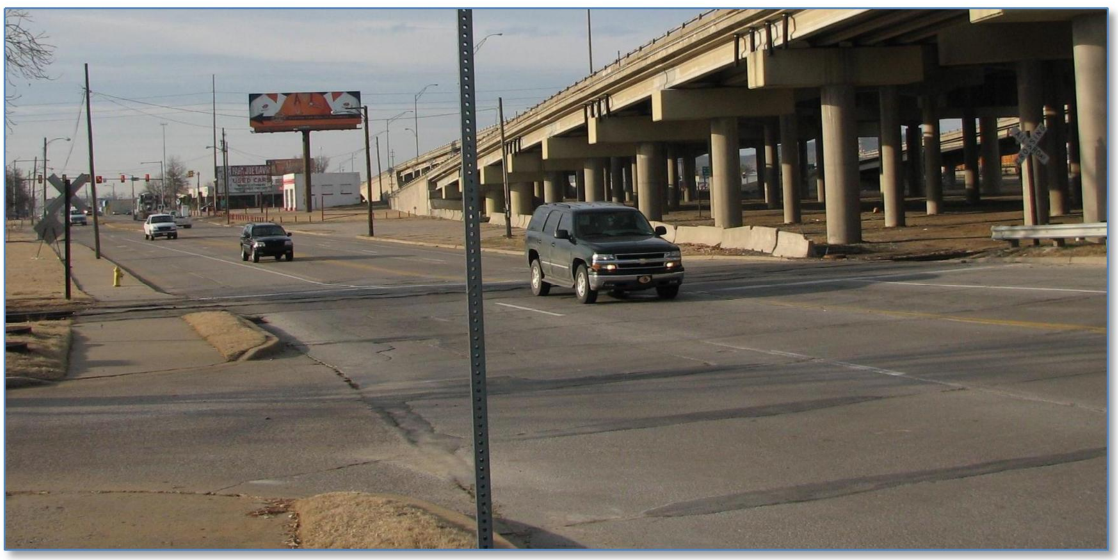
Oklahoma Urban Railroad Crossing
Safety Improvement Project

Benefit Cost Analysis Technical Memo



TIGER VII Grant Application
Oklahoma Department of Transportation

June 5, 2015

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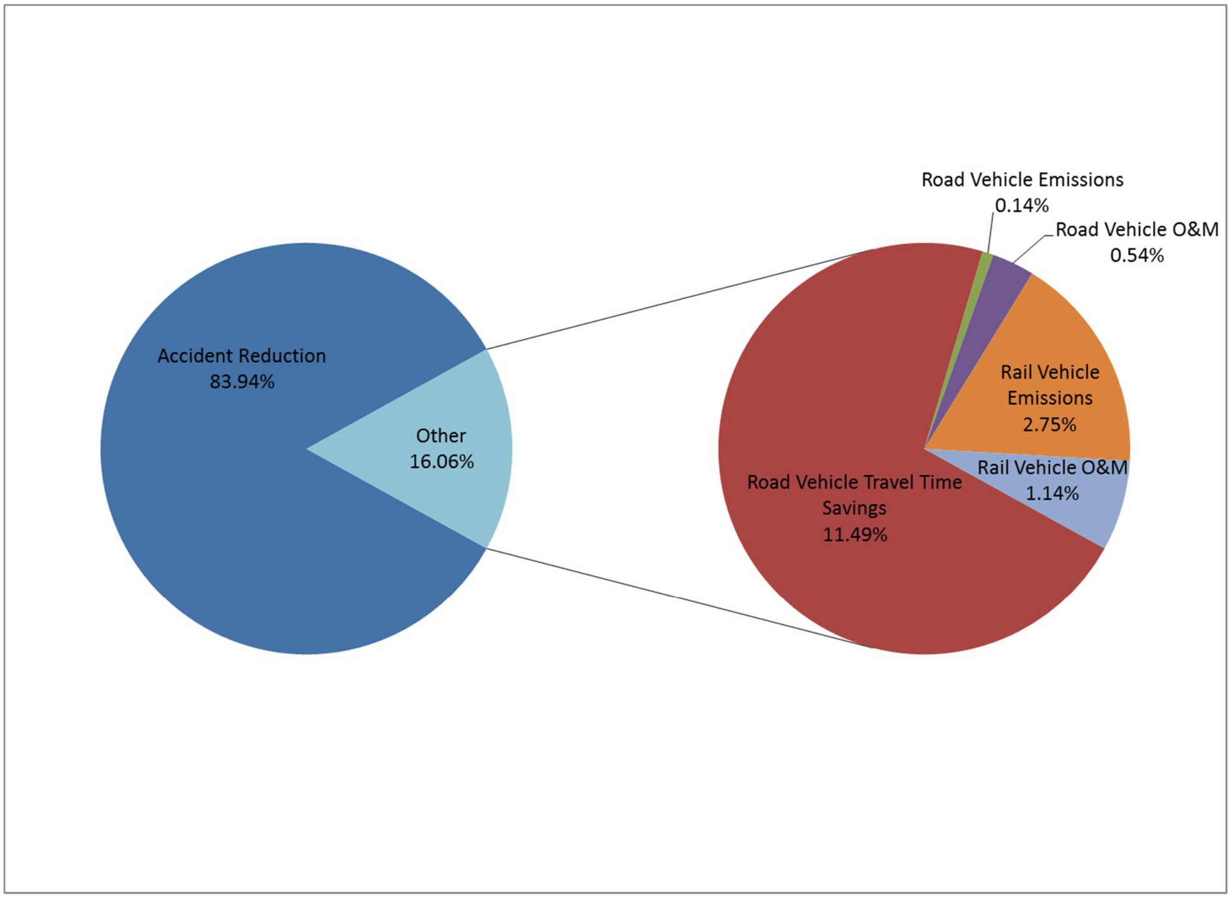
Executive Summary

