Economic Development RESEARCH GROUP

Benefit-Cost Analysis of the Hwy 6 / Hwy 10 Interchange Improvements

Prepared for:

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EXECUTIVE SUMMARY

Project Description

The existing system of highways and ramps comprising the Route 6/10 Interchange was originally constructed in the 1950s as a bypass around Olneyville, which at the time was its own distinct urban center in the western section of Providence, Rhode Island. As with most of the nation's highway infrastructure constructed during that period, steady growth in automobile traffic and increased reliance on heavy trucking for surface freight transport soon rendered many elements of the interchange incompatible with emerging highway safety and serviceability standards. Most all of the now functionally obsolete elements of the interchange (including insufficient merging lengths and curve radii, unusual and substandard on- and off-ramp configurations, and other deficiencies) persist to this day. Furthermore, as the urbanized limits of the capital city expanded and subsumed Olneyville, the severance imposed on neighboring communities by these highway corridors has become all too apparent.

The need to restore the interchange to a state of good repair has long been identified, given (a) the large volumes of traffic presently accommodated by both routes, and (b) the deteriorating condition of many original infrastructure elements, in particular the bridges that support elevated sections of freeway and overpasses (7 of which are classified as Structurally Deficient).

Engineers estimate that to replace what is already there now would cost approximately $500-million, but would not measurably improve safety or operations. The state's preferred design would cost $595-million, or just $95-million more than the baseline project. It would improve operations and safety by extending weave areas, and through general modernization, to include electronically activated wrong-way warnings, ramp metering, and more efficient connections. It will increase the quality of life within the neighborhood with better connections across the freeway.

The project will install ramp meters at as many on-ramps as possible within the project area, in order to regulate the peak-period influx of traffic to help keep the overall system moving well. Ramp meters are a long-proven strategy advocated by FHWA for greatly reducing freeway delay, and for increasing overall throughput without increasing the number of freeway lanes. Unfortunately ramp meters are rare in New England – this will be the first case of meters in Rhode Island, and introducing them now will help them migrate across the state and all of New England more quickly than they otherwise would.

This paper documents the Benefit Cost Analysis that is expected from this project, along with the approach that was used to determine key inputs to that analysis such as travel time improvements, safety improvements, etc.

Analysis Approach

The benefit cost analysis of the project was prepared according to the Benefit-Cost Analysis Guidance for Applicants for FASTLANE Grants published March 3, 2016 and with reference to OMB Circulars A-4 and A-94 concerning benefit cost analysis.

Table 1 provides the required Project Matrix summarizing the analysis of impacts from the incremental changes between the Baseline (a $500-M replace-existing project) and the Build (a $595-M redesign and modernization project).

Table 1 Project Summary Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline/ Alternatives	Type of Impacts	Population Affected by Impacts	Economic Benefit	Summary of Results	Page Reference in BCA
System-to-system interchange w/structurally deficient bridges, hazardous weaves, missing connections, poor operations	Reconstruct interchange; introduce ramp metering for operational efficiency; remove hazards	Reduce travel time and crashes and increase reliability of ship-ment delivery times	3.5-million truck trips and 66-million auto trips/year expected to benefit from reduced delay, improved safety	Discounted at 7%, benefits expected to be $367 million between 2020 and 2040	BCA of 4.97 expected from incremental benefits and costs of Base vs. Build due to travel time, operating costs, reliability, safety, and emissions	***p.4***

Table 2 summarizes the types of outcomes that have been identified for the project and the assessment approach adopted within the benefit-cost assessments. These outcomes are organized according to FASTLANE selection criteria. As detailed in Section 1 of this report, the quantification of benefits involves both spreadsheet evaluations and calculations performed by the TREDIS transportation economics tool (See Appendix 3).

The time horizon of the benefit-cost analysis covers the construction period from 2017-2020, and an operational period from 2020-2040. All benefits are expressed in constant 2016 dollars, and discounted to 2016.

