326**

[61] All benefits and costs are estimated at a 3 percent discount rate.
[62] Project estimated to begin construction in 2015 (year zero).
[63] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[64] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit D-7: Benefit Summary ($Million)

Discount Rate	(A) Traveler Benefits[65] Vehicle Operating Costs	(A) Traveler Benefits[65] Time & Reliability Costs	(B) Traveler Benefits[66] Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0%	$775	$2,125	$1,272	$121	$10,474	$8	$14,775
3%	$449	$1,231	$737	$75	$7,829	$5	$10,326
7%	$246	$674	$404	$44	$6,091	$3	$7,461

Project Net Benefits

Exhibit D-8 illustrates the net benefits of the proposed IH 45 project. The startup, operation, and maintenance costs are subtracted from the benefits to calculate the net benefits. All of the net benefit values are positive.

[65] Benefit (A) Traveler Benefits describe *out-of-pocket.*

[66] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit D-8: Project's Net Benefits ($Million Constant Dollars)[67]

Year[68]	3% Discount Rate	Construction Costs	Operation & Maintenance Cost	Total Cost	Total Benefits	Project Net Benefits
0	1.00	$670	$0	$670	$1,469	$799
1	0.97	$650	$0	$650	$1,426	$775
2	0.94	$632	$0	$632	$1,384	$753
3	0.92	$0	$10	$10	$229	$219
4	0.89	$0	$10	$10	$227	$217
5	0.86	$0	$10	$10	$224	$215
6	0.84	$0	$10	$10	$222	$212
7	0.81	$0	$9	$9	$220	$210
8	0.79	$0	$9	$9	$217	$208
9	0.77	$0	$9	$9	$215	$206
10	0.74	$0	$8	$8	$213	$204
11	0.72	$0	$8	$8	$210	$202
12	0.70	$0	$8	$8	$208	$200
13	0.68	$0	$8	$8	$206	$198
14	0.66	$0	$8	$8	$204	$196
15	0.64	$0	$7	$7	$202	$194
16	0.62	$0	$7	$7	$200	$192
17	0.61	$0	$7	$7	$198	$191
18	0.59	$0	$7	$7	$196	$189
19	0.57	$0	$7	$7	$194	$187
20	0.55	$0	$6	$6	$192	$185
21	0.54	$0	$6	$6	$190	$184
22	0.52	$0	$6	$6	$188	$182
23	0.51	$0	$6	$6	$186	$180
24	0.49	$0	$6	$6	$182	$176
25	0.48	$0	$5	$5	$179	$174
26	0.46	$0	$5	$5	$177	$172
27	0.45	$0	$5	$5	$174	$169
28	0.44	$0	$5	$5	$172	$167
29	0.42	$0	$5	$5	$170	$165
30	0.41	$0	$5	$5	$167	$163
31	0.40	$0	$5	$5	$165	$160
32	0.39	$0	$4	$4	$163	$158
33	0.38	$0	$4	$4	$160	$156
Total		**$1,952**	**$215**	**$2,167**	**$10,326**	**$8,159**

[67] All benefits and costs are estimated at a 3 percent discount rate.
[68] Project estimated to begin construction in 2015 (year zero).

Exhibit D-9: Project Net Benefits Summary ($Million)

Discount Rate	Construction Costs	Operation & Maintenance Costs	Total Costs	Total Benefits	Project Net Benefits
0%	$2,010	$353	$2,363	$14,775	$12,412
3%	$1,952	$215	$2,167	$10,326	$8,159
7%	$1,881	$125	$2,006	$7,461	$5,455

Benefit/Cost Analysis

Exhibits D-10 through D-12 summarize the benefit stream for the Houston IH 45 project in 2013 constant dollars. There are five types of benefit calculations shown (A through E, Exhibit D-10). The total cost stream including facility type, startup costs, annual operation and maintenance costs, and net total costs is also shown (Exhibit D-11). Traditionally, the ratio of traveler benefits (A and B), shipper/logistics cost savings (C), and social/environmental cost savings (E) to the net total cost is used for benefit/cost ratio purposes that do not include economic impacts.

Exhibit D-10: Present Value of Benefit Stream Summary ($Million)

Mode	(A) Traveler Benefits[69]		(B) Traveler Benefits[70]	(C) Shipper/ Logistics Cost	(F) Economic Benefits	(E) Social/ Environ.
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability			
Passenger Car – On the Job	$69	$478	$0	$0	No Separate Estimate	No Separate Estimate
Passenger Car – Commute	$207	$552	$553	$0		
Passenger Car – Pers/Rec	$69	$0	$184	$0		
All Trucks – Freight	$104	$202	$0	$75		
Total	**$449**	**$1,231**	**$737**	**$75**	**$7,829**	**$5**

Exhibit D-11: Present Value of Cost Stream ($Million)

Facility Type	Construction Costs	Sum of Annual Operation & Maintenance Costs	Net Total Costs
Road	$1,952	$215	$2,167

[69] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[70] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit D-12: Efficiency Measures ($Million)

Benefit Measure	Benefit Definition[71]	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits – Costs)	Benefit/ Cost Ratio
Traveler Benefit	A+B	$2,417	$2,167	$251	1.12
Full User Benefit	A+B+C	$2,492	$2,167	$325	1.15
Total Societal Benefit	A+B+C+D+E	$10,326	$2,167	$8,159	4.77

Economic Impacts

Exhibit D-13 shows the economic impacts of the project during construction and operation periods. Economic impacts calculated include business output, value added, jobs, wage income, and economic impact of wage income along the project segment. The assumptions used to calculate "economic benefit of wage income ($Million)" are as follows: 14.4 percent average tax rate, 6.2 percent Social Security rate, and 1.45 percent[72] Medicare rate for a total of 22.1 percent;[73] also included is a 3.2 percent savings rate and 2.44 wage multiplier.

[71] From Exhibit D-10.

[72] Average tax rate, Social Security rate, and Medicare rate were retrieved from the *Congressional Budget Office* http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/57xx/doc5746/08-13-effectivefedtaxrates.pdf.

[73] Total 22.1 percent retrieved from the *Bureau of Economic Analysis* http://www.bea.gov/newsreleases/national/pi/pinewsrelease.htm.

Exhibit D-13: Economic Impacts[74]

Year[75]	3% Discount Rate	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)	Economic Benefit of Wage Income ($Million)
0	1.00	$991	$581	6509	$473	$888
1	0.97	$963	$564	6509	$459	$862
2	0.94	$934	$547	6509	$445	$837
3	0.92	$96	$54	829	$45	$84
4	0.89	$95	$54	842	$44	$82
5	0.86	$94	$53	856	$43	$81
6	0.84	$93	$52	871	$43	$80
7	0.81	$91	$52	885	$42	$79
8	0.79	$90	$51	900	$42	$78
9	0.77	$89	$50	915	$41	$77
10	0.74	$88	$50	931	$41	$76
11	0.72	$87	$49	947	$40	$75
12	0.70	$86	$49	963	$39	$74
13	0.68	$85	$48	980	$39	$73
14	0.66	$84	$48	997	$38	$72
15	0.64	$83	$47	1014	$38	$71
16	0.62	$82	$46	1032	$38	$71
17	0.61	$81	$46	1050	$37	$70
18	0.59	$80	$45	1069	$37	$69
19	0.57	$79	$45	1087	$36	$68
20	0.55	$78	$44	1107	$36	$67
21	0.54	$77	$44	1127	$35	$66
22	0.52	$76	$43	1147	$35	$66
23	0.51	$75	$43	1168	$34	$65
24	0.49	$74	$42	1185	$34	$64
25	0.48	$73	$42	1202	$33	$63
26	0.46	$72	$41	1220	$33	$62
27	0.45	$71	$40	1237	$32	$61
28	0.44	$70	$40	1255	$32	$60
29	0.42	$69	$39	1273	$31	$59
30	0.41	$68	$39	1292	$31	$58
31	0.40	$67	$38	1311	$30	$57
32	0.39	$66	$38	1330	$30	$56
33	0.38	$65	$37	1349	$30	$55
Total		**$5,374**	**$3,101**		**$2,516**	**$4,727**

[74] All benefits and costs are estimated at a 3 percent discount rate.
[75] Project estimated to begin construction in 2015 (year zero).

Exhibit D-14: Economic Impact Summary ($Million)

Discount Rate	Business Output	Value Added	Wage Income	Economic Benefit of Wage Income
0%	$7,226	$4,155	$3,364	$6,320
3%	$5,374	$3,101	$2,516	$4,727
7%	$4,160	$2,410	$1,959	$3,680

Economic Impact by Industry

The economic impact for individual industries is examined for 2028, 10 years following the beginning of operation. Exhibit D-15 illustrates the industries that are affected as a result of the economic impact contributed from the completion of the Houston IH 45 corridor project.

Exhibit D-15: Economic Impact by Industry for 2028 (in 2013 Dollars)

NAICS[76]	Industry	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)
111–115, 211–213	Agriculture, Forestry, Mining, Oil & Gas Extraction	$4	$3	23	$2
221	Utilities	$2	$1	2	$1
230	Construction	$5	$3	36	$2
311–339	Manufacturing	$19	$6	38	$3
420	Wholesale Trade	$5	$4	23	$2
441–454	Retail Trade	$6	$4	103	$3
481–488	Transportation	$16	$8	151	$11
491–493	Postal Service & Warehousing	$1	$1	17	$1
511–519	Media and Information	$4	$2	12	$1
521–525, 531–	Finance, Insurance, & Real Estate	$15	$7	55	$3
541,551,561–562	Business Support Services (Prof., Mgmt., & Admin.)	$23	$17	212	$15
611, 621–624	Educational, Health Care, & Social Services	$15	$9	168	$9
711–713, 721–722, 811–814	Arts, Entertainment, Accommodation, Food, & Household Services	$9	$5	137	$4
920	Government	$1	$0	2	$0
	Total	**$125**	**$71**	**979**	**$57**

[76] North American Industry Classification System.

Tax Impacts

Taxes collected by the federal, state, and local governments were calculated for households and businesses surrounding the project segment (Exhibit D-16).

Exhibit D-16: Tax Impacts for 2028 (in 2013 Dollars)

Tax/Fee Collector	Tax/Fee Description	Taxes/Fees ($Million) Paid by:		Total ($Million)
		Households	Businesses	
Federal Government	Motor Fuel Tax	-$1	-$1	-$2
	Income Profits	$0	$0	$0
	Social Insurance Tax (FICA)	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
	Total Federal Government	**-$1**	**-$1**	**-$2**
State and Local Government	Motor Fuel Tax	-$1	-$1	-$2
	Motor Vehicle License Fees	$0	$0	$0
	Income/Profits	$0	$0	$0
	Sales Tax	not available	not available	$0
	Property Tax	$0	$0	$0
	Social Insurance Tax	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
	Total State and Local Government	**-$1**	**-$1**	**-$2**
	Grand Totals for Federal, State, and Local	**-$1**	**-$2**	**-$4**

Findings

The Houston IH 45 project proves cost effective in several ways. If provides a present value benefit stream of over $10.3 billion and will create over 6,500 jobs each year of construction and 830 to 1,350 jobs each year of operation.

APPENDIX E: SAN ANTONIO IH 35 RESULTS

This appendix summarizes the TREDIS calculations to compute and forecast the economic impact resulting from the San Antonio IH 35 corridor project. Exhibits included are:

- Project assumptions—project parameters including project time period, startup costs, operation and maintenance costs, and travel conditions.
- Congestion reduction—measures the reduction in traffic congestion along the project corridor by calculating average daily and peak period vehicle-miles traveled, average free-flow and current peak period speed, peak period proposed speed, current hours of congestion, and proposed hours of congestion.
- Impacts on travel characteristics—measured in vehicle-hours traveled and vehicle-miles traveled.
- Present value of benefit stream—establishes the economic efficiency of transportation investments; the dollar value of net gain to the project users and non-users.
- Project net benefits—measures the cost effectiveness of a project; the overall benefits of the possible project minus the costs.
- Benefit/cost analysis—a cost effectiveness measure; the dollar value of net gain to the project segment users and non-users compared to the project costs.
- Economic impacts—impacts measured in the dollar value of the business output, value added, jobs, wage income, and economic benefit of wage income.
- Economic impacts by industry—impacts on the specific industries measured in business output, value added, jobs, wage income, and economic benefit of wage income.
- Tax impacts—measures taxes and fees paid to the federal government and state and local governments by households and businesses around the project segment.

Project-Specific TREDIS Assumptions

Exhibit E-1 shows the San Antonio IH 35 project-specific assumptions on dates, travel growth rate, constant dollar year, and cost used for TREDIS assumptions and further calculations.

Exhibit E-1: Project Assumptions

Project Assumptions	
Construction Start	2017
Construction End	2020
Operation Start	2021
Operation End	2051
Analysis Year	2031
Travel Growth Rate	0.022
Constant Dollar Year	2013
Total Project Cost	$2.2 Million

Operation and Maintenance Cost

Annual maintenance costs were estimated by assuming the total cost would be 17 percent of the startup (construction) cost and dividing by the 30-year life of the roadway (Exhibit E-2).[77] The project is assumed to use Portland cement concrete (PCC) pavement. We assume that for every original $100 cost the project will incur $17 of maintenance expenses over the lifetime of the roadway (30 years). These costs are distributed as follows:

- $1 to reseal after 7 years,
- $2 to patch and reseal after 14 years,
- $3 to patch and reseal after 21 years,
- $5 to patch and reseal after 28 years, followed by
- $6 to overlay.

Exhibit E-2: Operation and Maintenance Costs

Operation & Maintenance Costs ($Million)		
Road Element	**Current Design**	**Possible Future**
Operation & Maintenance	$0	$345

Travel Conditions

Travel conditions shown in Exhibit E-3 include estimates of annual vehicle-miles traveled, annual vehicle-hours traveled, fraction congested, and buffer time. These were estimated with the FIXiT spreadsheet and are used by TREDIS in the benefit estimation process.

[77] Texas A&M Transportation Institute, Pavement Division, email dated June 20, 2013.

Exhibit E-3: Travel Conditions

Travel Conditions		
Annual Vehicle Trips	**Current Design**	**Possible Future**
Passenger Car: Business	20,967,839	20,967,839
Passenger Car: Commute	62,903,518	62,903,518
Passenger Car: Personal	20,967,839	20,967,839
All Trucks: Freight	13,623,172	13,623,172
Annual Vehicle-Miles Traveled		
Passenger Car: Business	293,130,393	293,130,393
Passenger Car: Commute	879,391,179	879,391,179
Passenger Car: Personal	293,130,393	293,130,393
All Trucks: Freight	190,451,950	190,451,950
Annual Vehicle-Hours Traveled		
Passenger Car: Business	5,115,822	4,905,182
Passenger Car: Commute	15,347,465	14,715,546
Passenger Car: Personal	5,115,822	4,905,182
All Trucks: Freight	3,323,839	3,186,983
Fraction Congested		
Passenger Car: Business	0.16	0.12
Passenger Car: Commute	0.16	0.12
Passenger Car: Personal	0.16	0.12
All Trucks: Freight	0.16	0.12
Average Buffer Time (Hours/Trip)		
Passenger Car: Business	0.01	0.01
Passenger Car: Commute	0.01	0.01
Passenger Car: Personal	0.01	0.01
All Trucks: Freight	0.01	0.01

Congestion Reduction

Exhibit E-4 shows the results of the congestion analysis performed with the FIXiT program. The key outputs that describe the proposed project enhancements are shown, along with the before conditions.

Exhibit E-4: Congestion Results

To	From	Avg Daily VMT	Avg Daily Peak Period VMT	Avg Free-Flow Speed	Current Peak Period Avg Speed	Best Estimate for Proposed Avg Peak Period Speed	Current Congested Levels (% VMT)	Proposed Congested Level (% VMT)
US 281	IH 410	803,717	401,859	65	55	61	8	4
US 281	IH 10	786,318	393,159	61	49	51	12	10
IH 35	IH 410	949,788	474,894	63	55	56	7	6
IH 35	IH 10	354,899	177,449	64	58	59	5	4
IH 410	SL 1604	1,592,025	796,013	65	51	58	16	8
SL 1604	FM 3009	688,586	344,293	65	48	50	28	26
Total		**2,280,611**	**1,140,305**	**64**	**52**	**56**	**16**	**12**

Travel Characteristics

Exhibit E-5 shows the difference in the travel characteristics between the current roadway design and the possible future design. The output is based on results from TREDIS assumptions and calculations.