A formal benefit-cost analysis (BCA) was conducted for the modernization and improvement of rail safety infrastructure at 23 railroad crossings in the Oklahoma City and Tulsa metropolitan areas. These improvements will help **prevent accidents** from occurring at the grade crossings and will **improve freight train fluidity and speed,** which will enhance economic competitiveness throughout the region.

At a 7 percent discount rate, this project is expected to cost $10.4 million, and will provide an estimated $39.3 million in total benefits, predominantly as a result of accident reduction (Figure 1). The resulting net present value is $28.9 million and the **benefit/cost ratio is 3.79**.

Figure 1: Sources of Evaluated Benefits



Construction is expected to begin in 2016 and be completed by 2019. Twenty years of benefits were modeled in the BCA, and cumulative benefits are expected to surpass cumulative project costs before the end of the fourth year of operation (see Figure 2).

A summary of the benefits evaluated for this project is provided in Table 1.

Figure 2: Cumulative Benefits and Costs in 2014 Dollars (Discounted at 7 percent)

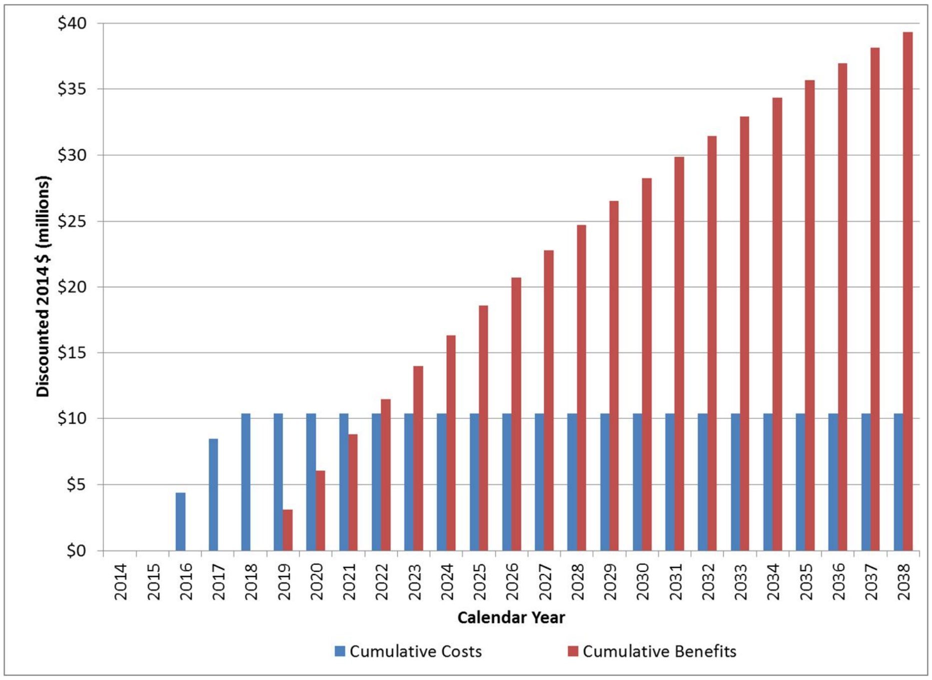


Table 1: Project Impact and Benefits Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline/Alternatives	Type of Impact	Population Affected by Impact	Economic Benefit	Summary of Results (at 7% discount rate)	Summary of Results (at 3% discount rate)	Page Reference in BCA
Safety at road/rail grade crossings	Gates installed along with other crossing safety infrastructure	Reduced accident frequency	Auto, truck, and bus drivers and passengers, along with their families and friends	Reductions in fatalities, injuries, and property damage	$33.0 million	$54.6 million	pp. 9-11
Delay at road/rail grade crossings	Lengthened circuit approaches at 4 crossings, resulting in faster train speeds	Improved diesel fuel efficiency for rail transport	Society and surrounding communities	Reductions in rail vehicle emissions	$1.1 million	$1.8 million	p. 11
Delay at road/rail grade crossings	Lengthened circuit approaches at 4 crossings, resulting in faster train speeds	Faster train speeds	Railroad companies, shippers, end consumers of bulk commodities	Reductions in rail operating costs	$448,400	$751,400	p. 12