Table 2 Project Outcomes

Long-Term Outcome	Type of Societal Benefits	Assessment Approach and Document Section Reference
State of Good Repair	Maintenance & repair savings	Quantitative assessment (TREDIS) ***Refer to Section 1.1***
	Shifted VMT from lower capacity roads	Quantitative assessment (TREDIS) ***Refer to Section 1.2***
Economic Competitiveness	Travel time savings from reduced congestion & resulting diversion	Quantitative assessment (TREDIS) ***Refer to Section 1.3***
	Operating cost savings from avoided congestion & resulting diversion	Quantitative assessment (TREDIS) ***Refer to Section 1.4***
	Short-term job creation from construction & long-term job creation from efficiency gains	Quantitative assessment (TREDIS) ***Refer to Section 2***
Safety	Prevented accidents both from improved road design	Quantitative assessment (Spreadsheet) ***Refer to Section 1.5***
Environmental Sustainability	Emission benefits from avoided extra mileage associated alternative routes	Quantitative assessment (Spreadsheet) ***Refer to Section 1.6***
Quality of Life	Improved mobility for residents and businesses connected by this road segment	Qualitative Assessment ***Refer to Section 1.7***

Summary of Benefits and Costs

Completion of the 6/10 improvements will result in a variety of benefits, the sum of which more than offset the costs of construction. The benefits realized by this project can be categorized into the cost savings associated with lower travel times and vehicle-operating costs, improvements in travel time reliability, improvements in safety, reduced vehicular emissions, wider economic benefits from improvements in productivity and quality of life impacts. Quality of life impacts are described qualitatively, while all other impacts are monetized and then compared in present value terms to project costs. Using a discount rate of **7%**, the ratio between monetized benefits and costs (in 2016 dollars) is **4.97**. A sensitivity analysis using a **3%** discount rate results in a benefit-cost ratio of **7.67**. Details of benefits and costs by year are presented in the appendix spreadsheet.

Table 3 Summary of Benefits (7% Discount Rate)

Benefit Type	Benefits ($ mil.)
Total Benefits	**332.8**
Monetary Time & Reliability	77.7
Non-Monetary Time & Reliability	78.7
Logistics & Supply Chain Benefits	9.1
Vehicle Operating Cost Savings	74.0
Safety Benefits	85.6
Environmental & Social Benefits	7.7

Table 4 Summary of Benefits and Costs

	Undiscounted	Discounted at 3%	Discounted at 7%
Project Costs*	95.0	84.6	72.9
O&M Costs	0.0	0.0	0.0
Residual Value	-30.0	-14.8	-5.9
Total Costs	65.0	69.8	66.9
Total Benefits	803.4	535.6	332.8
Benefit-Cost Ratio	***N/A***	***7.67***	***4.97***

* Project costs include capital outlays, along with adjustments for O&M costs, and a residual value calculated to account for the fact that the highways' useful lives extend beyond the analysis period.

Summary of Economic Impacts

In addition to a valuation of project benefits, economic impacts of the 6/10 improvements were estimated using the TREDIS transportation economics modeling suite. The project is expected to average 279 jobs/year during construction of the facility and a total number of permanent jobs increasing each year up to 184 by 2040, due to long-term efficiency gains.

Table 5 Summary of Economic Impacts

Source of Impact	Cumulative Impacts			Jobs
	Business Output ($ mil.)	GRP ($ mil.)	Wage Income ($ mil.)	
Construction (2017-2020)	154	73	53	279 average over period
Improved Transportation Efficiency (2021-2040)	460	269	179	184 permanent jobs added by 2040

Methodology for Obtaining Key Inputs

Benefits are determined based on the amount of Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), percentage of travel that is congested, improvements to safety, etc. **Appendix 1** provides an overview of how these key inputs to the analysis were determined, and directs you to an accompanying Excel workbook where much of the analysis actually occurs, and also where you can find more detailed outputs that were used in creating the summary tables in this document.

1 RESULTS OF BENEFIT-COST ANALYSIS

1.1 Project Costs

Design and construction of the 6/10 improvements are scheduled to occur in the four-year period from 2017-2020. During construction, the current roadway will remain open. Undiscounted, the project is expected to cost $595 Million, compared to the Baseline which would cost roughly $500 Million. Thus the net incremental cost on which this BCA is evaluated is $95 Million. Engineers estimate that ongoing cost of operations and maintenance would not be significantly different between Base and Build, so O&M costs were not considered. Because the life of the new infrastructure extends beyond the analysis period, a residual undiscounted value of $30.0 million is included in the last year of analysis (i.e., $30M of the $95M incremental cost is removed from this 2020-2040 BCA because its value will continue to accrue beyond 2040).