Exhibit E-5: Difference between Travel Characteristics (Current Design–Possible Future)

Year[78]	Vehicles			Passenger			Freight Tons		
	Trips	Miles	Hours	Trips	Miles	Hours	Trips	Miles	Hours
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	-957,322	0	0	-1,270,845	0	0	-2,647,707
5	0	0	-978,383	0	0	-1,298,804	0	0	-2,705,957
6	0	0	-999,908	0	0	-1,327,378	0	0	-2,765,488
7	0	0	-1,021,906	0	0	-1,356,580	0	0	-2,826,329
8	0	0	-1,044,387	0	0	-1,386,425	0	0	-2,888,508
9	0	0	-1,067,364	0	0	-1,416,926	0	0	-2,952,055
10	0	0	-1,090,846	0	0	-1,448,099	0	0	-3,017,000
11	0	0	-1,114,845	0	0	-1,479,957	0	0	-3,083,374
12	0	0	-1,139,371	0	0	-1,512,516	0	0	-3,151,208
13	0	0	-1,164,437	0	0	-1,545,791	0	0	-3,220,535
14	0	0	-1,190,055	0	0	-1,579,799	0	0	-3,291,387
15	0	0	-1,216,236	0	0	-1,614,554	0	0	-3,363,797
16	0	0	-1,242,993	0	0	-1,650,074	0	0	-3,437,801
17	0	0	-1,270,339	0	0	-1,686,376	0	0	-3,513,432
18	0	0	-1,298,287	0	0	-1,723,476	0	0	-3,590,728
19	0	0	-1,326,849	0	0	-1,761,393	0	0	-3,669,724
20	0	0	-1,356,040	0	0	-1,800,143	0	0	-3,750,458
21	0	0	-1,385,873	0	0	-1,839,746	0	0	-3,832,968
22	0	0	-1,416,362	0	0	-1,880,221	0	0	-3,917,293
23	0	0	-1,447,522	0	0	-1,921,586	0	0	-4,003,474
24	0	0	-1,479,367	0	0	-1,963,861	0	0	-4,091,550
25	0	0	-1,511,913	0	0	-2,007,066	0	0	-4,181,564
26	0	0	-1,545,175	0	0	-2,051,221	0	0	-4,273,559
27	0	0	-1,579,169	0	0	-2,096,348	0	0	-4,367,577
28	0	0	-1,613,911	0	0	-2,142,468	0	0	-4,463,663
29	0	0	-1,649,417	0	0	-2,189,602	0	0	-4,561,864
30	0	0	-1,685,704	0	0	-2,237,773	0	0	-4,662,225
31	0	0	-1,722,789	0	0	-2,287,004	0	0	-4,764,794
32	0	0	-1,760,691	0	0	-2,337,319	0	0	-4,869,620
33	0	0	-1,799,426	0	0	-2,388,740	0	0	-4,976,751
34	0	0	-1,839,013	0	0	-2,441,292	0	0	-5,086,240

[78] Project estimated to begin construction in 2017 (year zero).

Benefit Stream

Exhibit E-6 shows the five benefits (A through E) calculated for the IH 35 project segment. These include traveler benefits consisting of vehicle operating costs, travel time and reliability, traveler benefits consisting of value of personal time and reliability, shipper/logistics cost, economic benefits, and social and environmental benefits

Exhibit E-6: Present Value Benefit Stream ($Million Constant Dollars)[79]

Year[80]	3% Discount Rate	(A) Traveler Benefits[81] Vehicle Operating Costs	(A) Traveler Benefits[81] Time & Reliability Costs	(B) Traveler Benefits[82] Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0	1.00	$0	$0	$0	$0	$957	$0	$957
1	0.97	$0	$0	$0	$0	$929	$0	$929
2	0.94	$0	$0	$0	$0	$902	$0	$902
3	0.92	$0	$0	$0	$0	$876	$0	$876
4	0.89	$7	$19	$11	$3	$71	$0	$110
5	0.86	$7	$18	$11	$3	$70	$0	$108
6	0.84	$7	$18	$10	$3	$68	$0	$107
7	0.81	$7	$18	$10	$3	$67	$0	$106
8	0.79	$7	$18	$10	$3	$66	$0	$104
9	0.77	$7	$18	$10	$3	$65	$0	$103
10	0.74	$7	$18	$10	$3	$64	$0	$101
11	0.72	$7	$18	$10	$3	$63	$0	$100
12	0.70	$7	$17	$10	$3	$62	$0	$99
13	0.68	$7	$17	$10	$3	$61	$0	$97
14	0.66	$6	$17	$10	$3	$60	$0	$96
15	0.64	$6	$17	$10	$3	$59	$0	$95
16	0.62	$6	$17	$10	$3	$58	$0	$94
17	0.61	$6	$17	$10	$3	$57	$0	$93
18	0.59	$6	$17	$10	$3	$56	$0	$91
19	0.57	$6	$17	$9	$3	$55	$0	$90
20	0.55	$6	$16	$9	$3	$54	$0	$89
21	0.54	$6	$16	$9	$3	$54	$0	$88
22	0.52	$6	$16	$9	$3	$53	$0	$87
23	0.51	$6	$16	$9	$2	$52	$0	$86
24	0.49	$6	$16	$9	$2	$51	$0	$85
25	0.48	$6	$16	$9	$2	$50	$0	$83
26	0.46	$6	$16	$9	$2	$49	$0	$82
27	0.45	$6	$15	$9	$2	$49	$0	$81
28	0.44	$6	$15	$9	$2	$48	$0	$80

[79] All benefits and costs are estimated at a 3 percent discount rate.
[80] Project estimated to begin construction in 2017 (year zero).
[81] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[82] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit E-6: Present Value Benefit Stream ($Million Constant Dollars)[83] Cont.

Year	3% Discount Rate	(A) Traveler Benefits		(B) Traveler Benefits	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
		Vehicle Operating Costs	Time& Reliability Costs	Value of Personal Time & Reliability				
29	0.42	$6	$15	$9	$2	$47	$0	$78
30	0.41	$6	$15	$8	$2	$46	$0	$77
31	0.40	$6	$15	$8	$2	$45	$0	$76
32	0.39	$5	$14	$8	$2	$44	$0	$75
33	0.38	$5	$14	$8	$2	$44	$0	$74
34	0.37	$5	$14	$8	$2	$43	$0	$73
Total		**$192**	**$511**	**$292**	**$79**	**$5,394**	**$3**	**$6,471**

Exhibit E-7: Benefit Summary ($Million)

Discount Rate	(A) Traveler Benefits[84]		(B) Traveler Benefits[85]	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
0%	$342	$909	$519	$141	$6,850	$5	$8,765
3%	$192	$511	$292	$79	$5,394	$3	$6,471
7%	$101	$269	$154	$42	$4,400	$2	$4,968

Project Net Benefits

Exhibit E-8 illustrates the net benefits of the proposed IH 35 project. The startup, operation, and maintenance costs are subtracted from the benefits to calculate the net benefits. All of the net benefit values are positive.

[83] All benefits and costs are estimated at a 3 percent discount rate.
[84] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[85] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit E-8: Project's Net Benefits ($Million Constant Dollars)[86]

Year[87]	3% Discount Rate	Construction Costs	Operation & Maintenance Cost	Total Cost	Total Benefits	Project Net Benefits
0	1.00	$509	$0	$509	$957	$448
1	0.97	$494	$0	$494	$929	$435
2	0.94	$480	$0	$480	$902	$422
3	0.92	$466	$0	$466	$876	$410
4	0.89	$0	$10	$10	$110	$100
5	0.86	$0	$10	$10	$108	$98
6	0.84	$0	$10	$10	$107	$97
7	0.81	$0	$9	$9	$106	$96
8	0.79	$0	$9	$9	$104	$95
9	0.77	$0	$9	$9	$103	$94
10	0.74	$0	$9	$9	$101	$93
11	0.72	$0	$8	$8	$100	$92
12	0.70	$0	$8	$8	$99	$91
13	0.68	$0	$8	$8	$97	$90
14	0.66	$0	$8	$8	$96	$89
15	0.64	$0	$7	$7	$95	$88
16	0.62	$0	$7	$7	$94	$87
17	0.61	$0	$7	$7	$93	$86
18	0.59	$0	$7	$7	$91	$85
19	0.57	$0	$7	$7	$90	$84
20	0.55	$0	$6	$6	$89	$83
21	0.54	$0	$6	$6	$88	$82
22	0.52	$0	$6	$6	$87	$81
23	0.51	$0	$6	$6	$86	$80
24	0.49	$0	$6	$6	$85	$79
25	0.48	$0	$5	$5	$83	$78
26	0.46	$0	$5	$5	$82	$77
27	0.45	$0	$5	$5	$81	$76
28	0.44	$0	$5	$5	$80	$75
29	0.42	$0	$5	$5	$78	$74
30	0.41	$0	$5	$5	$77	$73
31	0.40	$0	$5	$5	$76	$71
32	0.39	$0	$4	$4	$75	$70
33	0.38	$0	$4	$4	$74	$69
34	.37	$0	$4	$5	$73	$68
Total		**$1,948**	**$206**	**$2,154**	**$6,399**	**$4,244**

[86] All benefits and costs are estimated at a 3 percent discount rate.
[87] Project estimated to begin construction in 2017 (year zero).

Exhibit E-9: Project Net Benefit Summary ($Million)

Discount Rate	Construction Costs	Operation & Maintenance Costs	Total Costs	Total Benefits	Project Net Benefits
0%	$2,036	$357	$2,393	$8,765	$6,373
3%	$1,948	$210	$2,159	$6,471	$4,312
7%	$1,844	$118	$1,962	$4,968	$3,006

Benefit/Cost Analysis

Exhibits E-10 through E-12 summarize the benefit stream for the San Antonio IH 35 project in 2013 constant dollars. There are five types of benefit calculations shown (A through E, Exhibit E-10). The total cost stream including facility type, startup costs, annual operation and maintenance costs, and net total costs is also shown (Exhibit E-11). Traditionally, the ratio of traveler benefits (A and B), shipper/logistics cost savings (C), and social/environmental cost savings (E) to the net total cost is used for benefit/cost ratio purposes that do not include economic impacts.

Exhibit E-10: Present Value of Benefit Stream Summary ($Million)

	(A) Traveler Benefits[88]		(B) Traveler Benefit[89]			
Mode	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ
Passenger Car – On the Job	$25	$168	$0	$0	No Separate Estimate	No Separate Estimate
Passenger Car – Commute	$76	$194	$219	$0		
Passenger Car – Pers/Rec	$25	$0	$73	$0		
All Trucks – Freight	$66	$149	$0	$79		
Total	**$192**	**$511**	**$292**	**$79**	**$5,394**	**$3**

Exhibit E-11: Present Value of Cost Stream ($Million)

Facility Type	Construction Costs	Sum of Annual Operation & Maintenance Costs	Net Total Costs
Road	$1,948	$210	$2,159

[88] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[89] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit E-12: Efficiency Measures ($Million)

Benefit Measure	Benefit Definition[90]	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits – Costs)	Benefit/ Cost Ratio
Traveler Benefit	A+B	$995	$2,159	-$1,164	0.46
Full User Benefit	A+B+C	$1,074	$2,159	-$1,085	0.50
Total Societal Benefit	A+B+C+D+E	$6,471	$2,159	$4,312	3.00

Economic Impacts

Exhibit E-13 shows the economic impacts of the project during construction and operation periods. Economic impacts calculated include business output, value added, jobs, wage income, and economic impact of wage income along the project segment. The assumptions used to calculate "economic benefit of wage income ($Million)" are as follows: 14.4 percent average tax rate, 6.2 percent Social Security rate, and 1.45 percent[91] Medicare rate for a total of 22.1 percent;[92] also included is a 3.2 percent savings rate and 2.44 wage multiplier.

[90] From Exhibit E-10.

[91] Average tax rate, Social Security rate, and Medicare rate were retrieved from the *Congressional Budget Office* http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/57xx/doc5746/08-13-effectivefedtaxrates.pdf.

[92] Total 22.1 percent retrieved from the *Bureau of Economic Analysis* http://www.bea.gov/newsreleases/national/pi/pinewsrelease.htm.

Exhibit E-13: Economic Impacts[93]

Year[94]	3% Discount Rate	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)	Economic Benefit of Wage Income ($Million)
0	1.00	$748	$392	6348	$302	$565
1	0.97	$726	$380	6348	$293	$549
2	0.94	$705	$369	6348	$285	$533
3	0.92	$685	$358	6348	$276	$517
4	0.89	$51	$27	558	$23	$44
5	0.86	$51	$26	565	$23	$43
6	0.84	$50	$26	572	$23	$42
7	0.81	$49	$26	580	$22	$42
8	0.79	$48	$25	587	$22	$41
9	0.77	$47	$25	595	$21	$40
10	0.74	$47	$25	602	$21	$39
11	0.72	$46	$24	610	$21	$39
12	0.70	$45	$24	618	$20	$38
13	0.68	$44	$23	626	$20	$37
14	0.66	$44	$23	635	$20	$37
15	0.64	$43	$23	643	$19	$36
16	0.62	$42	$22	652	$19	$36
17	0.61	$42	$22	661	$19	$35
18	0.59	$41	$22	670	$18	$34
19	0.57	$41	$21	680	$18	$34
20	0.55	$40	$21	689	$18	$33
21	0.54	$39	$21	699	$18	$33
22	0.52	$39	$21	709	$17	$32
23	0.51	$38	$20	719	$17	$32
24	0.49	$38	$20	730	$17	$31
25	0.48	$37	$20	739	$16	$31
26	0.46	$36	$19	747	$16	$30
27	0.45	$36	$19	756	$16	$30
28	0.44	$35	$19	765	$15	$29
29	0.42	$34	$18	774	$15	$28
30	0.41	$34	$18	783	$15	$28
31	0.40	$33	$18	792	$15	$27
32	0.39	$33	$17	802	$14	$27
33	0.38	$32	$17	811	$14	$26
34	0.37	$32	$17	821	$14	$26
Total		**$4,131**	**$2,170**		**$1,723**	**$3,224**

[93] All benefits and costs are estimated at a 3 percent discount rate.
[94] Project estimated to begin construction in 2017 (year zero).

Exhibit E-14: Economic Impact Summary ($Million)

Discount Rate	Business Output	Value Added	Wage Income	Economic Benefit of Wage Income
0%	$5,208	$2,740	$2,196	$4,110
3%	$4,131	$2,170	$1,723	$3,224
7%	$3,393	$1,779	$1,401	$2,621

Economic Impact by Industry

The economic impact for individual industries is examined for 2031, 10 years following the beginning of operation. Exhibit E-15 illustrates the industries that are affected as a result of the economic impact contributed from the completion of the San Antonio IH 35 corridor project.

Exhibit E-15: Economic Impact by Industry for 2031 (in 2013 Dollars)

NAICS[95]	Industry	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)
111–115, 211–213	Agriculture, Forestry, Mining, Oil & Gas Extraction	$1	$0	9	$0
221	Utilities	$0	$0	1	$0
230	Construction	$4	$2	35	$1
311–339	Manufacturing	$6	$2	17	$1
420	Wholesale Trade	$2	$2	12	$1
441–454	Retail Trade	$4	$2	64	$2
481–488	Transportation	$13	$6	148	$10
491–493	Postal Service & Warehousing	$1	$1	11	$1
511–519	Media and Information	$3	$1	8	$1
521–525, 531–	Finance, Insurance, & Real Estate	$10	$5	39	$2
541, 551, 561–562	Business Support Services (Prof., Mgmt., & Admin.)	$8	$5	109	$5
611, 621–624	Educational, Health Care, & Social Services	$8	$5	95	$5
711–713, 721–722, 811–814	Arts, Entertainment, Accommodation, Food, & Household Services	$5	$3	84	$2
920	Government	$1	$0	2	$0
	Total	**$66**	**$35**	**634**	**$30**

95 North American Industry Classification System.

Tax Impacts

Taxes collected by the federal, state, and local governments were calculated for households and businesses surrounding the project segment (Exhibit E-16).

Exhibit E-16: Tax Impacts for 2031 (in 2013 Dollars)

Tax/Fee Collector	Tax/Fee Description	Taxes/Fees ($Million) Paid by: Households	Businesses	Total ($Million)
Federal Government	Motor Fuel Tax	-$0.3	-$0.4	-$0.6
	Income Profits	$0.0	$0.0	$0.0
	Social Insurance Tax (FICA)	$0.0	$0.0	$0.0
	Miscellaneous Fees & Taxes	$0.0	-$0.1	-$0.1
	Total Federal Government	**-$0.3**	**-$0.5**	**-$0.7**
State and Local Government	Motor Fuel Tax	-$0.3	-$0.4	-$0.7
	Motor Vehicle License Fees	$0.0	$0.0	$0.0
	Income/Profits	$0.0	$0.0	$0.0
	Sales tax	not available	not available	$0.0
	Property Tax	$0.0	$0.0	$0.0
	Social Insurance Tax	$0.0	$0.0	$0.0
	Miscellaneous Fees & Taxes	$0.0	-$0.1	-$0.1
Total State and Local Government		**-$0.3**	**-$0.5**	**-$0.8**
Grand Totals for Federal, State, and Local		**-$0.6**	**-$1.0**	**-$1.5**

Findings

The San Antonio IH 35 project proves cost effective in several ways. It provides a present value benefit stream of almost $6.4 billion and will create over 6,300 jobs each year of construction and 560 to 820 jobs each year of operation.

