Benefit-Cost Analysis of the Route 6/10 and Interstate Route 95 Interchange Project

Prepared for:

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EXECUTIVE SUMMARY

Project Description

The Viaduct section of I-95 that runs through downtown Providence, RI was originally constructed in the 1960's and since then has not experienced any major system upgrades. 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 have overburdened the facility (including on/off ramps) and currently does not efficiently handle today's traffic demands. I-95 plays an important role in commercially linking business markets in New England and New York. In 2015, 2.9 million truck trips passed along this segment of I-95 North Bound (NB), which is expected to grow to 4.1 million trips by 2050.

The Viaduct, now over 50 years old, is dire need of structural replacement due to its deteriorated condition. It requires bi-monthly inspections led by FHWA and RIDOT. It has been identified for full replacement based on its poor structural condition due to age and the traffic loads it carries. The frequency of moderate to severe injury crashes on this section of I-95 is linked to recurring congestion and weaving areas associated with interchanges on this section of the Viaduct. Congestion attributable to traffic on the I-95 viaduct also affects highways with interchanges at I-95.

One such interchange, the Route 6/10 interchange at Dean Street, suffers from insufficient merging lengths and curve radii, unusual and substandard on- and off-ramp configurations among other deficiencies that contribute to local street congestion, creating a traffic burden on neighboring communities.

The need to expand capacity and improve safety for the I-95 viaduct and Route 6/10 interchange has long been identified given (a) the large volumes of traffic presently accommodated by both routes, and (b) the deteriorating condition of many original bridges that support elevated sections of freeway and overpasses (7 of which are classified as Structurally Deficient). Engineers estimate the projects to cost $226M which would improve operating conditions, safety, and efficient freight movement by mitigating weave areas, adding lanes, redesigning on/off ramps, implementing a Collector-Distributor roadway, new pavement and pavement rehabilitation, bridge replacement, and interchange modifications.

This report documents the Benefit Cost Analysis conducted for this project, along with a description of the approach and assumptions that were used as key inputs to that analysis such as travel time improvements, congestion reduction, safety improvements, among others.

Analysis Approach

The benefit cost analysis of the project was prepared per the Benefit-Cost Analysis Guidance for Applicants for FASTLANE Grants published November 17th, 2016 and in 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 changes due to the Route 6/10 and Interstate Route 95 Interchange project between the Baseline (maintain existing conditions) and the Build (a $226 replacement and improvement) scenarios.

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
Growing congestion, frequent accidents, structurally deficient bridges, hazardous weaves, & missing connections	Viaduct replacement, capacity and safety improvements, New Collector – Distributor roadway, interchange modifications, and pedestrian bridge.	Improve speeds, reduce crashes, & increase reliability for cars and freight deliveries	By 2050, 4.1 million truck trips and 78 million auto trips/year are expected to benefit from reduced delay & improved safety	Discounted at 7%, benefits are expected to be **$253** million between 2021 and 2050	Benefit Cost Ratio of **1.72** expected due to travel time, operating costs, reliability, safety, and emission benefits	***p.4***

Table 1 summarizes the types of outcomes that have been identified for the project and the assessment approach used to prepare the benefit-cost assessment. These outcomes are organized per FASTLANE selection criteria. As detailed in Section 1 of this report, the quantification of benefits involves both spreadsheet evaluations and calculations performed by the Transportation Economic Development Impact System (TREDIS) decision support tool (See Appendix 3).

The time horizon of the benefit-cost analysis covers a construction period from 2017-2024 and an operational period from 2021-2050. 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***
Economic Competitiveness	Travel time savings from reduced congestion & resulting diversion	Quantitative assessment (TREDIS) ***Refer to Section 1.2***
	Operating cost savings from avoided congestion & resulting diversion	Quantitative assessment (TREDIS) ***Refer to Section 1.3***
	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 1.4***
Environmental Sustainability	Emission benefits from reduced congested conditions	Quantitative assessment (Spreadsheet) ***Refer to Section 1.5***
Quality of Life	Improved mobility for residents and businesses connected by this road segment	Qualitative Assessment ***Refer to Section 0***