Delay at road/rail grade crossings	Lengthened circuit approaches at 4 crossings, resulting in faster train speeds	Reduced idling at grade crossings	Auto, truck, and bus drivers and passengers with reduced wait times	Travel time savings for road vehicles	$4.5 million	$7.9 million	pp. 12-13
Delay at road/rail grade crossings	Lengthened circuit approaches at 4 crossings, resulting in faster train speeds	Reduced idling at grade crossings	Automobile owners, trucking and bus companies	Reductions in road vehicle operating costs	$211,000	$362,400	p. 13
Delay at road/rail grade crossings	Lengthened circuit approaches at 4 crossings, resulting in faster train speeds	Reduced idling at grade crossings	Society and surrounding communities, due to less idling	Reductions in road vehicle emissions	$54,400	$94,800	pp. 13-15

Background

As described in the project application, rail traffic through Oklahoma has increased in recent years, with much of the growth coming from Bakken crude shipped from North Dakota to refineries along the Gulf Coast. In addition, the development of the BNSF Railway "Mid-Con Corridor" from Houston to Canada (which goes through Oklahoma City and Tulsa) is expected to enhance the flow of oil, coal and agricultural products and thereby increase rail traffic on Oklahoma railroads.

The Metropolitan Planning Organizations (MPOs) of Oklahoma City and Tulsa are respectively predicting a 33% and 39% increase in population in the metropolitan areas, with an associated increase in motor vehicle traffic of 35% and 40% by 2035.

Because of these projected increases for both railroad and motor vehicle traffic, a TIGER VII application was submitted to improve the safety of Oklahoma's most critical railroad/road crossings while reducing the potential for crude shipment related incidents.

The State of Oklahoma, through the Oklahoma Department of Transportation (ODOT), plans to address the growing potential hazard associated with increased train and motor vehicle traffic at these crossings by upgrading railroad crossing warning devices, enhancing crossing geometry and addressing sight distance issues to provide safer operations for the traveling public, railroad operators, and residents living near these crossings.