Table 6 Summary of Costs

	Undiscounted	Discounted at 3%	Discounted at 7%
Project Costs*	95.0	84.6	72.9
O&M Costs	0.0	0.0	0.0
Residual Value	-30.0	-14.8	-5.9
Total Costs	**65.0**	**69.8**	**66.9**

The above costs as computed by TREDIS are detailed by year in the Appendix spreadsheet on the “Discounted_Costs” tab.

1.2 State of Good Repair

The age of structures in this area is over 50-years old. The constant pounding of trucks and automobile demand, combined with salt applications each winter, has taken its toll on these bridges. The Rhode Island DOT (RIDOT) has determined it will be more expensive to continuously rehabilitate existing infrastructure than it will be to replace it. Benefits of the improved freight corridor are derived using assumptions about reductions in travel time, travel time reliability and crashes from recurring congestion for trucks and other vehicles.

1.3 Travel Time and Reliability Savings

Travel time and reliability savings are calculated within the TREDIS benefit-cost module based on changes in vehicle-hours traveled between base and build, as presented in the Appendix spreadsheet, and per-hour cost factors and vehicle occupancies for each mode-purpose combination. These factors are summarized in Appendix 2.

Travel time savings as calculated by TREDIS are shown below, and also available with year-by-year detain in the spreadsheet. *Logistics and Supply Change Benefits* accounts for the cost born by shippers and receivers of freight, associated with having freight tied up in transit, that are relieved by the build project.

Table 7 Value of Time & Reliability Savings, 2021-2040

	Undiscounted	Discounted 3%	Discounted 7%
Monetary Time & Reliability	188.8	125.5	77.7
Non-Monetary Time & Reliability	190.6	126.9	78.7
Logistics & Supply Chain Benefits	21.8	14.6	9.1
Total Time-Related Benefits	**401.2**	**267**	**165.5**

Value of Time and Reliability savings as calculated by TREDIS are presented in the "Discounted_Benefits" tab of the Appendix spreadsheet.

1.4 Vehicle Operating Cost Savings

Vehicle operating cost savings are calculated within the TREDIS benefit-cost module based on changes in vehicle-miles traveled between the base and build cases along with per-mile operating cost factors for cars and trucks. The cost-factors and their underlying assumptions are summarized in Appendix 2.

Vehicle operating cost savings as calculated by TREDIS are presented in the "Discounted_Benefits" tab of the Appendix spreadsheet.

Table 8 Savings in Vehicle Operating Costs, 2021-2040

	Undiscounted	Discounted at 3%	Discounted at 7%
Vehicle Operating Savings	176.9	118.5	74.0

1.5 Safety Benefits

Safety benefits include monetized savings associated with reductions in the number of crashes occurring per year. The reductions in numbers of crashes can be traced to two primary effects: (1) reduced accident rates within the improved 6/10 interchange due to safer weave distances and other safety features; and (2) reduced accidents due to ramp meters which create safe gaps for entering vehicles, reduce lane shifting by oncoming traffic, and reduce stop-n-go conditions.

Table 9 Value of Safety Benefits, 2021-2040

	Undiscounted	Discounted at 3%	Discounted at 7%
Safety Benefits	205.7	137.4	85.8

Safety benefits as calculated by TREDIS are presented in the "Discounted_Benefits" tab of the Appendix spreadsheet.

1.6 Environmental Sustainability

Environmental sustainability benefits are derived from reductions in a variety of emission types released into the air as a result of improved vehicle operations. The project is not likely to change overall VMT significantly, but it will reduce delay and will stabilize engines at a more consistent RPM, which will in-turn reduce fuel consumption and improve air quality. TREDIS estimates the overall reduction in emissions as well as the value of those emissions based on per-ton valuations for each emissions factor, as established in FASTLANE guidance.

Environmental sustainability and social benefits are shown as outputs of TREDIS in the "BCA Summary" tab of the Appendix spreadsheet under the "Environmental & Social Benefits" section. Benefits are categorized by CO2 vs other emissions that include volatile organic compounds, nitrogen oxides, sulfur dioxide, and particulate matter.

Table 10 Value of Environmental Benefits, 2021-2040

	Undiscounted	Discounted at 3%	Discounted at 7%
Reductions in CO2	18.9	12.3	7.4
Other emissions reductions	0.8	0.4	0.3
Total Environmental Benefits	**19.7**	**12.7**	**7.7**

In accordance with Federal interagency Social Cost of Carbon (SCC) guidance, the value of carbon dioxide emissions changes over time and is discounted at a lower discount rate of 3%, even in the 7% discount rate analysis.