Summary of Benefits and Costs

Completion of the Route 6/10 and Interstate Route 95 Interchange project 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. Business time and reliability benefits come from passenger car use associated with a business purpose (e.g. "on-the-clock") as well as driving crews responsible for freight deliveries (Table 3). Personal time and reliability benefits are associated with all car use for personal purposes. 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 **1.72 (**Table 4**)**. A sensitivity analysis using a **3%** discount rate results in a benefit-cost ratio of **3.39**. 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	**$252.8**
Business Time & Reliability	$23.1
Personal Time & Reliability	$90.9
Logistics & Supply Chain Benefits	$6.6
Vehicle Operating Cost Savings	$51.2
Safety Benefits	$64.0
Environmental & Social Benefits	$16.9

Table 4 Summary of Benefits and Costs

	Undiscounted	Discounted at 3%	Discounted at 7%
Project Costs*	$226.1	$196.1	$164.2
O&M Costs	-$52.9	-$30.6	-$17.1
Total Costs	$173.2	$165.6	$147.1
Total Benefits	$1,135.5	$560.6	$252.8
Benefit-Cost Ratio	***N/A***	***3.39***	***1.72***

* Project costs include capital outlays and adjustments for O&M costs.

Summary of Economic Impacts

In addition to monetizing project benefits, economic impacts of the Route 6/10 and Interstate Route 95 Interchange improvements were estimated using the TREDIS decision support tool. The project is expected to provide an average of 247 jobs/year during construction of the facility. The total number of permanent jobs increases each year up to 51 by 2050, due to long-term efficiency gains as businesses expand their sales and household increase their purchases, both of which are enabled by travel cost savings.

Table 5 Summary of Economic Impacts

	Cumulative Impacts			
Source of Impact	Business Output ($ mil.)	GRP ($ mil.)	Wage Income ($ mil.)	Jobs
Construction (2017-2024)	$324	$186	$106	247 average over period
Improved Transportation Efficiency (2021-2050)	$161	$77	$49	51 permanent jobs added by 2050

Methodology for Obtaining Key Inputs

Benefits are determined based on the amount of Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), reductions in the percentage of travel under congested conditions, and improvements to safety. At the end of this report **Appendix 1: Determining Project Effects** provides an overview of how key inputs to the analysis were determined and includes instructions for making use of an accompanying Excel workbook. This workbook provides detailed output that was used in creating the summary tables in this document.

1 RESULTS OF BENEFIT-COST ANALYSIS

1.1 Project Costs (State of Good Repair)

Design and construction of the Route 6/10 and Interstate Route 95 Interchange project scheduled to occur over the eight-year period from 2017-2024. Undiscounted, the project is expected to cost $226 Million. The age of structures in this area is over 50-years old and the constant wear and tear associated with truck and automobile traffic, combined with salt applications each winter, has taken its toll on these bridges.

Engineers estimate it would cost between $1 Million to $2.7 Million in annual operations and maintenance expenditures from 2017 to 2050 just to keep the existing Viaduct and 6/10 interchange functioning if the project was not implemented for a total of nearly $58 Million over the analysis period. However, by addressing the inadequate structural conditions of the Viaduct among other improvements, operation and maintenance costs are estimated to significantly decline from $130,000 in the early years to $270,000 per year in later years, a total of only $4.8 Million. A summary of the differences in project and O&M costs with and without the project is shown below in Table 6. The negative values in the O&M costs row reflect the fact that the project improvements will require less expenditures to operate and maintain the new facility than compared to supporting the older and deteriorating structures.