Figure 3: Proposed Grade Crossing Improvements in the Oklahoma City Urban Area

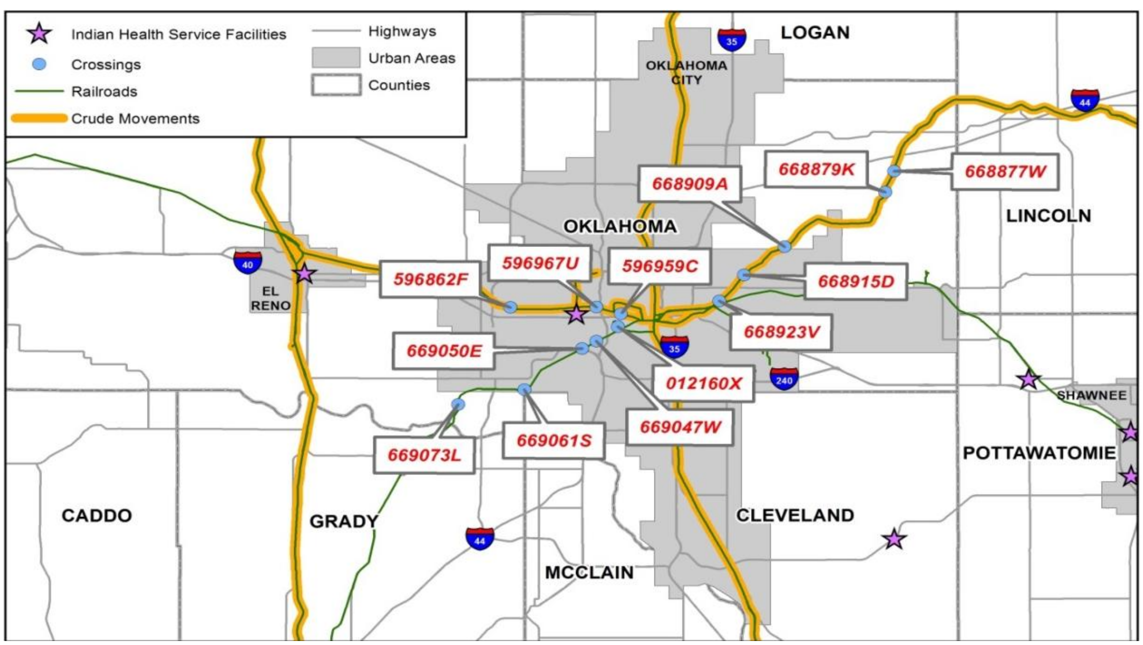
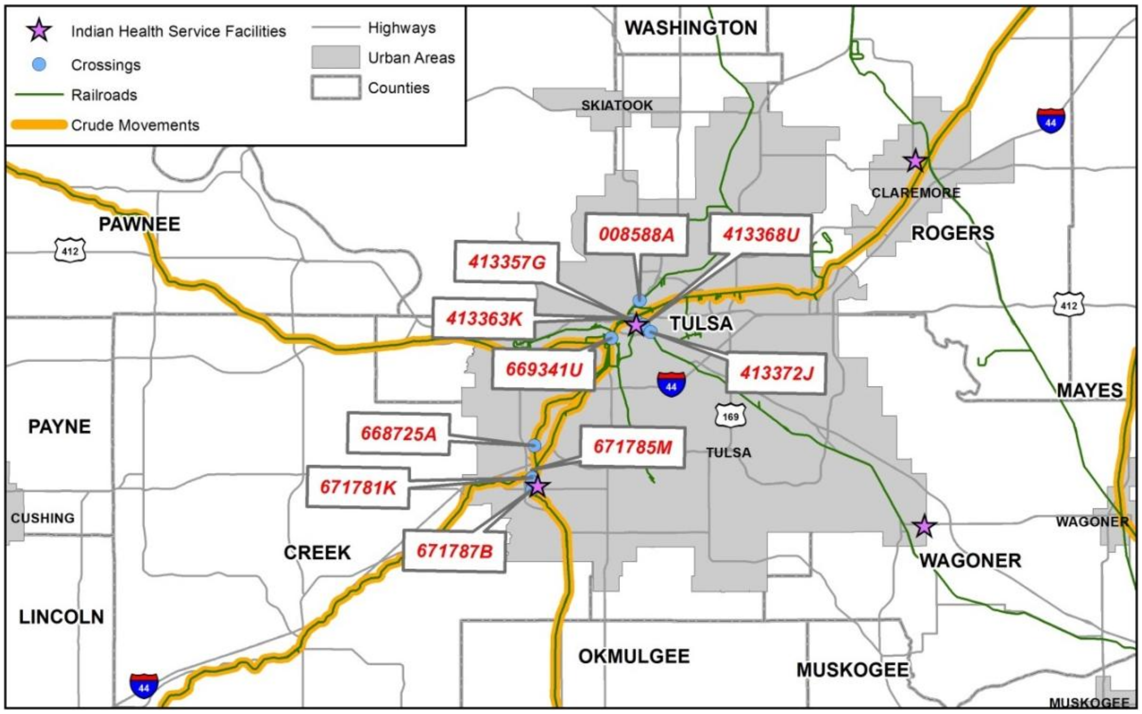


Figure 4: Proposed Grade Crossing Improvements in the Tulsa Urban Area



This project will modernize and improve rail safety infrastructure at 23 urban railroad crossings that either experience high volumes of unit trains transporting crude oil, or which intersect highway routes that serve Indian Health Service Facilities (shown in Figures 3 and 4).