1.7 Quality of Life

Prior sections of this benefit cost analysis have focused on quantifying the costs imposed on trucks and cars and on the city in a scenario in which the 6/10 interchange design is just replacement is not addressed through the proposed improvements and is therefore leading to delay and diversions. While these quantitative assessments demonstrate clearly the value of the improvement of Hwy 6 / Hwy 10 interchange relative to the cost of replacement, there is an additional qualitative story to be told about the benefits of the project in supporting quality of life in Providence. The project will increase the quality of life within the neighborhood with better connections across the highway and include premium landscaping, including many Boulevard-style treatments. Improved highway safety from the project also improves the quality of life, not only through the travel time savings from less incidence-related delay and unreliability, but also from the reduced probability of being in a crash oneself.

2 ECONOMIC IMPACTS

In addition to the benefit-cost analysis described in previous sections, an economic impact analysis was also performed for the Hwy 6/10 improvements. The benefit-cost analysis describes the efficiency of proposed investment in the highway improvements, by comparing (in present-value terms) the monetized value of net welfare gains from the project to the costs of the project. Economic impact assessments, on the other hand, describe project impacts in terms of the flow of money in the economy. Economic impacts are measured in terms of jobs, income, gross-regional product (GRP), and business output.

The economic impact analysis considers a) short-term stimulus from construction outlays, and b) enhanced economic activity from reduced transportation costs. The impact analysis includes both the direct effects (jobs, income, GRP, and business output directly resulting from construction outlays or transportation savings) as well as induced and indirect effects (multiplier effects as these dollars are spent in the economy and stimulate demand in other sectors).

Economic impacts are estimated using the TREDIS transportation economics suite—the most widely used system for economic impacts of transportation projects in the US and Canada. Appendix 3 provides information about TREDIS methodology and underlying economic data. Economic impacts are not required for FASTLANE applications, so detailed outputs are not available in the Appendix Spreadsheet, but summary statistics are shown below to illustrate the significance of the project to the economy in the region.

The incremental improvement of the Build relative to the Base is expected to support an average of 279 construction jobs during the construction period and a total of 184 permanent jobs by 2040, created through higher efficiency of the Build relative to the Base.

Table 11 Summary of Economic Impacts

	Cumulative Impacts			
Source of Impact	**Business Output ($ mil.)**	**GRP ($ mil.)**	**Wage Income ($ mil.)**	**Jobs**
Construction (2017-2020)	154	73	53	279 average over period
Improved Transportation Efficiency (2021-2040)	460	269	179	184 permanent jobs added by 2040

APPENDIX 1: DETERMINING PROJECT EFFECTS

Before you can monetize the benefits of a project, you must first estimate a reasonable approximation of those benefits. The Hwy 6/10 Interchange project area will improve many design elements resulting in more efficient operations and increased safety. It will also introduce ramp metering for the first time to Rhode Island, and that will similarly improve safety and operations.

RIDOT sponsored a 2035 Vissim microsimulation to determine the extent to which their proposed project would improve operations over the Baseline condition, which has short weaves, missing movements, and other deficiencies. The AM and PM peak hours of a typical weekday were simulated. Operational statistics from that analysis were used to estimate the number of trips affected, VMT, and VHT each day, and then daily was extrapolated to annual.

Vissim suggested delay in peak hours would be reduced by about 8% relative to the current design, even though total number of lanes in the system is not increasing. In addition, the NB-10 to WB-6 movement is a lot better off, and should add substantial gains. But this 8% only applies to about 6 hours of the typical weekday. Traffic at other times would not see significant benefits.

The effect of ramp meters was not directly modeled, but FHWA sources regarding ramp metering note that the average improvement across 5 cities with similarities to Providence was 46% reduced delay, and 43% reduced collisions. As a conservative estimate, we assumed half of that benefit, primarily because traffic entering from outside the project area would not be metered, and that could affect conditions within this area. Also, it is more conservative to assume the benefits realized in other cities may not end up as high in Providence for whatever reason.