Table 6 Summary of Costs (in millions)

Cost Category	Undiscounted	Discounted at 3%	Discounted at 7%
Project Costs*	$226.1	$196.1	$164.2
O&M Costs	-$52.9	-$30.6	-$17.1
Total Costs	**$173.2**	**$165.6**	**$147.1**

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

1.2 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 the base and project scenarios, 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 available with year-by-year detail in the accompanying spreadsheet. *Logistics and Supply Change Benefits* account 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, 2021-2050 (in millions)

Savings Category	Undiscounted	Discounted 3%	Discounted 7%
Business Time & Reliability	$107.1	$53.1	$23.1
Personal Time & Reliability	$424.4	$209.7	$90.9
Logistics & Supply Chain Benefits	$31.1	$15.3	$6.6
Total Time-Related Benefits	**$562.6**	**$278.1**	**$120.6**

Values of time and reliability savings as calculated by TREDIS are presented in the "Benefits by Year" tab of the Appendix spreadsheet.

1.3 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 project scenarios along with per-mile operating cost factors for cars and trucks. The cost-factors and their underlying assumptions are summarized in **Appendix 2**.

Table 8 Savings in Vehicle Operating Costs, 2021-2050 (in millions)

Savings Category	Undiscounted	Discounted at 3%	Discounted at 7%
Vehicle Operating Savings	$240.6	$118.6	$51.2

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

1.4 Safety Benefits

Safety benefits include monetized savings associated with reductions in the number of crashes occurring per year. The project is expected to reduce the number of crashes that currently occur due to design improvements which reduce weave areas, expand lane capacity, enable safer entry and exit via on/off ramps, and facilitate improved interchange functionality.

Table 9 Value of Safety Benefits, 2021-2050 (in millions)

Savings Category	Undiscounted	Discounted at 3%	Discounted at 7%
Safety Benefits	$295.8	$146.8	$64.0

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

1.5 Environmental Sustainability

Environmental sustainability benefits are derived from reductions in a variety of emissions because of improved vehicle operations. The project is not likely to change overall VMT significantly but it will reduce delay and congested conditions, thus stabilizing 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. Benefits are categorized by CO_2 and other emissions that include volatile organic compounds, nitrogen oxides, sulfur dioxide, and particulate matter (Table 10).

Table 10 Value of Environmental Benefits, 2021-2050 (in millions)

Savings Category	Undiscounted	Discounted at 3%	Discounted at 7%
Reductions in CO_2	$35.5	$16.7	$16.7
Other emissions reductions	$1.0	$0.5	$0.2
Total Environmental Benefits	**$36.4**	**$17.2**	**$16.9**

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.

Emissions savings as calculated by TREDIS are presented in the "Emissions by Year" tab of the Appendix spreadsheet.

1.6 Quality of Life

Prior sections of this benefit cost analysis have focused on quantifying the costs imposed on trucks and cars in scenarios with and without the Route 6/10 and Interstate Route 95 Interchange project. While these quantitative assessments clearly demonstrate the value of the project, there is an additional qualitative story to be told about the benefits of the project in supporting quality of life in Providence. The project is expected to provide local quality of life benefits to the surrounding urban core area within the City of Providence through improvements in air quality, pedestrian circulation, and access to transportation options.

2 ECONOMIC IMPACTS

In addition to the benefit-cost analysis described in previous sections, an economic impact analysis was also performed for the Route 6/10 and Interstate Route 95 Interchange 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 direct effects (jobs, income, GRP, and business output directly resulting from construction outlays or transportation savings) and 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 decision support tool. 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 Project scenario relative to the Base scenario is expected to support an average of 247 construction jobs during the construction period and a total of 51 permanent jobs by 2050, created through higher efficiency of the Project scenario relative to the Base scenario.

Table 11 Summary of Economic Impacts

Source of Impact	Cumulative Impacts			Jobs
	Business Output ($ mil.)	GRP ($ mil.)	Wage Income ($ mil.)	
Construction (2017-2024)	$324	$188	$106	247 average over period
Improved Transportation Efficiency (2021-2050)	$161	$77	$49	51 permanent jobs added by 2050

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 Route 6/10 and Interstate Route 95 Interchange project will improve many design elements resulting in more efficient operations and increased safety.

RIDOT sponsored a 2035 Vissim microsimulation to determine the extent to which their proposed project would improve operations over the baseline condition, which in addition to being overcapacity is prone to accidents due to recurring congestion, weaving driven by the location of on/off ramps, insufficient merge lengths, and other deficiencies. The AM and PM peak hours as well as the Rest of Day (ROD) periods of a typical weekday were simulated. Operational statistics from that analysis were used to estimate the number of trips affected, daily VMT, and daily VHT. These daily estimates were then extrapolated to annual values.