APPENDIX F: HOUSTON US 290 RESULTS

This appendix summarizes the TREDIS calculations to compute and forecast the economic impact resulting from the Houston US 290 corridor project. Exhibits included are:

- Project assumptions—project parameters including project time period, startup costs, operation and maintenance costs, and travel conditions.
- Congestion reduction—measures the reduction in traffic congestion along the project corridor by calculating average daily and peak period vehicle-miles traveled, average free-flow and current peak period speed, peak period proposed speed, current hours of congestion, and proposed hours of congestion.
- Impacts on travel characteristics—measured in vehicle-hours traveled and vehicle-miles traveled.
- Present value of benefit stream—establishes the economic efficiency of transportation investments; the dollar value of net gain to the project users and non-users.
- Project net benefits—measures the cost effectiveness of a project; the overall benefits of the possible project minus the costs.
- Benefit/cost analysis—a cost effectiveness measure; the dollar value of net gain to the project segment users and non-users compared to the project costs.
- Economic impacts—impacts measured in the dollar value of the business output, value added, jobs, wage income, and economic benefit of wage income.
- Economic impacts by industry—impacts on the specific industries measured in business output, value added, jobs, wage income, and economic benefit of wage income.
- Tax impacts—measures taxes and fees paid to the federal government and state and local governments by households and businesses around the project segment.

Project-Specific TREDIS Assumptions

Exhibit F-1 shows the Houston US 290 project-specific assumptions on dates, travel growth rate, constant dollar year, and cost used for TREDIS assumptions and further calculations.

Exhibit F-1: Project Assumptions

Project Assumptions	
Construction Start	2013
Construction End	2015
Operation Start	2016
Operation End	2046
Analysis Year	2026
Travel Growth Rate	0.022
Constant Dollar Year	2013
Total Project Cost	$888 Million

Operation and Maintenance Cost

Annual maintenance costs were estimated by assuming the total cost would be 17 percent of the startup (construction) cost and dividing by the 30-year life of the roadway (Exhibit F-2).[96] The project is assumed to use Portland cement concrete (PCC) pavement. We assume that for every original $100 cost the project will incur $17 of maintenance expenses over the lifetime of the roadway (30 years). These costs are distributed as follows:

- $1 to reseal after 7 years,
- $2 to patch and reseal after 14 years,
- $3 to patch and reseal after 21 years,
- $5 to patch and reseal after 28 years, followed by
- $6 to overlay.

Exhibit F-2: Operation and Maintenance Costs

Operation & Maintenance Costs ($Million)		
Road Element	**Current Design**	**Possible Future**
Operation & Maintenance	$0	$146

Travel Conditions

Travel conditions shown in Exhibit F-3 include estimates of annual vehicle-miles traveled, annual vehicle-hours traveled, fraction congested, and buffer time. These were estimated with the FIXiT spreadsheet and are used by TREDIS in the benefit estimation process.

[96] Texas A&M Transportation Institute, Pavement Division, email dated June 20, 2013.

Exhibit F-3: Travel Conditions

Travel Conditions		
Annual Vehicle Trips	**Current Design**	**Possible Future**
Passenger Car: Business	23,524,754	23,524,754
Passenger Car: Commute	70,574,263	70,574,263
Passenger Car: Personal	23,524,754	23,524,754
All Trucks: Freight	9,537,063	9,537,063
Annual Vehicle-Miles Traveled		
Passenger Car: Business	305,821,805	305,821,805
Passenger Car: Commute	917,465,416	917,465,416
Passenger Car: Personal	305,821,805	305,821,805
All Trucks: Freight	123,981,813	123,981,813
Annual Vehicle-Hours Traveled		
Passenger Car: Business	5,560,037	5,211,330
Passenger Car: Commute	16,680,110	15,633,990
Passenger Car: Personal	5,560,037	5,211,330
All Trucks: Freight	2,254,069	2,112,701
Fraction Congested		
Passenger Car: Business	0.2	0.2
Passenger Car: Commute	0.2	0.2
Passenger Car: Personal	0.2	0.2
All Trucks: Freight	0.2	0.2
Buffer Time (Hours/Trip)		
Passenger Car: Business	0.02	0.01
Passenger Car: Commute	0.02	0.01
Passenger Car: Personal	0.02	0.01
All Trucks: Freight	0.02	0.01

Congestion Reduction

Exhibit F-4 shows the results of the congestion analysis performed with the FIXiT program. The key outputs that describe the proposed project enhancements are shown, along with the before conditions.

Exhibit F-4: Congestion Results

To	From	Avg Daily VMT	Avg Daily Peak Period VMT	Avg Free-Flow Speed	Current Peak Period Avg Speed	Best Estimate for Proposed Avg Peak Period Speed	Current Congested Level (% VMT)	Proposed Congested Level (% VMT)
FM 529	IH 610	1,699,293	849,647	65	43	52	27	15
IH 45	IH 10	1,104,071	552,036	63	42	45	26	23
FM 1960	FM 529	593,783	296,892	65	48	58	16	9
FM 1960	BU 290	1,131,869	565,935	65	62	63	2	2
Total		**4,529,016**	**2,264,510**	**64**	**48**	**54**	**24**	**16**

Travel Characteristics

Exhibit F-5 shows the difference in the travel characteristics between the current roadway design and the possible future design. The output is based on results from TREDIS assumptions and calculations.

Exhibit F-5: Difference between Travel Characteristics (Current Design-Possible Future)

Year[97]	Vehicles			Passenger			Freight Tons		
	Trips	Miles	Hours	Trips	Miles	Hours	Trips	Miles	Hours
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	-1,516,281	0	0	-2,103,840	0	0	-2,734,999
4	0	0	-1,549,640	0	0	-2,150,125	0	0	-2,795,169
5	0	0	-1,583,732	0	0	-2,197,427	0	0	-2,856,663
6	0	0	-1,618,574	0	0	-2,245,771	0	0	-2,919,510
7	0	0	-1,654,182	0	0	-2,295,178	0	0	-2,983,739
8	0	0	-1,690,574	0	0	-2,345,672	0	0	-3,049,381
9	0	0	-1,727,767	0	0	-2,397,276	0	0	-3,116,468
10	0	0	-1,765,778	0	0	-2,450,016	0	0	-3,185,030
11	0	0	-1,804,625	0	0	-2,503,917	0	0	-3,255,101
12	0	0	-1,844,327	0	0	-2,559,003	0	0	-3,326,713
13	0	0	-1,884,902	0	0	-2,615,301	0	0	-3,399,900
14	0	0	-1,926,370	0	0	-2,672,838	0	0	-3,474,698
15	0	0	-1,968,750	0	0	-2,731,640	0	0	-3,551,142
16	0	0	-2,012,062	0	0	-2,791,736	0	0	-3,629,267
17	0	0	-2,056,328	0	0	-2,853,154	0	0	-3,709,111
18	0	0	-2,101,567	0	0	-2,915,924	0	0	-3,790,711
19	0	0	-2,147,802	0	0	-2,980,074	0	0	-3,874,107
20	0	0	-2,195,053	0	0	-3,045,636	0	0	-3,959,337
21	0	0	-2,243,344	0	0	-3,112,640	0	0	-4,046,442
22	0	0	-2,292,698	0	0	-3,181,118	0	0	-4,135,464
23	0	0	-2,343,137	0	0	-3,251,102	0	0	-4,226,444
24	0	0	-2,394,686	0	0	-3,322,626	0	0	-4,319,426
25	0	0	-2,447,369	0	0	-3,395,724	0	0	-4,414,453
26	0	0	-2,501,211	0	0	-3,470,430	0	0	-4,511,571
27	0	0	-2,556,238	0	0	-3,546,779	0	0	-4,610,826
28	0	0	-2,612,475	0	0	-3,624,809	0	0	-4,712,264
29	0	0	-2,669,950	0	0	-3,704,554	0	0	-4,815,934
30	0	0	-2,728,688	0	0	-3,786,055	0	0	-4,921,884
31	0	0	-2,788,720	0	0	-3,869,348	0	0	-5,030,166
32	0	0	-2,850,071	0	0	-3,954,473	0	0	-5,140,829
33	0	0	-2,912,773	0	0	-4,041,472	0	0	-5,253,928

[97] Project estimated to begin construction in 2013 (year zero).

Benefit Stream

Exhibit F-6 shows the five benefits (A through E) calculated for the US 290 project segment. These include traveler benefits consisting of vehicle operating costs, travel time and reliability, traveler benefits consisting of value of personal time and reliability, shipper/logistics cost, economic benefits, and social and environmental benefits.

Exhibit F-6: Present Value Benefit Stream ($Million Constant Dollars)[98]

Year[99]	3% Discount Rate	(A) Traveler Benefits[100] Vehicle Operating Costs	(A) Traveler Benefits[100] Time & Reliability Costs	(B) Traveler Benefits[101] Value of Personal Time & Reliability	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
0	1.00	$0	$0	$0	$0	$602	$0.0	$602
1	0.97	$0	$0	$0	$0	$584	$0.0	$584
2	0.94	$0	$0	$0	$0	$567	$0.0	$567
3	0.92	$11	$33	$20	$3	$91	$0.1	$158
4	0.89	$11	$33	$20	$3	$90	$0.1	$157
5	0.86	$11	$32	$20	$3	$89	$0.1	$155
6	0.84	$11	$32	$20	$3	$88	$0.1	$154
7	0.81	$11	$32	$19	$3	$87	$0.1	$152
8	0.79	$11	$32	$19	$3	$86	$0.2	$151
9	0.77	$11	$31	$19	$3	$85	$0.2	$149
10	0.74	$11	$31	$19	$3	$84	$0.1	$148
11	0.72	$11	$31	$19	$3	$83	$0.1	$147
12	0.70	$11	$31	$19	$3	$83	$0.1	$145
13	0.68	$10	$30	$18	$3	$82	$0.1	$144
14	0.66	$10	$30	$18	$3	$81	$0.1	$143
15	0.64	$10	$30	$18	$3	$80	$0.1	$141
16	0.62	$10	$30	$18	$3	$79	$0.1	$140
17	0.61	$10	$29	$18	$3	$78	$0.1	$139
18	0.59	$10	$29	$18	$3	$78	$0.1	$137
19	0.57	$10	$29	$18	$3	$77	$0.1	$136
20	0.55	$10	$29	$17	$3	$76	$0.1	$135
21	0.54	$10	$29	$17	$3	$75	$0.1	$134
22	0.52	$10	$28	$17	$3	$74	$0.1	$132
23	0.51	$10	$28	$17	$3	$74	$0.1	$131
24	0.49	$10	$28	$17	$1	$73	$0.1	$128
25	0.48	$9	$27	$17	$1	$72	$0.1	$127
26	0.46	$9	$27	$16	$1	$71	$0.1	$125
27	0.45	$9	$27	$16	$1	$70	$0.1	$123
28	0.44	$9	$26	$16	$1	$69	$0.1	$122
29	0.42	$9	$26	$16	$1	$68	$0.1	$120
30	0.41	$9	$26	$16	$1	$67	$0.1	$119
31	0.40	$9	$26	$16	$1	$66	$0.1	$117
32	0.39	$9	$25	$15	$1	$65	$0.1	$115
33	0.38	$9	$25	$15	$1	$64	$0.1	$114
Total		**$310**	**$902**	**$548**	**$71**	**$4,157**	**$3**	**$5,992**

[98] All benefits and costs are estimated at a 3 percent discount rate.
[99] Project estimated to begin construction in 2013 (year zero).
[100] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[101] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit F-7: Benefit Summary ($Million)

Discount Rate	(A) Traveler Benefits[102]		(B) Traveler Benefits[103]	(C) Shipper/ Logistics Cost	(D) Economic Benefits	(E) Social/ Environ.	Total Benefits
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability				
0%	$536	$1,557	$945	$115	$5,930	$6	$9,090
3%	$310	$902	$548	$71	$4,157	$3	$5,992
7%	$170	$494	$300	$42	$3,015	$2	$4,022

Project Net Benefits

Exhibit F-8 illustrates the net benefits of the proposed Houston US 290 project. The startup, operation and maintenance costs are subtracted from the benefits to calculate the net benefits. All of the net benefit values are positive.

[102] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[103] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit F-8: Project's Net Benefits ($Million Constant Dollars)[104]

Year[105]	3% Discount Rate	Construction Costs	Operation & Maintenance Cost	Total Cost	Total Benefits	Project Net Benefits
0	1.00	$275	$0	$275	$602	$327
1	0.97	$267	$0	$267	$584	$318
2	0.94	$259	$0	$259	$567	$308
3	0.92	$0	$4	$4	$158	$154
4	0.89	$0	$4	$4	$157	$153
5	0.86	$0	$4	$4	$155	$151
6	0.84	$0	$4	$4	$154	$150
7	0.81	$0	$4	$4	$152	$149
8	0.79	$0	$4	$4	$151	$147
9	0.77	$0	$4	$4	$149	$146
10	0.74	$0	$3	$3	$148	$145
11	0.72	$0	$3	$3	$147	$143
12	0.70	$0	$3	$3	$145	$142
13	0.68	$0	$3	$3	$144	$141
14	0.66	$0	$3	$3	$143	$140
15	0.64	$0	$3	$3	$141	$138
16	0.62	$0	$3	$3	$140	$137
17	0.61	$0	$3	$3	$139	$136
18	0.59	$0	$3	$3	$137	$135
19	0.57	$0	$3	$3	$136	$133
20	0.55	$0	$3	$3	$135	$132
21	0.54	$0	$3	$3	$134	$131
22	0.52	$0	$2	$2	$132	$130
23	0.51	$0	$2	$2	$131	$129
24	0.49	$0	$2	$2	$128	$126
25	0.48	$0	$2	$2	$127	$124
26	0.46	$0	$2	$2	$125	$123
27	0.45	$0	$2	$2	$123	$121
28	0.44	$0	$2	$2	$122	$120
29	0.42	$0	$2	$2	$120	$118
30	0.41	$0	$2	$2	$119	$117
31	0.40	$0	$2	$2	$117	$115
32	0.39	$0	$2	$2	$115	$114
33	0.38	$0	$2	$2	$114	$112
Total		**$800**	**$89**	**$888**	**$5,992**	**$5,104**

[104] All benefits and costs are estimated at a 3 percent discount rate.
[105] Project estimated to begin construction in 2013 (year zero).

Exhibit F-9: Project Net Benefits Summary ($Million)

Discount Rate	Construction Costs	Operation & Maintenance Costs	Total Costs	Total Benefits	Project Net Benefits
0%	$824	$146	$969	$9,090	$8,120
3%	$800	$89	$888	$5,992	$5,104
7%	$771	$51	$822	$4,022	$3,200

Benefit/Cost Analysis

Exhibits F-10 through F-12 summarize the benefit stream for the Houston US 290 project in 2013 constant dollars. There are five types of benefit calculations shown (A through E, Exhibit F-10). The total cost stream including facility type, startup costs, annual operation and maintenance costs, and net total costs is also shown (Exhibit F-11). Traditionally, the ratio of traveler benefits (A and B), shipper/logistics cost savings (C), and social/environmental cost savings (E) to the net total cost is used for benefit/cost ratio purposes that do not include economic impacts.

Exhibit F-10: Present Value of Benefit Stream Summary ($Million)

Mode	(A) Traveler Benefits[106]		(B) Traveler Benefits[107]	(C) Shipper/ Logistics Cost	(F) Economic Benefits	(E) Social/ Environ.
	Vehicle Operating Costs	Time & Reliability Costs	Value of Personal Time & Reliability			
Passenger Car – On the Job	$47	$358	$0	$0	No Separate Estimate	No Separate Estimate
Passenger Car – Commute	$142	$413	$411	$0		
Passenger Car – Pers/Rec	$47	$0	$137	$0		
All Trucks – Freight	$75	$131	$0	$71		
Total	**$310**	**$902**	**$548**	**$71**	**$4,157**	**$3**

Exhibit F-11: Present Value of Cost Stream ($Million)

Facility Type	Construction Costs	Sum of Annual Operation & Maintenance Costs	Net Total Costs
Road	$800	$89	$888

[106] Benefit (A) Traveler Benefits describe *out-of-pocket.*
[107] Benefit (B) Traveler Benefits describe *not-out-of-pocket.*

Exhibit F-12: Efficiency Affect Measures ($Million)

Benefit Measure	Benefit Definition[108]	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits – Costs)	Benefit/Cost Ratio
Traveler Benefit	A+B	$1,760	$888	$872	1.98
Full User Benefit	A+B+C	$1,832	$888	$943	2.06
Total Societal	A+B+C+D+E	$5,992	$888	$5,104	6.75

Economic Impacts

Exhibit F-13 shows the economic impacts of the project during construction and operation periods. Economic impacts calculated include business output, value added, jobs, wage income, and economic impact of wage income along the project segment. The assumptions used to calculate "economic benefit of wage income ($Million)" are as follows: 14.4 percent average tax rate, 6.2 percent Social Security rate, and 1.45 percent[109] Medicare rate for a total of 22.1 percent;[110] also included is a 3.2 percent savings rate and 2.44 income multiplier.