General Methodology and Assumptions:

The accompanying spreadsheet “RI_FASTLANE_610_Interchange_BCA.xlsx” contains the equations used to convert from 2035 peak hour statistics to 2020 and 2040 Daily and Annual equivalents. Below is the general approach followed in the spreadsheet.

Goal: Starting with 2035 peak hour volumes available from the Vissim modeling, end up with annual values for 2020 and 2040.

1. Developed 2020 values from 2035, by back-casting 15 years, assuming .5% change per year (i.e., 2020 is 92.5% of 2035 – 7.5% smaller). Developed 2040 by forward-

casting for 5 years (i.e., final traffic is 2.5% larger than the 2035 values modeled in Vissim).

2. Applied factor of .77 to the Build VHT, to account for travel time improvements due to ramp metering (1-.46/2 = .77).

3. To derive total daily trips in the system, used data from "Urban Interstate ADJ Factors.pdf," a RIDOT source which suggests that on average about 8.5% of AWDT occurs in the AM peak hour. Thus dividing Vissim's AM peak by 8.5% results in a reasonable estimate of total daily trips within the relevant study area.

4. Converted AM and PM peak hour volumes, VMT, and VHT into 3-hour peak periods, by dividing by .37 (i.e., assumes that 37% of 3-hour volume occurs in heaviest 1 hour). This accounts for peak spreading across the 3-hours, but also acknowledges that 2 of 3 hours are not as heavy as the third hour.

5. Knowing 6 hours of the day, and the whole day, estimated remaining 18 hours. Took care to avoid giving VHT benefits to these 18 hours, other than for the new movements that are better off, but no congestion relief benefits since there would be no congestion.

6. Assumed that overall trips and VMT would be effectively identical between Base vs. Build. There is little evidence to suggest Trips or VMT would be significantly different either way.

7. With a full picture of weekday conditions, computed total weekdays per year using (5/7)*365 = 261, less 10 or so for holidays, = 251 days/yr experiencing significant congestion.

8. For remaining weekend days, computed total trips, VMT, and uncongested VHT. Did not apply metering benefit nor Vissim congestion benefits to these days.

9. Split annual values into "freight-based vs. other" by applying 5% of the traffic stream as freight-based (value reported by RIDOT to be accurate). This is likely conservative, because it does not include a wide aspect of small-scale freight movement that occurs in regular vehicles or full-size vans.

10. The end result of this suggests that the project would improve annual VHT by about 15%, which accounts for off-peak hours and weekends with very little effect.

11. Safety: The national experience from ramp meters appears to be about 42% reduction in accidents, or a CMF of .58. To be conservative, assumed just .80

because other parts of the system are not metered, which can reduce the effects within the areas that are. Also because it is possible Providence simply will not attain the national average for whatever reason. Design improvements will also improve safety: improvements in weaving, wrong-way warnings and other signing, and general modernization of a 50+ year old system, should conservatively result in at least another 5% improvement for a conservative composite CMF of .75.

Refer to "RI_FASTLANE_610_Interchange_BCA.xlsx" to see the above methodology applied, as well as for tables generated by TREDIS based on those inputs.

APPENDIX 2: VALUATION FACTORS

Below are the key input assumptions and valuation factors used within the TREDIS benefit-cost analysis and spreadsheet modeling of emissions and safety benefits. All data sources are documented in footnotes. Conversions to 2016 dollars are made using the Bureau of Labor Statistics CPI Inflation Calculator.[1]

Value of Time

The value of time that was used in this analysis is shown below. Benefit estimation also adopts the FASTLANE suggested car trip purpose splits for intercity travel by conventional surface modes. Freight time costs are calculated within the TREDIS model, using per ton-hour cost factors and a customized regional commodity profile based on the FHWA Freight Analysis Framework.

Table 12 Value of Time by Mode and Purpose

Mode/Purpose	Value (2016 $ per person-hour)[2]	Buffer Time Value
Truck – All	$26.89	$62.34
Car – Business + Personal	$11.85	$11.85

[1] Accessible at: http://www.bls.gov/data/inflation_calculator.htm

[2] Values derived by the TREDIS software group, using multiple sources: Vehicle operating cost per mile is defined for cars as an average of small, medium and large cars and SUV; source AAA (2011). Vehicle operating costs per mile for trucks were calculated by multiplying estimated gallons per mile (FHWA Highway Statistics Series 2010 Data) by applicable gasoline or diesel prices, and then adding in American Trucking Research Institute (ATRI) 2011 data on costs per mile for truck/trailer lease or purchase payments, repair and maintenance, truck insurance premiums, permits and licenses, tires, and tolls. ATRI supplementary data were held constant for all truck types. Diesel prices were drawn from 2011 figures from the U.S. Energy Information Administration "Weekly Retail Gasoline and Diesel Prices" (see http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm). The default value for all trucks is a weighted average based on an estimated mix of truck types.