Additional assumptions and modifications were applied to the Vissim results such as the expected speed improvement for traffic on I-95 (3 mph) and local traffic diverting to I-95 (1.5 mph) due improved speed and less congested conditions. Level of Service (LOS) "D" was used as a basis to assess changes in congestion attributable to the construction of the project.

Other assumptions:

- Trips diverted from local roads to I-95 because of improved speeds, less congestion, and safer conditions in the year 2035 were also added to the 2020 scenarios with and without the project.
- Calculated benefits are a conservative estimate because network effects of less traffic on arterial and local road systems due to diversions onto I-95 were not included in the micro-simulation model.

General Methodology and Assumptions:

The accompanying spreadsheet "RIDOT FastLane I-95 NB BCA Appendix.xlsx" contains the equations used to convert from 2035 peak hour (AM & PM) and rest of day (ROD) statistics to 2020 and 2050 Daily and Annual equivalents (tab "Transportation Performance"). Below is the general approach followed in the spreadsheet.

Goal: Starting with 2035 volumes available from the Vissim modeling, compute annual values for 2020 and 2050.

1. Adjusted 2015 trip values to include diverted trips which represented 21% - 27% of 2035 values. Estimates for 2020 trip values calculated by applying a compound annual growth rate (CAGR) between adjusted 2015 and 2035 Project scenario trip values. 2035 base scenario trips were increased to include diverted trips because all trips are within the state of Rhode Island.
2. Annualized average weekday trips per year using 5 days * 52 weeks = 260 days.
3. Trip Purposes were applied for Business related trips (10%) and Personal related trips (90%)
4. An average distance of 5 miles was used to compute the reduction of vehicle operating costs associated less congested conditions as well as to estimate changes in travel time and improved reliability for each passenger car and truck trip within the geographic boundary of the Vissim model simulation for the project (per VHB).
5. Speeds were increased by an average of 3 miles per hour for all vehicles on I-95 North Bound associated with the project based on expected average speeds increases on I-95 NB within Providence county rather than just within the 5-mile geography evaluated by Vissim (information provided by VHB). For traffic anticipated to divert from local roads onto I-95 NB this 3-mph speed improvement was reduced in half (1.5 mph) to account for the speed difference compared to those experienced on the local road network.
6. Congestion levels were adjusted to raise the threshold of congested conditions from a Level of Service (LOS "C") to a LOS "D". This was accomplished by reducing the percent of VMT experiencing congestion levels by 50% which still maintains the same percentage difference in congestion reduction enabled by the project. This was done to provide a more conservative estimate of congestion reduction. More reliable driving conditions are achieved by reducing the amount of buffer time added to trip planning and departures to ensure an on-time arrival.
7. Safety improvements were based on the expectation of reduced accidents. Along this section of I-95, an estimated 100 personal injury and 500 property damage only accidents occurred within the past 5 years. It is expected that both within the next 5 years and all subsequent 5 year increments until 2050, the number of personal injury accidents will be reduced to 80 and property damage only accidents will be reduced to 400, an overall 20% reduction for both types of accidents.
8. Currently, an average of 50 pedestrian trips that cross under the I-95 Viaduct are estimated to occur daily. Annualizing these trips over 365 days in a year results in

over 18,000 pedestrian trips per year which were estimated to grow .5% annually until 2050. With the addition of the pedestrian bridge, it is estimated that each pedestrian trip will incur an additional delay of 2 minutes per trip by taking the elevator up, walking along the bridge spanning I-95, and then taking the elevator to descend to the street level. Additional delay could occur of the stairs are used instead of the elevator. No information was found that could be used to estimate changes in safety by taking the pedestrian bridge over I-95 instead of walking underneath I-95.