[108] From Exhibit F-10.

[109] Average tax rate, Social Security rate, and Medicare rate were retrieved from the *Congressional Budget Office* http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/57xx/doc5746/08-13-effectivefedtaxrates.pdf.

[110] Total 22.1 percent retrieved from the *Bureau of Economic Analysis* http://www.bea.gov/newsreleases/national/pi/pinewsrelease.htm.

Exhibit F-13: Economic Impacts[111]

Year[112]	3% Discount Rate	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)	Economic Benefit of Wage Income ($Million)
0	1.00	$406	$238	2667	$194	$364
1	0.97	$394	$231	2667	$188	$353
2	0.94	$383	$224	2667	$183	$343
3	0.92	$64	$36	546	$29	$55
4	0.89	$63	$36	557	$29	$54
5	0.86	$62	$36	567	$28	$53
6	0.84	$62	$35	578	$28	$53
7	0.81	$61	$35	588	$28	$52
8	0.79	$60	$35	599	$27	$52
9	0.77	$60	$34	611	$27	$51
10	0.74	$59	$34	622	$27	$50
11	0.72	$59	$34	634	$27	$50
12	0.70	$58	$33	646	$26	$49
13	0.68	$57	$33	659	$26	$49
14	0.66	$57	$33	671	$26	$48
15	0.64	$56	$32	684	$25	$48
16	0.62	$56	$32	697	$25	$47
17	0.61	$55	$32	711	$25	$47
18	0.59	$54	$31	724	$25	$46
19	0.57	$54	$31	739	$24	$46
20	0.55	$53	$31	753	$24	$45
21	0.54	$53	$30	768	$24	$45
22	0.52	$52	$30	783	$24	$44
23	0.51	$52	$30	798	$23	$44
24	0.49	$51	$29	811	$23	$43
25	0.48	$50	$29	823	$23	$43
26	0.46	$50	$29	836	$22	$42
27	0.45	$49	$28	850	$22	$42
28	0.44	$48	$28	863	$22	$41
29	0.42	$48	$27	877	$21	$40
30	0.41	$47	$27	890	$21	$40
31	0.40	$46	$27	905	$21	$39
32	0.39	$46	$26	919	$21	$39
33	0.38	$45	$26	933	$20	$38
Total		**$2,873**	**$1,661**		**$1,328**	**$2,496**

[111] All benefits and costs are estimated at a 3 percent discount rate.
[112] Project estimated to begin construction in 2013 (year zero).

Exhibit F-14: Economic Impact Summary ($Million)

Discount Rate	Business Output	Value Added	Wage Income	Economic Benefit of Wage Income
0%	$4,118	$2,376	$1,891	$3,553
3%	$2,873	$1,661	$1,328	$2,496
7%	$2,072	$1,201	$965	$1,814

Economic Impact by Industry

The economic impact for individual industries is examined for 2026, 10 years following the beginning of operation. Exhibit F-15 illustrates the industries that are affected as a result of the economic impact contributed from the completion of the Houston US 290 corridor project.

Exhibit F-15: Economic Impact by Industry for 2026 (in 2013 Dollars)

NAICS[113]	Industry	Business Output ($Million)	Value Added ($Million)	Jobs	Wage Income ($Million)
111–115, 211–213	Agriculture, Forestry, Mining, Oil & Gas Extraction	$3	$2	15	$1
221	Utilities	$1	$1	1	$0
230	Construction	$3	$1	19	$1
311–339	Manufacturing	$13	$4	27	$2
420	Wholesale Trade	$3	$3	16	$2
441–454	Retail Trade	$4	$3	75	$2
481–488	Transportation	$10	$5	82	$6
491–493	Postal Service & Warehousing	$1	$1	12	$1
511–519	Media and Information	$3	$2	8	$1
521–525, 531–	Finance, Insurance, & Real Estate	$11	$5	38	$2
541, 551, 561–562	Business Support Services (Prof., Mgmt., & Admin.)	$16	$12	151	$11
611, 621–624	Educational, Health Care, & Social Services	$10	$7	118	$6
711–713, 721–722, 811–814	Arts, Entertainment, Accommodation, Food, & Household Services	$6	$4	96	$3
920	Government	$0	$0	1	$0
	Total	**$84**	**$48**	**659**	**$38**

[113] North American Industry Classification System.

Tax Impacts

Taxes collected by the federal, state, and local governments were calculated for households and businesses surrounding the project segment (Exhibit F-16).

Exhibit F-16: Tax Impacts for 2026 (in 2013 Dollars)

Tax/Fee Collector	Tax/Fee Description	Taxes/Fees ($Million) Paid by:		Total ($Million)
		Households	Businesses	
Federal Government	Motor Fuel Tax	$0	-$1	-$1
	Income Profits	$0	$0	$0
	Social Insurance Tax (FICA)	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
	Total Federal Government	**$0**	**-$1**	**-$1**
State and Local Government	Motor Fuel Tax	-$1	-$1	-$1
	Motor Vehicle License Fees	$0	$0	$0
	Income/Profits	$0	$0	$0
	Sales Tax	not available	not available	$0
	Property Tax	$0	$0	$0
	Social Insurance Tax	$0	$0	$0
	Miscellaneous Fees & Taxes	$0	$0	$0
Total State and Local Government		**-$1**	**-$1**	**-$1**
Grand Totals for Federal, State, and Local		**-$1**	**-$2**	**-$3**

Findings

The Houston US 290 project proves cost effective in several ways. It provides a present value benefit stream of over $5.9 billion and will create over 2600 jobs each year of construction and 545 to 930 jobs each year of operation.

APPENDIX G: FIXiT CONGESTION REDUCTION METHODOLOGY

Introduction

The congestion estimator spreadsheet, known as the Future Improvement Examination Technique (FIXiT), can be used to estimate the effect of a wide range of congestion relief projects, programs, and plans along urban congested corridors. The goal is to provide a planning level assessment of the benefits from congestion projects when no other estimate is available. The FIXiT spreadsheet is open to user modifications and allows analysts to see every step of the process and have input regarding multiple characteristics of the proposed project. For example, FIXiT was used for an analysis of several relatively large projects in Austin, Houston, and San Antonio in a Mobility Investment Priorities project in 2013 (*1*). Specific, detailed analyses that might involve detailed computer modeling are more appropriate for a full analysis of any mitigation strategy, but FIXiT is a good starting place.

The FIXiT spreadsheet is based on a number of assumptions that can affect the congestion benefit estimates, but users can easily adjust the assumptions based on project-specific data. The tool is designed to produce conservative estimates of peak period congestion reduction, but the user-adjustments and sensitivity analysis offers an approach to understand the range of benefit estimates.

The analysis uses elements from the Texas 100 Congested Roadways dataset (*2*) and TxDOT's Road-Highway Inventory (RHiNo) (*3*) to the greatest extent possible. Models and estimates are also used, but the goal is to have the analysis results be similar in character to the Texas 100 list. The Texas 100 Most Congested Sections list is calculated each year by combining TxDOT's roadway inventory and traffic volumes dataset with speed data from a competitively bid private-sector data provider. The congested roadway analysis is computed on all major Texas roads regardless of the agency that built or maintains the road. The 2012 dataset consisted of 2011 speeds on more than 800 road sections (generally between 3 and 10 miles).

The FIXiT methodology uses project effect studies that are summarized in the strategy descriptions developed in the Mobility Investment Priorities study. More than 50 project types are described in the congestion mitigation strategy section of the website (*4*). These technique effects are summarized in the "Strategy Effect" worksheet of the FIXiT spreadsheet file.

The analysis focuses on congestion relief during peak periods. In some corridors, there would also be midday and weekend congestion relief; the peak period changes are the most substantial and are typically those analyzed by the before/after reports. The analysis is based on methodologies used in the Urban Mobility Report (*5*) and uses empirically derived benefit estimates. As additional before/after studies are completed, this dataset will expand and improve. The FIXiT method, the data, and assumptions are summarized in Exhibits G-1 and G-2.

Exhibit G-1: Outline of the FIXiT Methodology Sections

Section A: Input Data

Organizes the information from the *Texas 100* and RHiNo databases. The proposed improvement strategies are also selected.

Section B: Perform Interim Calculations

Input data are converted to provide a consistent basis for comparison of before and after conditions. Initial calculations are performed to estimate percent change in peak period speed due to selected improvements.

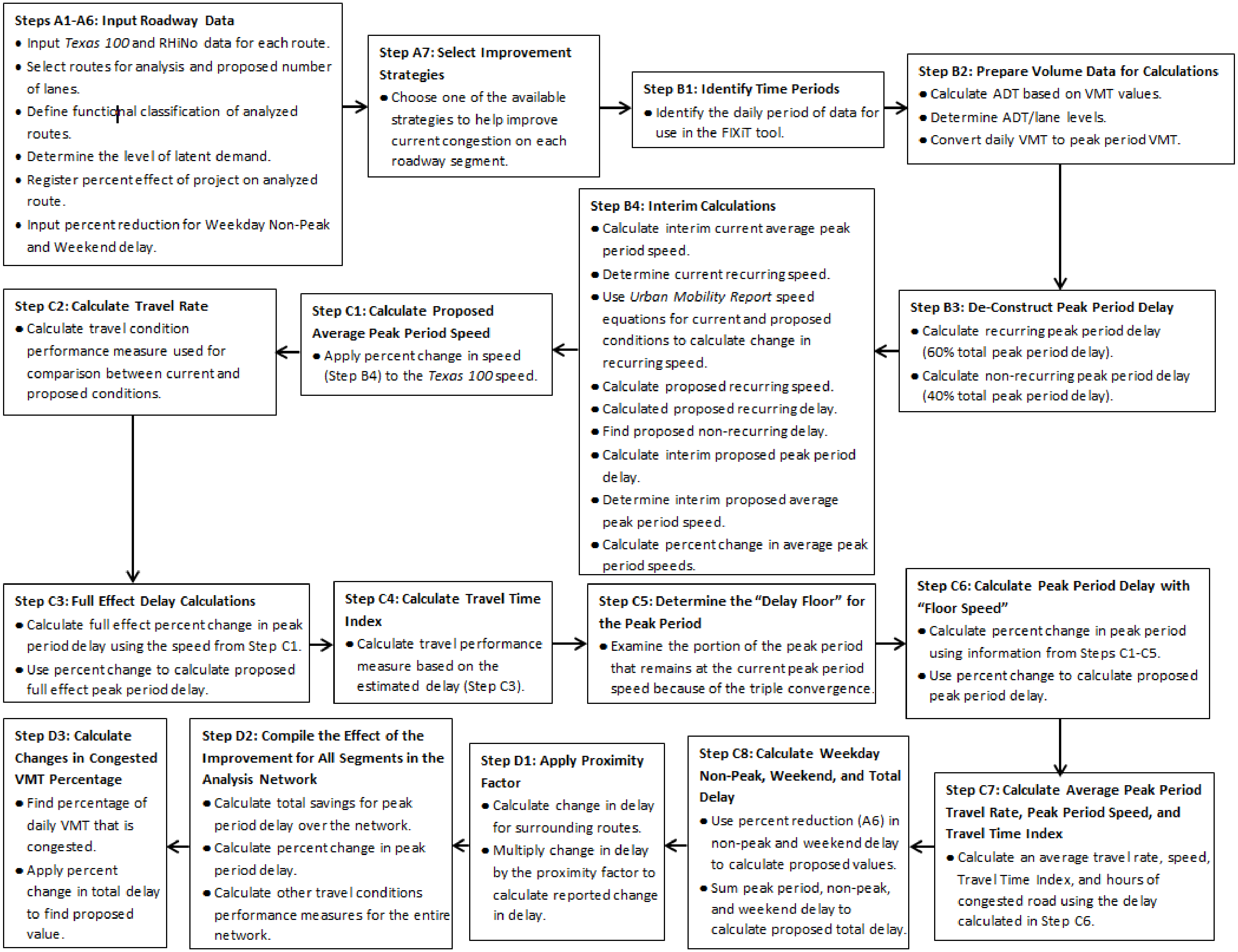
Section C: Estimate Congestion Effects of Proposed Project

Apply percent change in speed to base year conditions to estimate 'after condition' peak period delay; results include the effect of latent demand.

Section D: Summarize Network Effects

Previous steps are repeated for all surrounding sections (adjusting for proximity to the project) to calculate the network effects of the improvement strategies.

Exhibit G-2: FIXiT Methodology Flowchart



Section A: Input Data

Several data elements are gathered from the *Texas 100* dataset, TxDOT roadway inventory items, and several project-specific characteristics. Steps A1 through A7 summarize the input gathering steps.

Step A1: Load Congested Section Data

The *Texas 100* dataset and RHiNo information are loaded into the "Project Input Data" tab of the FIXiT spreadsheet. The input data correspond to the 2012 congestion information for all analyzed congested segments:

- City.
- Analyzed segment.
- Endpoints of each segment.
- Length of the segment.
- Average daily vehicle-miles of travel.
- Average free-flow speed.
- Average peak period speed.
- Travel Time Index.
- Annual peak period delay.
- Annual off-peak delay.
- Annual weekend delay.
- Annual total delay.
- Hours of congested road.

The average number of lanes includes mainlanes and managed lanes, and is provided by TxDOT's RHiNo dataset, which contains information about the physical characteristics of the roadway and volumes.

All the FIXiT input and output statistics are in units of annual person-hours of delay. The following constants are used to convert data for daily vehicle conditions, and are included in nearly all calculations involving delay (*5*). These values are applied to the daily peak period vehicle-miles of travel (discussed in Step B2), when analyzing speeds or delay, to properly convert the units.

- Average vehicle occupancy – 1.25 persons per vehicle.
- Weekdays per year – 250 days.

Step A2: Choose the Road to Be Analyzed (Congested Road or Alternate Route)

The spreadsheet is programmed with a dropdown menu containing all of the *Texas 100* segments loaded in the "Project Input Data" tab. When the route is selected, the spreadsheet automatically retrieves the necessary data (including the vehicle-miles of travel, the calculated average traffic volumes, average peak period speed, free-flow speed, segment boundaries, segment length, number of lanes, and the Travel Time Index). This step is designed to reduce the amount of data transferred by the user, enhancing usefulness and reducing errors.

The proposed number of lanes should include all travel lanes (mainlanes and managed lanes) in the design option for the analyzed segment. The proposed design is input to the FIXiT tool and the spreadsheet calculates the difference between the existing and proposed number of lanes. The proposed number of lanes may be the same as existing if operational improvements or demand management were implemented.

Step A3: Functional Classification

The spreadsheet uses three roadway functional classifications during the calculation process: 1) Freeway, 2) Urban Street, and 3) Rural Highway. Any roadway contained within a rural area is classified as a rural highway, while an urban street is any non-freeway roadway in an urban area. The primary congestion effects are on the major road, rather than including any of the frontage or service roads that are adjacent to the congested roadway. The functional classification is again selected from a dropdown menu. All roadways in the initial project analysis are freeways.

Step A4: Latent Demand

There will likely be an increase in the traffic volume on the project roadway during the period immediately after project completion due to the increase in capacity, an effect known as latent demand. This traffic congestion reduction could come from three sources:

- Change in mode choice—The users who previously took public transportation or carpooled and now feel more comfortable traveling in their vehicle.
- Change in route choice—Those who use the newly improved road instead of their previous route because the travel times are shorter.
- Change in time of travel—Travelers may change their departure time, for example, to sleep later knowing they can reach their destination in less travel time.

These three factors were described as "triple convergence" by Anthony Downs in *Still Stuck in Traffic* (*6*). Including latent demand can produce more realistic congestion relief benefits because it acknowledges that delay will not disappear and traffic will likely increase after the improvement is implemented. Including the latent demand can also produce a more conservative estimate of the congestion benefits.

The latent demand factor in FIXiT is based on research conducted on a range of project types; a 10 percent increase in traffic volume after large urban freeway projects are implemented in heavily congested corridors appears to be the median effect (*7*). This value can be changed if better or more specific information is available for the analyzed routes.