Vehicle Occupancy

Table 13 Crew, Passenger, and Freight Vehicle Loading Factors

Mode/Purpose	Crew Per Vehicle	Passenger per Vehicle[3]	US Freight Tons Per Vehicle[4]
Truck – All	1.1[5]	0	24
Car – All	0	1.6	0

Vehicle Operating Costs

Table 14 Per-Mile Vehicle Operating Costs

Mode/Purpose	Value (2016 $ per mile)[6]
Truck, Free Flow	$1.06
Car, Free Flow	$0.31
Truck, Congested	$1.31
Car, Congested	$0.33

[3] Based on average vehicle occupancy for car trips from the 2009 NHTS. http://nhts.ornl.gov/tables09/fatcat/2009/avo_TRPTRANS_WHYTRP1S.html

[4] 2002 Vehicle Travel Information System (VTRIS) average estimates of truck share and mean gross vehicle weight for straight trucks and tractor + single trailer trucks nationally, as summarized in FAF2 Freight Traffic Analysis. Chapter 3: Development of Truck Payload Equivalency Factors. Table 3.1: Results of Vehicle Weight Validation. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c3_payload.htm

[5] Based on vehicle occupancy rates for single-unit and combined trucks defined in HERS-ST Highway Economic Requirements System - State Version: Technical Report (http://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech05.cfm#sect552) and the split of 2010 vehicle miles traveled between single-unit trucks and combination trucks on other arterial rural highways, from the 2010 Highway Statistics Series, Annual Vehicle Distance Traveled in Miles and Related Data - 2010 1/ By Highway Category and Vehicle Type (http://www.fhwa.dot.gov/policyinformation/statistics/2010/vm1.cfm).

[6] Values derived by the TREDIS software group, using multiple sources: Vehicle operating cost per mile is defined for cars as an average of small, medium and large cars and SUV; source AAA (2015). Vehicle operating costs per mile for trucks were calculated by multiplying estimated gallons per mile (FHWA Highway Statistics Series 2010 Data) by applicable gasoline or diesel prices, and then adding in American Trucking Research Institute (ATRI) 2011 data on costs per mile for truck/trailer lease or purchase payments, repair and maintenance, truck insurance premiums, permits and licenses, tires, and tolls. ATRI supplementary data were held constant for all truck types. Diesel prices were drawn from 2015 figures from the U.S. Energy Information Administration "Weekly Retail Gasoline and Diesel Prices" (see http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm). The default value for all trucks is a weighted average based on an estimated mix of truck types.

Safety Costs

FASTLANE Guidance recommends monetizing the value of injuries according to the maximum Abbreviated Injury Scale (AIS). Therefore, assumptions must be made to convert aggregate injury crash statistics into the AIS scale. The conversion is made based on the mapping presented in Table 15. Personal injuries are then valued based on the calculations presented in Table 16. Final valuation factors are presented in Table 17.

Table 15 Mapping of Accident Classification to FASTLANE Guidance Classification

Crash Classification	FASTLANE Guidance Classification
Fatality	AIS 6 Unsurvivable
Personal Injury	KABCO Injured (Severity Unknown)
Property Damage	Property Damage Only (PDO) Crashes

Table 16 Calculation of weighted average AIS-based cost for personal injury accidents[7]

AIS	U - Injured Severity Unknown	AIS Cost (2015$)
0	0.21538	$0
1	0.62728	$28,800
2	0.10400	$451,200
3	0.03858	$1,008,000
4	0.00442	$2,553,600
5	0.01034	$5,692,800
	Weighted average (2015 $s)	$174,030

Table 17 Crash Valuation Factors

Value	$ per Fatalities Accident[8]	$ Per Personal Injury Accident	$ Per Property Damage Accident[9]
2015 $	$9,600,000	$174,030	$4,198

Environmental Costs

Emissions generated on a per mile basis were calculated, using information from the U.S. EPA Office of Transportation and Air Quality. Emissions are then valued according to FASTLANE

[7] TIGER and FASTLANE BCA Resource Guide, March 2016, page 3. KABCO/Unknown – AIS Data Conversion Matrix.