Refer to “RIDOT FastLane I-95 NB BCA Appendix.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 (2015 $ per person-hour)[2]	Buffer Time Value[3]
Truck – All	$27.2	$72.57
Car - Business	$25.4	$25.4
Car - Personal	$13.6	$13.6

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

[2] Values based on FastLane BCA Resource Guide on recommended hourly values of travel time savings (2015$'s).

[3] The costs of travel time variability (non - recurring delay) is calculated using the concept of "buffer time", which is defined as the additional schedule time needed to ensure an on-time arrival 95% of the time (19 out of every 20 trips) versus the average travel time. For example, if a weekday commute normally (i.e., on average) takes 30 minutes to complete, but unplanned congestion causes 5% of trips (about 1 per month) to take 45 minutes, then the commuter must schedule 45 minutes for the trip on the average day to ensure an on-time arrival (even though it is likely to only to take 30 minutes). This trip therefore requires 15 minutes of "buffer time". For passenger travel, buffer time has been shown to be valued similarly to travel time unless a schedule constraint exists. For freight, the value of buffer time can vary widely for carrier types and commodity, but is generally higher than passenger travel (relative to travel time). US DOT reports that the value of reliability can vary from 20% to 250% of "standard" delay (http://ops.fhwa.dot.gov/freight/documents/improve_econ.pdf)

Vehicle Occupancy

Table 13 Crew, Passenger, and Freight Vehicle Loading Factors

Mode/Purpose	Crew Per Vehicle	Passenger per Vehicle[4]	US Freight Tons Per Vehicle[5]
Truck – All	1.1[6]	0	24
Car – Business	0	1.22	0
Car - Personal	0	1.84	0

Vehicle Operating Costs

Table 14 Per-Mile Vehicle Operating Costs

Mode/Purpose	Value (2015 $ per mile)[7]
Truck, Free Flow	$1.08
Car, Free Flow	$0.31
Truck, Congested	$1.33
Car, Congested	$0.33

Safety Costs

FASTLANE Guidance recommends monetizing the value of injuries per 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

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

[5] 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

[6] 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). The default crew size for all trucks is a weighted average based on an estimated mix of truck vehicles.

[7] 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.

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[8]

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[9]	$ Per Personal Injury Accident	$ Per Property Damage Accident[10]
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 per FASTLANE 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.

[8] FASTLANE BCA Resource Guide, Nov. 17th, 2016. Page 12, Table 4. KABCO/Unknown – AIS Data Conversion Matrix.
[9] FASTLANE BCA Resource Guide, Nov. 17th, 2016. Page 2, Table 1.
[10] FASTLANE BCA Resource Guide, Nov. 17th, 2016. Page 3, Table 1.

Table 18 Emissions Generated on a Per Mile Basis[11]

	Long tons per VMT				
Mode	**VOCs**	**NOx**	**SOx**	**PM**	**CO_2**
Passenger Car	1.14E-06	7.64E-07	0.00E+00	4.68E-09	4.06E-04
Trucks (Free Flow)	4.9E-07	9.49E-06	6.28E-09	2.32E-07	2.12E-03
Trucks (Congested)	6.9E-07	1.33E-05	8.80E-09	3.25E-07	2.96E-03

Table 19 Value per Metric Ton of Non-Carbon Emissions

Value per metric ton[12]	VOCs	NOx	SOx	PM
2015 $	$1,844	$7,266	$42,947	$332,405

[11] 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.

[12] FASTLANE Benefit-Cost Analysis (BCA) Resource Guide, Nov. 17th, 2106. Page 5.

Table 20 Value per Metric Ton of Carbon Emissions

Year	CO3 values (2015 $)[13]
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

[13] FASTLANE Benefit-Cost Analysis (BCA) Resource Guide, Nov. 17th, 2016. Page 6.

APPENDIX 3: TREDIS METHODOLOGY

Inside the TREDIS Model

Project benefits, costs, and economic impacts are estimated using the Transportation Economic Development Impact System (TREDIS) decision support tool —the most widely used system for economic impacts of transportation projects in the US and Canada.[14] Embedded within TREDIS is baseline economic data from IMPLAN[15], 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 per 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

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.

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

[15] 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