Step A5: Percent Effect

The percent effect is an optional input factor that can be used to adjust the congestion reduction effect of an improvement project according to where the improvement is in relation to the congestion. The factor is used to alter the generic improvement estimates (calculated in later steps of the model). The percent can be the product of three considerations:

- The percentage of the segment length affected by the improvement project.
- The location of congestion in the segment, relative to the analyzed segment.
- The type of strategy used.

For example, if a 2-mile widening project is the final section of widening in a 10-mile section of road, the percent effect might be close to 100 percent if it eliminates the congestion-causing bottleneck. On the other hand, if the project is the initial portion of widening, the percent effect is likely less than the 20 percent indicated by the ratio of the two lengths. The final decision of input of this section is at the user's discretion. The default input for the percent effect is 100 percent.

Step A6: Input Reduction for Weekday Non-Peak and Weekend Delay

A significant amount of the FIXiT tool operation calculates the change in peak period delay. A smaller portion estimates the change in the weekday non-peak (off-peak) and weekend delay. The basic analysis and the dataset it draws from contains relatively less information about these periods, and users input an estimated percent reduction for each of them. The delay reduction is applied to current values for off-peak and weekend delay. The default value for this reduction is 50 percent, but this can be adjusted for more specific analysis.

Step A7: Select Improvement Strategies

The user chooses the strategy implemented to help alleviate congestion along the selected roadway. A drop-down list draws from the “Strategy Effect” worksheet in the spreadsheet file that provides a choice of more than 50 congestion mitigation strategies. These strategies include capacity, operational, and demand management improvement projects (*4*). The estimated effects of the selected strategy on roadway capacity, congestion, or delay are automatically updated in the calculator and applied to the expected improvement project. A summary of the available strategies is provided in Exhibit G-3.

The table summarizes the effects on capacity increase, non-recurring delay reduction, or a reduction of the total peak period delay. All of these values are used in the estimation of congestion reduction effects.

- The capacity increase represents the equivalent portion of a standard lane that is added or the percent increase in current capacity when the strategies are implemented.
- The non-recurring reduction is a percent reduction of the delay caused by crashes and other irregular events (i.e., weather or special events) that can cause congestion along the roadway.
- The percent delay reduction (right-most column) is used to estimate the overall peak period delay if that is the best approach to estimating the delay reduction effects.

The FIXiT spreadsheet allows users to examine the potential effects of various projects; there is no one-size-fits-all project for every congested corridor. The technique allows the analyst to easily change the mitigation strategy to examine the potential effects of each project.

Exhibit G-3: Congestion Mitigation Project Effects

Strategy	Capacity Addition for Recurring Congestion (Number of Equivalent Lanes)	Capacity Increase for Recurring Congestion (Percent of Current Capacity)	Non-Recurring Congestion Reduction	Peak Period Delay Reduction
Acceleration/Deceleration Lanes	50%	---	15%	---
Access Management	---	---	20%	---
Adding New Toll Road	100%	---	20%	---
Aggressive Incident Clearance	---	---	---	8%
Carpooling	---	---	---	3%
Compressed Work Weeks	---	---	---	2%
Construction Contracting Options	---	---	---	2%
Direct Connector	50%	---	20%	---
Diverging Diamond Interchange	---	20%	20%	---
Dynamic Merge Control	50%	---	15%	---
Dynamic Rerouting[1]	---	---	---	---
Dynamic Truck Restrictions	---	---	---	3%
Electronic Toll Collection	100%	---	20%	---
Flexible Work Hours	---	---	---	2%
Grade Separation	---	10%	20%	---
Improving Intersection Skew Angles	---	---	---	10%
Innovative Intersections	---	10%	10%	---
Intersection Improvements	---	10%	15%	---
Interchange Upgrade	---	10%	10%	---
Intersection Turn Lanes	---	10%	15%	---
Lighting	---	---	4%	---
Loop Ramps Eliminating Left Turns	---	---	---	20%

Strategy (Cont.)	Capacity Addition for Recurring Congestion (Number of Equivalent Lanes)	Capacity Increase for Recurring Congestion (Percent of Current Capacity)	Non-Recurring Congestion Reduction	Peak Period Delay Reduction
Managed Lanes	100%	---	20%	---
Median U-Turns	---	10%	10%	---
Modern Roundabout	---	10%	15%	
Multimodal Transportation Centers[1]	---	---	---	---
New Lanes/Roads	100%	---	20%	---
Parking Management	---	---	---	2%
Pavement Recycling	---	---	---	5%
Pay-As-You-Drive Insurance	---	---	---	1%
Pedestrian Treatments[2]	---	---	---	---
Quadrant Roadway Intersections	---	10%	10%	---
Queue Warning[1,2]	---	---	---	---
Ramp Configuration	25%	---	20%	---
Ramp Flow Control	---	---	---	3%
Real-Time Ride Sharing	---	---	---	3%
Reducing Construction/ Maintenance Interference	---	---	---	5%
Reversible Traffic Lanes	100%	---	20%	---
Roadway Rehabilitation	---	---	4%	---
Shoulder Pavement Upgrades	---	---	---	5%
Signal Improvements	---	---	---	10%
State Employee Trip Reduction	---	---	---	2%
Superstreets	---	---	---	10%
Sustainable Pavements	---	---	---	5%
Telecommuting	---	---	---	2%
Temporary Shoulder Use	50%	---	---	---
Traveler Information Systems	---	---	---	2%
Trip Reduction Ordinances	---	---	---	8%
Truck Incentives and Use Restrictions[1]	---	---	---	---
Truck Lane Restrictions	---	---	---	3%
Vanpool	---	---	---	1%
Variable Pricing	---	---	---	4%
Variable Speed Limits	---	20%	10%	---

Notes
1. Projects are known improvements, but the effects are determined regionally.
2. Projects primarily provide a safety benefit; congestion benefits are secondary.

Section B: Interim Calculations

The Section B steps describe the process to convert data for use in the primary calculations steps.

Step B1: Identify Time Periods

The *Texas 100* data include three time periods of delay: weekday peak period, weekday non-peak period (i.e., middle of the day), and the weekend period. The weekday peak period, when most congestion occurs (typically between 6 and 9 a.m. and 4 and 7 p.m.), consists of the more in-depth calculations and data. The effect of many improvement strategies in non-peak period times has not been studied in detail; the midday and weekend are not typically congested with commuters. However, FIXiT assumes a basic reduction that is input by the user (Step A-6). The default assumption is a 50 percent reduction for both the weekday non-peak period and the weekend period. This assumption can be adjusted if the user has more specific information regarding the proposed project.

Step B2: Prepare Traffic Volume Data for Calculations

The average daily traffic (ADT) value, required for various portions of the interim calculations using the *Urban Mobility Report* procedures (*5*), is based on the average daily vehicle-miles of travel (VMT). The ADT value for each of the analyzed segments is calculated using Equation 1.

$$\text{Average Daily Traffic (ADT)} = \frac{\text{Average Daily Vehicle-Miles of Travel}}{\text{Segment Length}} \qquad \text{(Equation 1)}$$

The resulting ADT value is used to calculate the daily traffic volume per lane (Equation 2), which is used in subsequent calculation steps.

$$\begin{matrix}\text{Average Daily}\\ \text{Traffic per Lane}\end{matrix} = \frac{\text{Average Daily Traffic}}{\text{Total Number of Lanes}} \qquad \text{(Equation 2)}$$

The ADT and ADT per lane for the current and proposed conditions are calculated in the same fashion, but with some differences in the variable values. The proposed ADT per lane value includes the proposed lane count ***and*** the 10 percent increase in volume caused by the latent demand.

Daily traffic volume is a *Texas 100* data item, but most of the calculation steps use peak period traffic volume because FIXiT is used to estimate improvements in peak period delay. According to the hourly volume curves used in the *Texas 100* estimation process, the peak period contains roughly half the average daily VMT for large urban areas (*5*). The conversion from daily volume to peak period VMT is accomplished using Equation 3. The peak period VMT for the proposed condition is calculated in the same fashion, but it includes the 10 percent latent demand increase.

$$\begin{matrix}\text{Peak Period Vehicle}\\ \text{Miles of Travel}\end{matrix} = \begin{matrix}\text{Daily Vehicle}\\ \text{Miles of Travel}\end{matrix} \times 50\% \qquad \text{(Equation 3)}$$

Step B3: De-Construct Peak Period Delay

Delay is typically categorized as two types, caused by either: 1) regular events such as traffic volume exceeding the available capacity (i.e., recurring congestion) or 2) irregular occurrences such as crashes, stalled vehicles, weather, road maintenance, and special events (i.e., non-recurring congestion).

The *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies* (SHRP2) research study (*8*) examined these two delay components in detail in three cities in the United States—

the most rigorous examination of this issue ever performed using actual travel speeds and event information. The three studies indicated recurring congestion comprised 60 percent of total peak period delay, while non-recurring delay made up the remaining 40 percent. The *Texas 100* data contain the *total* peak period delay for each route, but this peak period value must be separated into recurring and non-recurring delay for the FIXiT spreadsheet using Equations 4 and 5. As with other FIXiT steps, the analyst can substitute more accurate project-specific values if available.

$$\text{Current Recurring Delay} = \text{Total Peak Period Delay} \times 60\% \qquad \text{(Equation 4)}$$

$$\text{Current Non-Recurring Delay} = \text{Total Peak Period Delay} \times 40\% \qquad \text{(Equation 5)}$$

Step B4: Interim Calculations

The FIXiT calculations generally proceed as follows:

- Use existing conditions as the base values.
- Calculate percentage changes due to improvement strategies using models and estimation techniques.
- Apply the percentage changes to the existing conditions to estimate the effects on speed and peak period delay.

The paragraphs below in Step B4 describe the actions in the second bullet point. The interim calculations required to estimate the percentage reduction do not represent real-world values, but are instead a modeled comparison of current and possible future conditions. The application of the percentage changes (the third bullet) is discussed in Steps C and D.

The interim existing value for average peak period speed is close to the *Texas 100* dataset value, but differs in that the FIXiT congestion reduction estimator assumes all sections have 50 percent of the daily vehicle-miles of travel in the peak periods (*5*). The actual value for each corridor is the result of several calculations within the *Texas 100* procedures; 50 percent is in the range of the actual values for very congested corridors in large urban areas. The 50 percent assumption allows the analyst to proceed without a requirement to find the exact percentage for every segment; it also removes the need for an estimate of the percentage for the new project. The average peak period speed is calculated using an adjusted version of the equation in the *Urban Mobility Report* (Equation 6).

$$\begin{matrix}\text{Interim Current}\\ \text{Peak Period Speed}\end{matrix} = \frac{\text{Current Peak Period Vehicle-Miles of Travel}}{\text{Current Peak Period Delay} + \text{Free-Flow Travel Time}} \qquad \text{(Equation 6)}$$

The speed associated with the current recurring delay (Step B3) is estimated using Equation 7 (similar to Equation 6). This peak period speed (that represents only the recurring congested conditions) is used to examine the mitigation strategy effects on the recurring portion of delay resulting from Step B3.

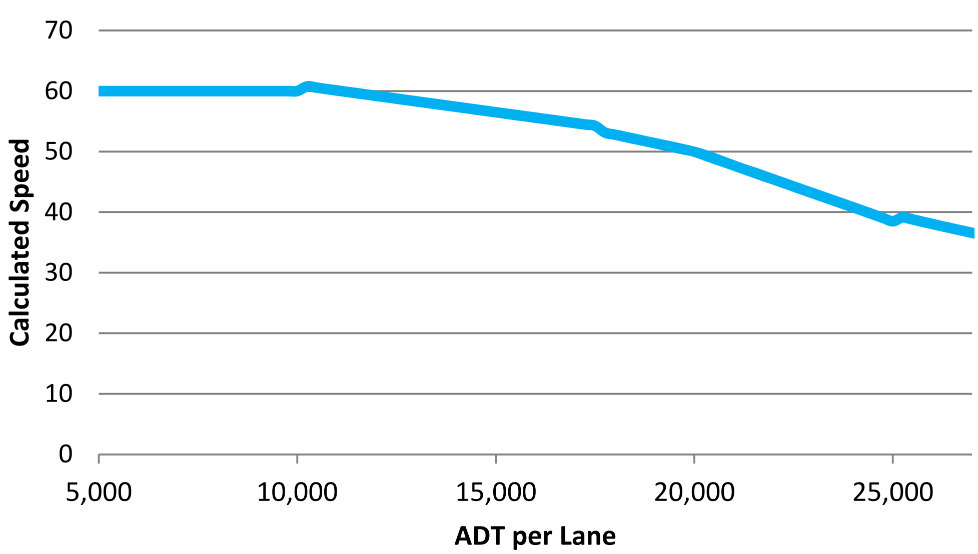
$$\begin{matrix}\text{Current}\\ \text{Recurring Speed}\end{matrix} = \frac{\text{Current Peak Period Vehicle-Miles of Travel}}{\text{Current Recurring Delay} + \text{Free-Flow Travel Time}} \qquad \text{(Equation 7)}$$

The FIXiT spreadsheet speed equations are based on the road's functional classification (Step A5) and the ADT per lane values calculated in Step B2. A summary of these equations and a graph of the freeway equations is provided in Exhibits G-4 and G-5 (*5*).

Exhibit G-4: Urban Mobility Report Speed Equations

Facility and Congestion Level	Daily Traffic Volume per Lane	Speed Estimate Equation	
		Peak Direction	Off-Peak Direction
Freeway			
Uncongested	Under 10,000	60	60
Medium	10,001–17,500	70–(0.9*ADT/Lane)	67–(0.6*ADT/Lane)
Heavy	17,501–20,000	78–(1.4*ADT/Lane)	71–(0.85*ADT/Lane)
Severe	20,001–25,000	96–(2.3*ADT/Lane)	88–(1.7*ADT/Lane)
Extreme	Over 25,000	76–(1.46*ADT/Lane)	85.7–(1.6*ADT/Lane)
		Lowest is 35 mph	Lowest is 40 mph
Arterial Street			
Uncongested	Under 3,000	35	35
Medium	3,001–7,000	33.58–(0.74*ADT/Lane)	33.82–(0.59*ADT/Lane)
Heavy	7,001–8,500	33.8–(0.77*ADT/Lane)	33.90–(0.59*ADT/Lane)
Severe	8,501–10,000	31.65–(0.51*ADT/Lane)	30.10–(0.15*ADT/Lane)
Extreme	Over 10,000	32.57–(0.62*ADT/Lane)	31.23–(0.27*ADT/Lane)
		Lowest is 20 mph	Lowest is 27 mph
Rural Highway			
Uncongested	Under 5,500	55	55
Medium	5,501–7,000	53.58–(0.74*ADT/Lane)	53.82–(0.59*ADT/Lane)
Heavy	7,001–8,500	53.80–(0.77*ADT/Lane)	53.90–(0.59*ADT/Lane)
Severe	8,501–10,000	51.65–(0.51*ADT/Lane)	50.10–(0.15*ADT/Lane)
Extreme	Over 10,000	52.57–(0.62*ADT/Lane)	51.23–(0.27*ADT/Lane)
		Lowest is 40 mph	Lowest is 47 mph

Exhibit G-5: Freeway Speed Equation Relating Daily Traffic Volume per Lane to Speed



The equations in Exhibit G-4 are implemented by the FIXiT spreadsheet based on the traffic volume per lane ranges derived in Equation 2. The speed estimate produced for the current conditions represents the interim value of the estimated recurring speed for the current capacity. The speed estimate for the proposed conditions includes the effect of the capacity increase, operating strategies, and the latent travel demand to calculate the proposed ADT per lane, as discussed in Step B2. The equations in Exhibit G-4 are used to generate an interim recurring speed for the proposed conditions. The percent change in recurring speed between the current and proposed conditions is calculated using Equation 8.

$$\begin{array}{c}\text{Interim}\\ \text{Percent Change}\end{array} = \frac{\text{Interim Proposed Recurring Speed - Interim Current Recurring Speed}}{\text{Interim Current Recurring Speed}} \quad \text{(Equation 8)}$$

The interim percent change value is applied to current recurring speed to find the proposed recurring speed (Equation 9).

$$\begin{array}{c}\text{Proposed}\\ \text{Recurring Speed}\end{array} = \text{Current Recurring Speed} \times \left(1.0 + \begin{array}{c}\text{Interim}\\ \text{Percent Change}\end{array}\right) \quad \text{(Equation 9)}$$

Analysts should be aware that the proposed recurring speed calculated using this equation can, at times, exceed the free-flow speed. The FIXiT tool automatically adjusts such an outcome so that the proposed recurring speed is no more than the free-flow speed, regardless of the interim percentage change in speed.