[8] TIGER and FASTLANE BCA Resource Guide, March 2016. Table 1, Page 2.

[9] TIGER and FASTLANE BCA Resource Guide, March 2016. Page 4.

Guidance, with a conversion factor from long tons to metric tons of: (2,240 lbs./2,205 lbs) = 1.01587 metric tons per long ton.

Table 18 Emissions Generated on a Per Mile Basis[10]

	Long tons per VMT				
Mode	**VOCs**	**NOx**	**SOx**	**PM**	**CO2**
Passenger Car	1.05E-06	7.04E-07	0.00E+00	4.32E-09	3.74E-04
All Trucks	1.18E-06	2.47E-06	1.79E-09	4.37E-08	9.63E-04

Table 19 Value per Metric Ton of Non-Carbon Emissions

Value per metric ton[11]	VOCs	NOx	SOx	PM
2015 $	$1,844	$7,266	$42,947	$332,405

[10] Values derived by the TREDIS software group, using multiple sources: EPA. Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks, October 2008, http://www.epa.gov/otaq/consumer/420f08024.pdf; Average In-Use Emissions from Heavy-Duty Trucks, October 2008, http://www.epa.gov/otaq/consumer/420f08027.pdf; Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008, http://epa.gov/climatechange/emissions/usinventoryreport.html; MOVES2010 model, March 2010 Build, Database MOVES20091221, in Hours of Service (HOS) Environmental Assessment, 2011, Appendix A, Exhibit A-4, "Long-haul and Drayage Truck Travel Emission Factors," http://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/2011_HOS_Final_Rule_EA_Appendices.pdf; "Policy Discussion – Heavy-Duty Truck Fuel Economy," Presentation by Drew Kodjak, National Commission on Energy Policy, 10th Diesel Engine Emissions Reduction (DEER) Conference, August 29 – September 2, 2004, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/deer_2004/session6/2004_deer_kodjak.pdf.

[11] TIGER and FASTLANE Benefit-Cost Analysis (BCA) Resource Guide, March 2016. Page 6.

Table 20 Value per Metric Ton of Carbon Emissions

Year	CO3 values (2015 $)[12]
2016	43
2017	44
2018	45
2019	46
2020	47
2021	47
2022	48
2023	50
2024	51
2025	52
2026	53
2027	54
2028	55
2029	55
2030	56
2031	58
2032	59
2033	60
2034	61
2035	62
2036	63
2037	64
2038	65
2039	67
2040	68

[12] TIGER and FASTLANE Benefit-Cost Analysis (BCA) Resource Guide, March 2016. Page 7.

APPENDIX 3: TREDIS METHODOLOGY

Inside the TREDIS Model

Project benefits, costs, and economic impacts are estimated using the TREDIS transportation economics suite—the most widely used system for economic impacts of transportation projects in the US and Canada.[13] Embedded within TREDIS is baseline economic data from IMPLAN[14], along with future projections of industry growth by sector from forecasters Moody's Analytics. Also included within the TREDIS model is region-specific data on freight flows by commodity, which enables region-specific valuation of freight time savings.

When conducting a TREDIS analysis, users enter information on transportation performance changes (e.g. travel time and distance) and project timing. Within the benefit-cost module, TREDIS values and discounts these changes according to selected cost factors (detailed in Appendix 2).

When also calculating economic impacts of a transportation project, TREDIS first translates transportation performance changes and cost savings into resulting shifts in household spending and changes in production costs for businesses. An IMPLAN input-output model is then used to calculate how direct project impacts trigger additional macroeconomic changes, including inter-industry (indirect) supply-chain impacts and wage spending (induced) impacts.

Study Region Definition for Economic Analysis

In order to conduct an economic impact evaluation of this project's short and long-term economic effects, the TREDIS model was applied using an IMPLAN-based input-output structure for the entire state of Rhode Island.

[13] For more information, visit www.tredis.com

[14] IMPLAN is the most widely used input-output economic modeling system in the US. This system uses industry- and region-specific economic data to translate direct effects into indirect and induced impacts. More information is available at www.implan.com