The proposed recurring speed is used to estimate the proposed recurring delay. The *Urban Mobility Report* delay equation is once again implemented to calculate the proposed recurring delay (Equation 10). A 1.1 factor is included in this version of the equation to represent the 10 percent additional traffic volume from latent demand and is used to grow the peak period VMT for the proposed conditions after completing the project. This new value represents the proposed peak period VMT.

$$\begin{array}{c}\text{Proposed}\\ \text{Recurring Delay}\end{array} = \frac{\begin{array}{c}\text{Proposed Peak Period}\\ \text{Vehicle-Miles of Travel}\end{array}}{\text{Proposed Recurring Speed}} - \frac{\begin{array}{c}\text{Proposed Peak}\\ \text{Vehicle-Miles of Travel}\end{array}}{\text{Free-Flow Speed}} \quad \text{(Equation 10)}$$

The proposed non-recurring delay is calculated by applying the reduction listed in the "Strategy Impact" tab (Exhibit G-3) of the FIXiT spreadsheet. The registered factor is applied by subtracting the impact value from 100 percent (Equation 11).

$$\begin{array}{c}\text{Proposed}\\ \text{Non-Recurring Delay}\end{array} = \begin{array}{c}\text{Current}\\ \text{Non-Recurring Delay}\end{array} \times \left(1.0 + \begin{array}{c}\text{Strategy}\\ \text{Reduction}\end{array}\right) \quad \text{(Equation 11)}$$

The estimated reduction in non-recurring delay represents the mix of various items that are identified as part of the proposed project to help reduce the non-recurring delay. This means that treatments such as incident clearance, signal coordination, and various travel information systems can be included to help reduce the non-recurring delay; the delay reduction effects taken from the strategy summaries (*4*) are shown on the Strategy Effects tab of the FIXiT spreadsheet.

The interim proposed peak period delay consists of the sum of the proposed recurring and non-recurring delay values, similar to the *Texas 100* peak period delay, but is used only for comparison rather than representing the expected delay on the roadway. The interim proposed peak period delay is calculated by summing the recurring delay and the non-recurring delay of the proposed project (Equation 12).

$$\begin{array}{c}\text{Interim Proposed}\\\text{Peak Period Delay}\end{array} = \begin{array}{c}\text{Proposed}\\\text{Recurring Delay}\end{array} + \begin{array}{c}\text{Proposed}\\\text{Non-Recurring Delay}\end{array} \qquad \text{(Equation 12)}$$

The interim average peak period speed for the proposed conditions is calculated using the interim proposed total delay (Equation 12) and the equation used throughout other portions of the FIXiT spreadsheet in Equation 13. This speed is used as a method of comparison between the interim values for current and proposed conditions.

$$\begin{array}{c}\text{Interim Proposed}\\\text{Peak Period Speed}\end{array} = \frac{\begin{array}{c}\text{Proposed Peak Period}\\\text{Vehicle-Miles of Travel}\end{array}}{\begin{array}{c}\text{Proposed Peak}\\\text{Period Delay}\end{array} + \begin{array}{c}\text{Proposed Free-Flow}\\\text{Travel Time}\end{array}} \qquad \text{(Equation 13)}$$

The percent change in speeds between the current peak period conditions (from Equation 6) and the proposed peak period conditions is calculated using Equation 14. The percent change in the average peak period speed is used to adjust the *Texas 100* average peak period speed for each of the analyzed segments.

$$\text{Percent Change} = \frac{\begin{array}{c}\text{Proposed Peak}\\\text{Period Speed}\end{array} - \begin{array}{c}\text{Current Peak}\\\text{Period Speed}\end{array}}{\text{Current Peak Period Speed}} \qquad \text{(Equation 14)}$$

Section C: Apply Interim Calculation Results to Proposed Improvements

The comparison completed with interim calculations is applied to the actual input values from the *Texas 100* dataset to estimate the effects of the improvements on peak period delay. The application of these numbers is presented in Steps C1 through C7.

Step C1: Calculate Proposed Average Peak Period Speed

The proposed average peak period speed represents an estimated speed for portions of the traffic after the completion of the project. This speed is calculated in Equation 15 using the known *Texas 100* peak period speed and the percent change calculated in the previous section.

$$\begin{array}{c}\text{Proposed Peak}\\\text{Period Speed}\end{array} = \begin{array}{c}\textit{Texas 100}\\\text{Peak Period Speed}\end{array} \times \left(1.0 + \begin{array}{c}\text{Percent}\\\text{Change}\end{array}\right) \qquad \text{(Equation 15)}$$

Similar to the proposed recurring speed calculated in Step B4, if the estimated proposed speed exceeds the free-flow speed, the FIXiT spreadsheet is programmed to adjust the new peak period speed; the speed is lowered to one mile per hour less than the free-flow speed in this step.

Step C2: Calculate Travel Rate

The travel rate measure is calculated for the full proposed conditions and the adjusted proposed conditions to further describe the effects of mitigation projects in terms other than speed. The travel rate for the current and proposed conditions is also calculated for the known *Texas 100* and calculated proposed speeds. Travel rate allows spreadsheet users to examine the effect of slow speeds in a way that communicates the longer travel times in a more direct way (Equation 16).

$$\text{Travel Rate} = \frac{\text{60 minutes per hour}}{\text{Proposed Peak Period Speed (mph)}} \qquad \text{(Equation 16)}$$

Step C3: Full Effect Delay Calculations

The current *Texas 100* peak period travel rate and the proposed peak period travel rate (Step C2) are both used in conjunction with the current and proposed peak period VMT, and other factors, to calculate a percent change in delay using Equation 17.

$$\text{Percent Change in Delay} = \frac{\text{Current Delay – Proposed Delay}}{\text{Current Delay}} \qquad \text{(Equation 17)}$$

The output of Equation 17 is essentially an estimate of the new conditions if all travelers continued to make the same trips. When capacity is added or traffic is improved, however, travelers change their departure time, their route and travel mode—the triple convergence phenomenon mentioned in Part A—making the speed estimates based on Equations 15 and 17 too high. Steps C4 and C5 adjust the condition estimates to provide a more realistic estimate of project benefits.

The percent change in delay is used to make the calculations more consistent in the analysis process, similar to the percent change in speed calculated with Equation 14. The percent change in peak period delay is applied to the known *Texas 100* peak period delay (Equation 18) to estimate the proposed peak period delay.

$$\begin{matrix}\text{Proposed Full Effect}\\ \text{Peak Period Delay}\end{matrix} = \begin{matrix}\textit{Texas 100}\\ \text{Peak Period Delay}\end{matrix} - \left(\begin{matrix}\textit{Texas 100}\\ \text{Peak Period Delay}\end{matrix} \times \begin{matrix}\text{Percent}\\ \text{Change}\end{matrix}\right) \qquad \text{(Equation 18)}$$

Step C4: Calculate Travel Time Index

The Travel Time Index is a ratio between the travel time for the congested condition and the travel rate for the free-flow conditions (*5*). The index value indicates the amount of extra travel time in congested conditions; a value of 1.30 indicates a 20-minute trip in low-volume conditions requires 26 minutes in the peak period. The Travel Time Index values are calculated for the full proposed condition by calculating the percent change in Travel Time Index (Equation 19) and applying it to the current value (Equation 20).

$$\begin{matrix}\text{Percent Change}\\ \text{in Travel Time Index}\end{matrix} = \frac{\left(\dfrac{\begin{matrix}\text{Current Peak}\\ \text{Period Delay}\end{matrix} + \begin{matrix}\text{Free-Flow}\\ \text{Travel Time}\end{matrix}}{\begin{matrix}\text{Free-Flow}\\ \text{Travel Time}\end{matrix}}\right) - \left(\dfrac{\begin{matrix}\text{Propsed Peak}\\ \text{Period Delay}\end{matrix} + \begin{matrix}\text{Free Flow}\\ \text{Travel Time}\end{matrix}}{\begin{matrix}\text{Free-Flow}\\ \text{Travel Time}\end{matrix}}\right)}{\dfrac{\begin{matrix}\text{Current Peak}\\ \text{Period Delay}\end{matrix} + \begin{matrix}\text{Free-Flow}\\ \text{Trave Time}\end{matrix}}{\begin{matrix}\text{Free-Flow}\\ \text{Travel Time}\end{matrix}}} \qquad \text{(Equation 19)}$$

$$\begin{matrix}\text{Proposed}\\ \text{Travel Time Index}\end{matrix} = \begin{matrix}\text{Current}\\ \text{Travel Time Index}\end{matrix} - \left(\begin{matrix}\text{Current}\\ \text{Travel Time Index}\end{matrix} * \begin{matrix}\text{Percent}\\ \text{Change}\end{matrix}\right) \qquad \text{(Equation 20)}$$

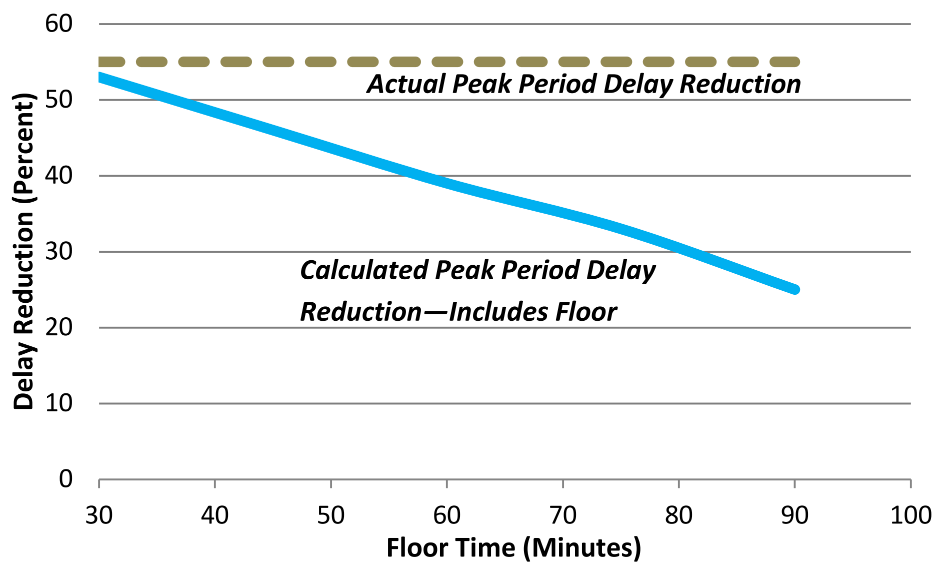
Step C5: Determine the "Delay Floor" for the Peak Period

The triple convergence phenomenon referred to in Step A4 is used to estimate a "delay floor"—a minimum value of travel delay that cannot be eliminated regardless of the improvement extent.

Houston’s Katy Freeway (IH 10 West) was expanded (in general terms) from 6 mainlanes plus an HOV lane to 10 mainlanes plus four managed lanes. Peak period speeds increased and delay decreased, but congestion did not disappear. Corridor travelers changed their departure time to closer to the time they wished to make a trip and took different routes to take advantage of the new capacity. Congestion is no longer an 8- to 10-hour phenomenon, but slow speeds exist for more than the peak hour in the morning and evening. This occurrence on the Katy Freeway (IH 10 West) is discussed in greater detail in the validation section of this document.

The basic assumption is that the newly calculated speed (Step C1) applies to the portion of the peak period outside of the “floor speed” period. The floor speed is estimated as the average peak period speed in the base year. It appears that 60 minutes is approximately the right amount of “floor time,” based on analysis of the Katy Freeway (IH 10 West) data (more information on this calculation is available in the validation section at the end of this document). The benefits are very sensitive to the assumption about this time (see Exhibit G-6)—a 30-minute floor produces 53 percent reduction, a 45-minute floor produces a 46 percent reduction, a 60-minute floor produces a 39 percent reduction in delay, a 75-minute floor produces a 33 percent delay reduction, and a 90-minute floor results in a 25 percent reduction.

Exhibit G-6: The Effect of Floor Speed on Peak Period Delay Estimates for Katy Freeway (IH 10 West)



Step C6: Calculate Peak Period Delay with Floor Speed

The estimated 60-minute floor time portion of the peak period from Step C4 is applied to the travel delay estimates in all analyzed segments. FIXiT also allows the user an option to change the floor time period should there be more specific information regarding a particular roadway segment. The proposed peak period delay calculated in Equation 21 represents the estimate for delay improvement on each of the analyzed segments. The percent change equation includes the same variables discussed in Step C3, Equation 17. The proposed delay includes the delay floor and is calculated with both the proposed peak period speed and current peak period speed.

$$\text{Percent Change} = \frac{\text{Current Delay} - \text{Proposed Delay with Delay Floor}}{\text{Current Delay}} \qquad \text{(Equation 21)}$$

The estimated peak period delay is calculated in the same fashion as Step C3, but with the percent change calculated with Equation 21. The output of Equation 22 is the actual estimate of peak period delay reported for the analyzed roadway segment.

$$\begin{matrix}\text{Proposed Peak}\\ \text{Period Delay with}\\ \text{"Floor Speed"}\end{matrix} = \begin{matrix}\textit{Texas 100}\\ \text{Peak Period Delay}\end{matrix} - \left(\begin{matrix}\textit{Texas 100}\\ \text{Peak Period Delay}\end{matrix} \times \begin{matrix}\text{Percent}\\ \text{Change}\end{matrix}\right) \quad \text{(Equation 22)}$$

Step C7: Calculate Average Peak Travel Rate, Peak Period Speed, and Travel Time Index

An average peak travel rate is calculated based on the known current speed and calculated delays found in the previous steps. The FIXiT tool first calculates a percent change in the travel rate in order to keep the calculations consistent through the methodology. The percent change in travel rate is calculated using Equation 23, while the actual travel rate is calculated with Equation 24.

$$\begin{matrix}\text{Percent Change in}\\ \text{Peak Period Travel Rate}\end{matrix} = \frac{\frac{60}{\begin{matrix}\text{Calculated Proposed}\\ \text{Peak Period Speed}\end{matrix}} - \frac{60}{\begin{matrix}\text{Calculated Current}\\ \text{Peak Period Speed}\end{matrix}}}{\frac{60}{\begin{matrix}\text{Calculated Current}\\ \text{Peak Period Speed}\end{matrix}}} \quad \text{(Equation 23)}$$

$$\begin{matrix}\text{Proposed}\\ \text{Travel Rate}\end{matrix} = \begin{matrix}\text{Current Travel}\\ \text{Rate}\end{matrix} \times \left(1 - \begin{matrix}\text{Percent}\\ \text{Change}\end{matrix}\right) \quad \text{(Equation 24)}$$

The average peak period speed that includes the floor speed is calculated using the proposed travel rate calculated in Equation 24. This is done using a basic conversion between the travel rate and speed. The peak period speed calculated in Equation 25 is the anticipated travel speed after the improvement is implemented over the analyzed segment.

$$\begin{matrix}\text{Proposed Peak}\\ \text{Period Speed}\end{matrix} = \frac{60}{\text{Proposed Travel Rate}} \quad \text{(Equation 25)}$$

The Travel Time Index for the proposed conditions is calculated using the same equation as Step C4 (Equations 19 and 20). This index value is calculated with the delay and speeds that incorporate the floor speed.

Step C8: Calculate Weekday Non-Peak, Weekend, and Total Delay

The original assumption regarding the weekday non-peak and weekend delay was that they would not be factored into the analysis. However, they appear to be important in the full analysis of each improvement. Therefore, although they are included in the full analysis, the proposed values are calculated in a different fashion than the peak period. Two of the initial inputs (Step A6) include the proposed reduction of the weekday non-peak period and weekend period delay. These reduction percentages are applied to the current values to estimate the proposed conditions. The proximity factor is also applied to calculate the true proposed value. The proposed delay values and the percent change are calculated using Equations 26 and 27.

$$\begin{matrix}\text{Proposed Off-Peak } \textbf{OR}\\ \text{Weekend Delay}\end{matrix} = \begin{matrix}\text{Current}\\ \text{Value}\end{matrix} \times \left(1 - \begin{matrix}\text{Percent}\\ \text{Reduction}\end{matrix} \times \begin{matrix}\text{Proximity}\\ \text{Factor}\end{matrix}\right) \quad \text{(Equation 26)}$$

$$\text{Percent Change} = \frac{\text{Current Value} - \text{Proposed Value}}{\text{Current Value}} \quad \text{(Equation 27)}$$

The total delay is made of three portions: 1) peak period delay, 2) off-peak delay, and 3) weekend delay. The *Texas 100* list has a current value for the total delay. The proposed total delay is calculated using the proposed values for each of the three primary portions (Equations 28 and 29).

$$\text{Proposed Total Delay} = \text{Proposed Peak Period Delay} + \text{Proposed Off-Peak Delay} + \text{Proposed Weekend Delay} \quad \text{(Equation 28)}$$

$$\text{Percent Change} = \frac{\text{Current Total Delay} - \text{Proposed Total Delay}}{\text{Current Total Delay}} \quad \text{(Equation 29)}$$

The proposed hours of congested road value is calculated in Equation 30 by applying the percent change in peak period delay (Step B9) to the current hours of congested road.

$$\text{Proposed Hours of Congested Road} = \text{Current Hours of Congested Road} \times (1 - \text{Percent Change in Total Delay}) \quad \text{(Equation 30)}$$

Section D: Network Analysis

An important element of the FIXiT tool is the ability to examine network segments to get the big picture of congestion relief effects from certain projects. The improvement effects will not be limited to the project segment, but will also be felt on other transportation facilities. In the case of the MIP analysis dataset, the network consists of other roads, but they could also be transit lines or diversions to telecommuting as well. The network analysis steps to include the other benefits are provided in Step D procedures.

Step D1: Apply Proximity Factor

The congestion benefit analysis of the additional network segments is the same as that applied to the congested segment. FIXiT assumes that the same level of capacity or operational improvement is applicable to all surrounding roadways, and then adjusts the effect based on the proximity to the proposed improvement. A reduction in the delay reduction adjusts for the fact that delay will be reduced by some amount on nearby roads, but congestion will not likely decline on other roads in the same magnitude that it will on the improved roadway segment. FIXiT incorporates a proximity factor for all analyzed routes, but also allows the analyst to use project-specific information if available.

The percent change in speed, travel rate, and peak period delay are initially calculated with the same equations (Equations 15, 17, 18, 21, 22, 25) as for the congested segment. The weekday non-peak and weekend delay values are also calculated using the same equations (Equations 26 and 28). The benefits of these changes are reduced with the proximity factor (Equation 31).

$$\text{Adjusted Delay Change} = \text{Calculated Delay Change} \times \text{Proximity Factor} \quad \text{(Equation 31)}$$

Step D2: Compile the Effect of the Improvement for All Segments in the Analysis Network

After analyzing each of the segments separately, the roads are combined into one project value for the economic analysis steps. The delay savings for each segment are summed using Equation 32 to estimate the total reduction in peak period delay over the entire network.

$$\text{Peak Period Delay Savings} = \begin{matrix}\text{Current Peak}\\\text{Period Delay}\end{matrix} - \begin{matrix}\text{Proposed Peak}\\\text{Period Delay}\end{matrix} \qquad \text{(Equation 32)}$$

The percent change in peak period delay for the entire network is calculated in Equation 33 using the peak period delay savings and the sum of the current peak period delay for the roads being analyzed.

$$\text{Percent Change} = \frac{\text{Peak Period Delay Savings}}{\text{Current Peak Period Delay}} \qquad \text{(Equation 33)}$$

Similarly, the hours of congested road are estimated for each road and a network average produced by weighting each road's hours by the amount of miles traveled (for example, a road with 1,000,000 miles traveled is given five times the weight as a road with 200,000 miles traveled). This weighted average is used to calculate the proposed number of congested hours for the network.

Step D3: Calculate Changes Congested VMT Percentage

The economic analysis for the congestion study requires a change in percent congested VMT, which is any portion of the VMT where the volume divided by the capacity exceeds 0.8. This particular step incorporates more data from the *Texas 100* list and the change in total delay from FIXiT.

The data required from the *Texas 100* list are the percentage of the congested VMT and the amount of total delay created by this portion of the congested VMT, which comes from the segment data. The total delay from the FIXiT spreadsheet is also used to help calculate the change in percent congested VMT. The network percent congested VMT is based on the weighted average of the individual percentages. Each of the individual percentages is multiplied by the delay for that portion of the VMT, similar to weighting the speeds for a network average.

After inputting the current percentage for individual segments and calculating the value for the network, the change in total delay calculated in the FIXiT spreadsheet is used to estimate the proposed congested VMT percentage.

$$\begin{matrix}\text{Proposed Congested}\\\text{VMT Percentage}\end{matrix} = \begin{matrix}\text{Current Congested}\\\text{VMT Percentage}\end{matrix} \times \left(1 - \begin{matrix}\text{Percent Change in}\\\text{Total Delay}\end{matrix}\right) \qquad \text{(Equation 34)}$$

The final calculation is to find the change in congested VMT percentage between the current and proposed conditions. This difference is crucial to creating the benefit/cost ratio calculated in the economic report. The difference is calculated as a subtraction between the current and proposed values (Equation 35).

$$\begin{matrix}\text{Change in}\\\text{Percent}\end{matrix} = \begin{matrix}\text{Current Congested}\\\text{VMT Percentage}\end{matrix} - \begin{matrix}\text{Proposed Congested}\\\text{VMT Percentage}\end{matrix} \qquad \text{(Equation 35)}$$

Validation of the FIXiT Methodology

The FIXiT methodology is designed to be open to analyst-provided data using specific project characteristics. As it has been applied to the Mobility Investment Priorities project (http://mobility.tamu.edu/mip), several assumptions have been used. Calibrating the method to any individual project is difficult given the complicated nature of large-scale improvements. The relative ease of use, however, allows the analyst to examine many different assumptions and create a range of plausible values. As additional projects are assessed, constructed, and analyzed, FIXiT can be refined. As an illustration and initial validation of the methodology, FIXiT was used to analyze the Katy Freeway (IH 10 West) expansion project in Houston.

The Katy Freeway (IH 10 West) project consisted of a six-year, 20-mile program to rebuild the pavement and expand capacity from six freeway mainlanes and a reversible lane that provided high-speed and reliable service for bus and carpool passengers. The new Katy Freeway (IH 10 West) includes 10 to 14 freeway mainlanes and up to 4 managed lanes that serve buses and carpoolers, as well as other toll paying motorists over much of the project length (https://www.hctra.org/katymanagedlanes).

Peak period speed data from 2001 and 2010 were averaged from the TranStar traffic management center dataset (*9*) for Katy Freeway (IH 10 West) before and after conditions (the *Texas 100* dataset only began in 2010). Compiling before and after data from the same source also builds consistency in the validation process.

The average peak period speeds for both directions and both peak periods of the Katy Freeway were compiled using a weighted average based on the person-miles traveled and using an estimate of 60 percent of system trips in the peak direction and 40 percent in the non-peak direction. Peak period speeds were estimated to be 37.3 mph in 2001 and 48.7 mph in 2010. Plots of the average Katy Freeway (IH 10 West) speeds for eastbound and westbound traffic from 1998 to 2009 between Barker-Cypress and Taylor Street are provided in Exhibits G-7 and G-8.

Exhibit G-7: Morning Peak Period Speeds for Both Directions of Katy Freeway (IH 10 West), Houston

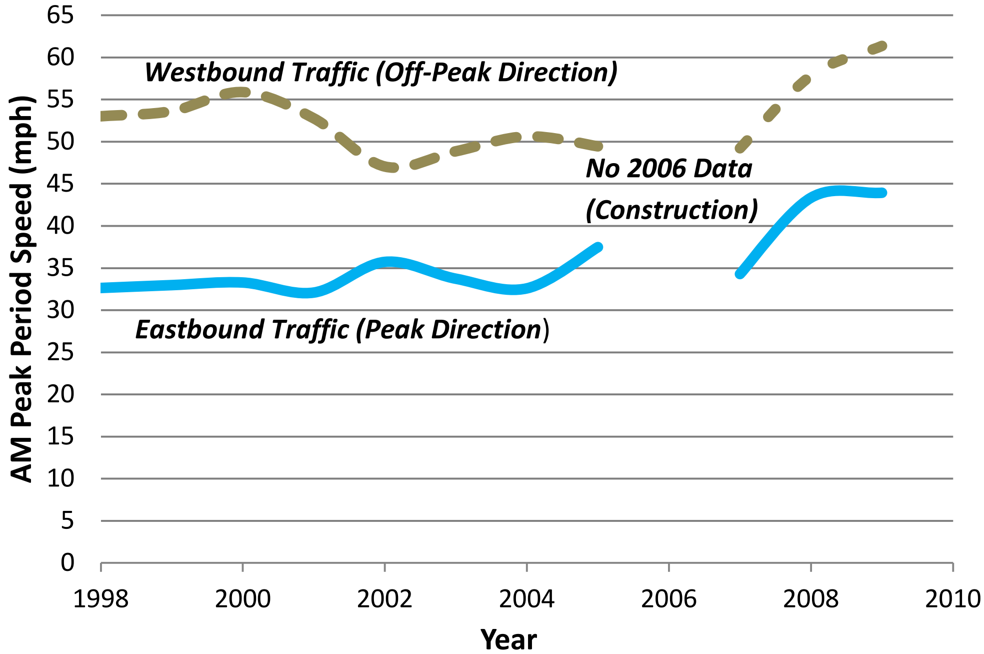
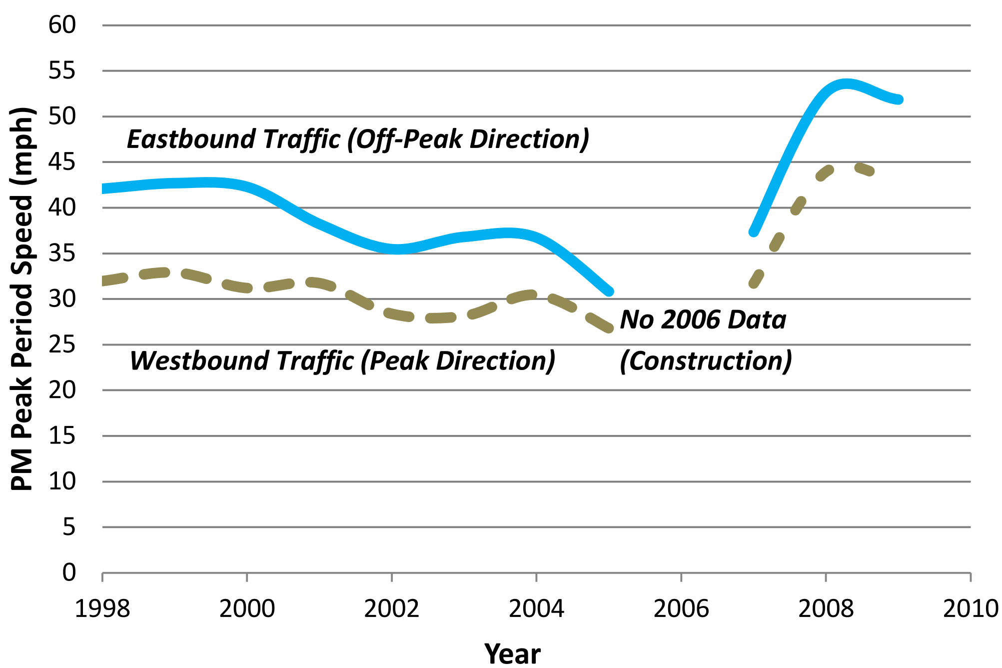


Exhibit G-8: Afternoon Peak Period Speeds for Both Directions of Katy Freeway (IH 10 West), Houston



These plots show that the speeds are consistently low for the peak direction of both peak periods before and during the expansion project. These low speeds were caused by the lack of capacity available for the traffic levels. As freeway construction was completed, however, the average speeds climbed, although congestion remained (due to the triple convergence phenomenon). The gap in 2006 is due to the removal of the data collection devices during construction.

Exhibit G-9 provides a summary of the validation findings and the estimated actual Katy Freeway (IH 10 West) values used to refine the FIXiT methodology.

Exhibit G-9: Validation Results for Katy Freeway (IH 10 West), Houston

Scenario	Peak Period Delay Before Expansion (2001)	Estimated Peak Period Delay After Expansion (2010)	Percent Change in Peak Period Delay
Real-World – Estimated using TranStar traffic data in 2001 and 2010	8.4 Million Hours	3.8 Million Hours	55%
With Floor Speed (Calculated using a period of "before condition" speed – see Step C4)	8.4 Million Hours	5.5 Million Hours	35%
Full Change to Peak Period (Calculated without a floor speed time period – see Step C3)	8.4 Million Hours	2.7 Million Hours	68%

Exhibit G-9 shows that the calculated change in delay does not perfectly match the real-world conditions, but that the calculations are still plausible. Although the real-world and calculated values that include the floor speed (second row) do not match exactly, they appear to be a better option than not including the floor speed. Including the minimum delay better represents the real-world condition than not including the value. The lower value can give the users an adequate idea of the benefits, but it does not inflate the benefits registered for each of the analyzed segments. A delay floor of 30 minutes (see Exhibit G-6) was also considered as it might provide a delay percentage reduction closest to the real world data, but given the number of assumptions in the methodology, it was decided to maintain a conservative approach until more projects and data can be examined.

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1. Texas A&M Transportation Institute. "Congestion Problems: The Worst in the State." *Mobility Investment Priorities*, http://mobility.tamu.edu/mip/congestion.php, 2013. (Accessed January 1, 2013).

2. Texas Department of Transportation. "TxDOT Releases List of 100 Most Congested Roadways." Texas Department of Transportation, http://www.dot.state.tx.us/news/042-2012.htm, August 31, 2012 (Accessed April 10, 2013).

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5. Schrank, D., B. Eisele, and T. Lomax. *Appendix A – Methodology for the 2012 Urban Mobility Report,* Texas A&M Transportation Institute, College Station, TX, December 2012.

6. Downs, A. *Still Stuck in Traffic: Coping with Peak-Hour Traffic Congestion,* The Brookings Institution, Washington, DC, and The Lincoln Institute of Land Policy, Cambridge, MA, 1992.

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8. Margiotta, R. *SHRP 2 L03 – Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies*, Transportation Research Board, Washington, D.C., February 28, 2010.

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APPENDIX H: CONGESTION REDUCTION RESULTS

Introduction

The Future Improvement Examination Technique (FIXiT) spreadsheet is a transparent analysis tool that uses analyst-specified factors, an extensive database of congestion reduction strategies, and available data to estimate the effect of improvement projects and programs. The initial use of FIXiT was to analyze several large possible roadway projects in Austin, Houston, and San Antonio. This document presents the estimated before and after conditions for each of the roadways and some of the surrounding road segments in the project corridors. This document also provides a brief sensitivity analysis regarding three input variables for each project network.

The FIXiT procedure generally uses a four-step analysis process:

- Input data—Information from the *Texas 100 Most Congested Sections List* (*1*) and Road-Highway Inventory (RHiNo) (*2*) databases are input to the FIXiT spreadsheet, and the proposed improvement strategy is selected from the available list (*3*). The input data for each segment analysis include free-flow speeds, peak period speeds, lane counts (current and proposed), and peak period delay.
- Perform interim calculations—The input data are converted and used in background calculations to provide a consistent basis for comparison of before and after conditions. The initial calculations are performed to estimate percent change in peak period speed due to the selected improvements.
- Estimate congestion effects of proposed project—The percent change in peak period speed is applied to base year conditions to estimate after conditions. The speeds are used to calculate the proposed peak period delay and the change in peak period delay.
- Summarize network effects—The previous steps are repeated for some of the surrounding sections of the altered route (adjusting for proximity to the project) to calculate the network effect of the improvement strategies.

Discussion of Results

Five large roadway projects with a variety of configurations were analyzed in Austin, Houston, and San Antonio. The analysis includes the road directly affected by the project, as well as other segments in the surrounding network. This section presents the estimated effects of each project analyzed with the FIXiT spreadsheet.

The results presented in this document consist of the current and proposed values for the peak period speed, Travel Time Index (TTI), and peak period delay. Two forms of the final calculations for proposed conditions are included in the following tables:

- Full effect estimate—Benefit estimates calculated under the assumption that all travelers experience the improved conditions.
- Delay floor estimate—Estimates acknowledging that congestion does not disappear after project implementation and a portion of travel will be in congested conditions.

The estimates that include the delay floor assume there is always a 60-minute period where traffic travels at the current (before condition) peak period speed. This recognizes the triple convergence phenomenon identified by Anthony Downs in *Still Stuck in Traffic* (*4*)—when a facility is widened, traffic volume is attracted to use the new peak-hour capacity from other times of the peak period, other routes, and other travel modes. The increased volume and resulting decrease in improved peak period speeds result in lower (but usually significant) benefits than would be achieved if all travelers were assumed to maintain their routes, times, and modes of travel. The full effect analysis is provided for comparison and does not represent the best estimate for congestion benefits.

The analysis results that include the delay floor presented in this document were incorporated into the economic effect estimates. More information on the corridors and the improvement projects can be found in the corridor summaries.

IH 35 North in Austin

The IH 35 project is still in the early planning stages; this analysis assumed that the improvement will be the addition of one managed lane in each direction for the entire length of the highway in Travis County (www.austin-mobility.com/corridor-development-i-35). These calculations include road sections throughout Travis County and shorter sections reaching into Williamson County and Hays County.

Exhibits H-1 and H-2 show the full effect estimates and the estimates for the delay floor calculation. The exhibits show the initial full effect estimates are rather large owing to the high congestion levels in the corridor. The values calculated with the delay floor present more conservative values for the congestion benefits, but still predict a 34 percent reduction in peak period delay over the network.

Exhibit H-1: Full Effect Analysis Results for IH 35 North in Austin

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 35	**SH 71**	**US 183**	**38.1**	**46.5**	**2,950,000**	**1,710,000**
IH 35	US 183	Howard Lane	53.2	63.3	648,000	87,000
IH 35	Howard Lane	FM 3406	53.5	62.6	759,000	149,000
IH 35	SH 71/ US 290	RM 150	60.3	64.6	546,000	53,000
		Network	**51.9**	**59.2**	**4,903,000**	**1,999,000**

Exhibit H-2: Best Estimate Results for IH 35 North in Austin

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 35	**SH 71**	**US 183**	**38.1**	**43**	**2,950,000**	**2,280,000**
IH 35	US 183	Howard Lane	53.2	59.1	650,000	320,000
IH 35	Howard Lane	FM 3406	53.5	58.9	760,000	403,000
IH 35	SH 71/ US 290	RM 150	60.3	62.9	546,000	256,000
		Network	**51.9**	**56.2**	**4,903,000**	**3,260,000**

Note: Estimates include delay floor

Loop 1 (South MoPac) in Austin

The Loop 1 South MoPac project is in the environmental stage, and a final design concept has not been determined. This analysis assumed that the project would be one additional managed lane in each direction between Cesar Chavez and SH 71 (http://www.mobilityauthority.com/projects/planned-expressways.php).

The calculations for the full effect and those including the delay floor are displayed in Exhibits H-3 and H-4. Although the project is applied to the southern portion of the congested route, the changes are estimated to affect other portions of MoPac. The reduction on the congested segment can also help traffic flow along the northern section of the roadway. The full effect estimates show that congestion is reduced 38 percent, which may be due to the size of the improvement. Inclusion of the delay floor results in a still-substantial 21 percent reduction in peak period delay.

Exhibit H-3: Full Effect Analysis Results for Loop 1 (South MoPac) in Austin

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
Loop 1 South	**Cesar Chavez**	**SH 71**	**48.5**	**55.3**	**1,400,000**	**765,000**
Loop 1 South	US 183	Cesar Chavez	48.5	56.3	1,030,000	705,000
Loop 1 South	US 183	FM 734	50	52.5	74,000	69,000
Loop 1 South	US 290/ SH 71	SH 45	49.9	50.9	27,000	27,000
		Network	**48.9**	**54.8**	**2,531,000**	**1,566,000**

Exhibit H-4: Best Estimate Results for Loop 1 (South MoPac) in Austin

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
Loop 1 South	**Cesar Chavez**	**SH 71**	**48.5**	**53.9**	**1,400,000**	**1,100,000**
Loop 1 South	US 183	Cesar Chavez	48.5	50.5	1,030,000	847,000
Loop 1 South	US 183	FM 734	50	50.8	74,000	71,000
Loop 1 South	US 290/ SH 71	SH 45	49.9	50.6	27,000	27,000
		Network	**48.9**	**51.5**	**2,531,000**	**2,045,000**

Note: Estimates include delay floor

IH 45 North in Houston

The North Houston Highway Improvement Project is evaluating the IH 45 North corridor from near downtown Houston to Beltway 8 North and other connecting roads. Several options are being considered, but most of the preliminary options include four managed lanes added to the current roadway layout to reduce congestion (http://www.ih45northandmore.com). The FIXiT analysis area also includes other segments of IH 45 and IH 10.

Exhibits H-5 and H-6 show the full effect and delay floor benefit calculations. The values for the full effect estimates show that nearly all congestion is alleviated on the actual congested route segments of IH 45, and the speeds nearly reach the free-flow speed, but this does not include the triple convergence phenomenon (*1*).

The calculations that include the delay floor, however, have a lower estimate than the full effect and show that some congestion remains. Although the reported effects are not as large as the full effect, the calculations including the delay floor still reduce the peak period delay by around 24 percent for the network. The congested segments of IH 45 are reduced by much higher percentages—between 45 and 54 percent, meaning the delay floor calculation still estimates a sizeable congestion reduction.

Exhibit H-5: Full Effect Analysis Results for IH 45 North in Houston

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 45	**SL 8**	**IH 610**	**55.4**	**63.7**	**1,200,000**	**100,000**
IH 45	SL 8	FM 2920	54.9	62.6	1,410,000	1,300,000
IH 45	**IH 10**	**IH 610**	**47.9**	**58.9**	**795,000**	**180,000**
IH 10	IH 45	IH 610 West	52.4	58.1	1,110,000	970,000
IH 10	IH 45	US 59	52	59.2	176,000	101,000
IH 45	IH 10	IH 610 South	45.7	56.7	1,660,000	1,100,000
		Network	**51.9**	**60.4**	**6,351,000**	**3,751,000**

Exhibit H-6: Best Estimate Results for IH 45 North in Houston

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 45	**SL 8**	**IH 610**	**55.4**	**60.4**	**1,200,000**	**552,000**
IH 45	SL 8	FM 2920	54.9	56	1,410,000	1,345,000
IH 45	**IH 10**	**IH 610**	**47.9**	**54.3**	**795,000**	**438,000**
IH 10	IH 45	IH 610 West	52.4	53.9	1,110,000	1,030,000
IH 10	IH 45	US 59	52	54.4	176,000	132,000
IH 45	IH 10	IH 610 South	45.7	49.4	1,660,000	1,340,000
		Network	**51.9**	**54.9**	**6,351,000**	**4,837,000**

Note: Estimates include delay floor

IH 35 North in San Antonio

The environmental study examining possible projects to reduce congestion on IH 35 North in San Antonio center on adding four managed lanes between US 281 and SL 1604. A previous planning study examined several other project possibilities and narrowed the likely build concepts to versions of expansions including four managed lanes (http://www.my35.org/default.htm). The analysis zone includes other segments of IH 35 and US 281.

Exhibits H-7 and H-8 show the full effect estimates and the estimates that include the delay floor. The full effect analysis suggests that delay will become nearly non-existent on IH 35 after implementing the proposed project, and significantly reduce congestion on the surrounding segments. This large reduction in delay is likely caused by the proposed project that increases the number of lanes by about 50 percent. The addition of the delay floor in the reported estimate reduces peak period congestion on network roads to around 30 percent for the entire network.

Exhibit H-7: Full Effect Analysis Results for IH 35 North in San Antonio

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 35	**US 281**	**IH 410**	**56.4**	**63.2**	**351,000**	**60,000**
IH 35	US 281	IH 10	50.7	59.3	510,000	394,000
US 281	IH 35	IH 410	55.5	60.5	332,000	307,000
US 281	IH 35	IH 10	60	64.3	89,000	67,000
IH 35	**IH 410**	**SL 1604**	**52.1**	**63**	**1,220,000**	**161,000**
IH 35	SL 1604	FM 3009	54	64	689,000	531,000
		Network	**54**	**62.3**	**3,191,000**	**1,520,000**

Exhibit H-8: Best Estimate Results for IH 35 North in San Antonio

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
IH 35	**US 281**	**IH 410**	**56.4**	**60.5**	**351,000**	**181,000**
IH 35	US 281	IH 10	50.7	52.5	510,000	442,000
US 281	IH 35	IH 410	55.5	56.3	332,000	318,000
US 281	IH 35	IH 10	60	61	89,000	76,000
IH 35	**IH 410**	**SL 1604**	**52.1**	**58.5**	**1,220,000**	**599,000**
IH 35	SL 1604	FM 3009	54	56.1	689,000	596,000
		Network	**52.7**	**57.8**	**3,191,000**	**2,212,000**

Note: Estimates include delay floor

US 290 in Houston

The proposed US 290 project involves two new mainlanes and a total of three managed lanes (http://www.my290.com). The surrounding network includes a northern extension of US 290 and a segment of IH 610.

Exhibits H-9 and H-10 show the full effect estimates and estimates including the delay floor. The full effect again shows that congestion on the altered segments is nearly eliminated. The estimates including the delay floor also have a relatively high reduction of around 35 percent. The results also indicate that the US 290 project will reduce the peak period delay on IH 610 by 13 percent, an important improvement in an adjacent congested network segment.

Exhibit H-9: Full Effect Analysis Results for US 290 in Houston

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
US 290	**FM 529**	**IH 610**	**47.3**	**61.5**	**2,510,000**	**411,000**
IH 610 N/W	IH 45	IH 10	46	57.5	1,330,000	1,020,000
US 290	**FM 1960**	**FM 529**	**51.5**	**59.2**	**563,000**	**230,000**
US 290	FM 1960	BU 290H	63.3	63.9	125,000	106,000
		Network	**50.6**	**60.6**	**4,528,000**	**1,767,000**

Exhibit H-10: Best Estimate Results for US 290 in Houston

Route	Begin	End	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay
US 290	**FM 529**	**IH 610**	**47.3**	**55.3**	**2,510,000**	**1,280,000**
IH 610 N/W	IH 45	IH 10	46	48.8	1,330,000	1,150,000
US 290	**FM 1960**	**FM 529**	**51.5**	**56.1**	**563,000**	**374,000**
US 290	FM 1960	BU 290H	63.3	63.5	125,000	115,000
		Network	**50.6**	**55.3**	**4,528,000**	**2,919,000**

Note: Estimates include delay floor

FIXiT Congestion Reduction Analysis Results Summary

The analysis of five projects in Austin, Houston, and San Antonio estimated a reduction in daily peak period delay between 500,000 and 1.6 million person-hours, representing an improvement between 21 percent and 35 percent. Congestion benefits on the improved segments are estimated between 23 and 54 percent reduction in peak period delay. Surrounding network roads, with less direct effect from the improvements, have lower benefits that range between zero and 25 percent, with most above 10 percent. Exhibit H-11 presents the actual reported speeds and peak period delay for each project network. The presented estimates include the delay floor.

Exhibit H-11: Best Estimates for Each Network

City	Route	Current Peak Period Speed	Proposed Peak Period Speed	Current Peak Period Delay	Proposed Peak Period Delay	% Change in Peak Delay
Austin	IH 35 North	51.9	56.2	4,903,000	3,260,000	34%
Austin	Loop 1 South	48.9	51.5	2,531,000	2,045,000	21%
Houston	IH 45 North	51.9	54.9	6,351,000	4,837,000	24%
San Antonio	IH 35 North	52.7	57.8	3,191,000	2,212,000	31%
Houston	US 290	50.6	55.3	4,528,000	2,919,000	35%

Sensitivity Analysis

The FIXiT methodology and assumptions are based on previous methods included in the *Urban Mobility Report* (*5*), various published documents, and other knowledge regarding congestion. However, some of the inputs consist of a range of possible values, which can change the calculated outputs if a different assumption is used during the analysis. These possible differences in the analysis necessitate a sensitivity analysis of some of the input variables.

The effect of changes in three of the input variables on the percent change in peak period congestion was examined.

- Latent demand.
- Proximity factors.
- Delay floor portion of peak period delay.

FIXiT's transparency allows users to change nearly every input. Therefore, other inputs could change the reported output calculations, and users should be mindful of the relationships built into the FIXiT spreadsheet; this will depend on the specifics of each analyzed project.

Latent Demand

Latent demand is an increase in volume along the roadway immediately after completing the proposed project, affecting the percent change in peak period delay. According to report by Henk and Hanks (*6*), latent demand typically ranges between 5 and 15 percent increase in traffic volume after expanding a roadway. This analysis assumed an average latent demand of 10 percent for each roadway. This sensitivity analysis examines the effect of varying latent demand percentages that users might assume for future analyses. The latent demand percentages examined include 5, 7.5, 10, 12.5, and 15 percent.

Exhibit H-12 shows the effect of the selected latent demand levels on the peak period congestion reduction for each of the proposed projects. The table includes the percent latent demand and the level of decrease in peak period delay. The analysis finds that the percent change in delay increases by 0 to 4 percentage points when a lower latent demand is assumed. The percent change in peak period delay decreases by 1 to 8 percent when assuming a larger latent demand.

Exhibit H-12: Peak Period Delay Reduction with Varying Latent Demand Percentages

	Latent Demand Percentage				
Network	**5%**	**8%**	**10%**	**13%**	**15%**
IH 35 North in Austin	38%	36%	34%	30%	26%
Loop 1 (South MoPac) in Austin	24%	22%	21%	18%	15%
IH 45 North in Houston	26%	25%	24%	22%	20%
IH 35 North in San Antonio	31%	31%	31%	30%	30%
US 290 in Houston	38%	36%	35%	35%	34%

Proximity Factors

The second variable examined in the sensitivity analysis is the proximity factor used during the network analysis included in the FIXiT spreadsheet. The proximity factors are used to scale down the effects on other network segments that are included in the analysis. The values for the proximity factor are based on the relationship between the locations of the congested segment and the surrounding roadway segment.

The proximity factor portion of the sensitivity analysis examines the effects of changing the proximity factor by 10 percentage points above and below the assumed levels. Changing the value by 10 percentage points means if the actual proximity factor is 25 percent, the sensitivity analysis illustrates the effect of changing the proximity factor between 15 percent and 35 percent.

Exhibit H-13 shows the effect of proximity factor alterations for each of the analyzed network segments. This portion of sensitivity analysis finds that greater proximity factors produce larger total effects on peak period network delay, while smaller proximity factors create smaller changes in delay. This effect is likely because a greater portion of the network effect is included in the final analysis as the proximity factor increases. The change in peak period delay ranges between 0 and 6 percentage points along each roadway for the tested proximity factors. The altered proximity factors changed the network analysis between 1 and 3 percentage points.

Exhibit H-13: Peak Period Delay Percent Change Sensitivity Analysis (Proximity Factors)

Network	Lower Proximity Factor (−10)	Assumed Proximity Factor	Higher Proximity Factor (+10)
IH 35 North in Austin	32%	34%	---*
Loop 1 (South MoPac) in Austin	20%	21%	22%
IH 45 North in Houston	21%	24%	26%
IH 35 North in San Antonio	28%	31%	33%
US 290 in Houston	34%	35%	37%

*Proximity factors were initially assumed to be 100 percent.

Delay Floor Time Period

The third portion of the sensitivity analysis examines the size of the peak period portion in the delay floor. The delay floor assumes that there is a portion of the peak period where the traffic travels at the current (before condition) peak period speed. The delay floor is assumed to cover 60 minutes of each peak period for the calculated results.

This sensitivity analysis includes an examination of five levels of delay floor portions of the peak period, including the current level. These unchanged portions of the peak period include 30 minutes, 45 minutes, 60 minutes, 75 minutes, and 90 minutes.

Exhibit H-14 displays the output calculations from each of the delay floor time segments. The important characteristic is that as the unchanged portion of the peak period becomes larger, the percent change in peak period delay is reduced. Therefore, the 75-minute and 90-minute delay floor portions limit the estimated effect of the improvement, while the 30- and 45-minute segments produce a larger change in peak period delay. The increase in percent change ranges between 4 and 13 percentage points when users input a time segment smaller than 60 minutes. The percent change also decreases between 4 and 13 percentage points when a period larger than 60 minutes is used.

Exhibit H-14: Peak Period Delay Percent Change Sensitivity Analysis (Delay Floor)

Network	30 Minutes	45 Minutes	60 Minutes (Current)	75 Minutes	90 Minutes
IH 35 North in Austin	46%	40%	34%	27%	21%
Loop 1 (South MoPac) in Austin	29%	25%	21%	17%	13%
IH 45 North in Houston	32%	28%	24%	20%	15%
IH 35 North in San Antonio	41%	36%	31%	25%	20%
US 290 in Houston	48%	42%	35%	29%	23%

Sensitivity Analysis Summary

The sensitivity analysis discussed in this document covered three variables included in the FIXiT tool—latent demand, proximity factors, and the delay floor portions of the peak period. It is important to examine how sensitive the FIXiT model is to variable changes, as altering the input values can change the estimated benefits for the analyzed projects.

The analysis finds that the FIXiT methodology is sensitive to each of the tested inputs, but the degree of sensitivity depends on the variable. The latent demand alteration changed between 0 and 8 percentage points from the initial calculations. The proximity factor changed the output between 1 and 3 percentage points from the reported results. The alterations to the delay floor produced the greatest difference in percent change in peak period delay—between a 13 percentage point increase and a 13 percentage point decrease.

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2. Roadway-Highway Inventory (RHiNo). Texas Department of Transportation, Austin, TX, 2011 Data.

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Project Websites

1. IH 35 North in Austin: www.austin-mobility.com/corridor-development-i-35
2. Loop 1 (South MoPac) in Austin: http://www.mobilityauthority.com/projects/planned-expressways.php
3. IH 45 North in Houston: http://www.ih45northandmore.com
4. IH 35 North in San Antonio: http://www.my35.org/default.htm
5. US 290 in Houston: http://www.my290.com