This BCA was conducted for submission to the U.S. Department of Transportation (U.S. DOT) as a requirement of a discretionary grant application for the TIGER VII program. The analysis was conducted in accordance with the benefit-cost methodology recommended by U.S. DOT in the Federal Register,[1] and other guidance provided on the TIGER program website.[2]

Discount Rates

Dollar figures throughout the BCA are expressed in constant 2014 dollars. In instances where certain cost estimates or benefit valuations were originally provided in dollar values in other (historical) years, the U.S. Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) was used to adjust them.[3]

[1] 80 Fed. Reg. 18283.

[2] http://www.dot.gov/tiger/guidance

[3] U.S. Bureau of Labor Statistics. Consumer Price Index, All Urban Consumers, U.S. City Average, Series CUSR0000SA0. 1982-1984=100

The real discount rates used for this analysis were 3.0 and 7.0 percent, consistent with U.S. DOT guidance for TIGER grants[4] and OMB Circular A-94.[5]

Evaluation Period

The evaluation period for the project includes the relevant (post-design) construction period during which capital expenditures are undertaken, plus 20 years of operations beyond the end of construction within which benefits accrue. Although the expected lifespan of the project's infrastructure is longer than 20 years, no residual value was assumed as there is no right-of-way acquisition, and the signal and surfacing infrastructure improvements themselves are of low liquidity.

For the purposes of this analysis, it has been assumed that construction begins January 1, 2016 and continues through December 31, 2018. The new and upgraded infrastructure will become serviceable at all crossings on January 1, 2019 and the analysis period therefore begins with the first year of benefits in 2019 and continues for 20 years through 2038. All benefits and costs are assumed to occur at the end of each year.

Project Region

This proposed multi-location, multi-jurisdictional project will upgrade 13 urban railroad crossings in the Oklahoma City metropolitan area (Figure 3) and 10 urban railroad crossings in the Tulsa metropolitan area (Figure 4) with new gated signal installations and other crossing improvements to enhance the safety of motor vehicle and railroad operations. Four of the project crossings, located along the Stillwater Central Railroad's Sooner Subdivision linking Tulsa and Oklahoma City, will also be equipped with lengthened circuit approaches, which have the additional benefit of facilitating train speeds of 10 mph higher than present over approximately 20 miles of track.

Key Benefit-Cost Evaluation Measures

As described in the application, the project's benefits pertain to each of the five long-term benefit categories specified in the TIGER Notice of Funding Availability: Safety, Sustainability, Economic Competitiveness, Livability, and State of Good Repair. The project benefits are both quantitative and qualitative, and were monetized where possible. Unquantifiable benefits are discussed in the application.

The calculated project impacts over the twenty year evaluation period are shown in Table 2, which shows the magnitude of change and direction of the various impact categories. These impacts were used to develop the total values of the benefits.

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[4]TIGER 2015 NOFA: Benefit-Cost Analysis Guidance, Updated March 27, 2015; http://www.dot.gov/tiger/guidance

[5] White House Office of Management and Budget, Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (October 29, 1992). (http://www.whitehouse.gov/omb/circulars_a094).

Table 2: Project Impacts, Cumulative 2019-2038 (inclusive)

Category (Units)	Quantity
Road vehicle travel time (person-hours)	▼ 735,326
Road vehicle travel time (vehicle-hours)	▼ 506,007
Rail travel time (train-hours)	▼ 4,605
Rail vehicle emissions (tons of CO_2, NO_x, and PM)	▼ 3,880
Road vehicle emissions (tons of CO_2, NO_x, PM, and VOC)	▼ 1,513
Total accidents (number)	▼ 67
Total fatalities (number)	▼ 8

Project Impacts and Economic Benefits

The project's monetized benefits are as follows:

- Accident reduction: With improved signaling and rail safety infrastructure, the frequency of accidents will decrease.
- Rail emissions reduction: More efficient rail operations will optimize diesel fuel usage, reducing emissions of pollutants such as CO_2, NOx, and particulate matter.
- Rail operating cost savings: Part of the project crossing improvements include lengthened circuit approaches at four crossings along the Sooner Subdivision, which will allow rail to run more efficiently through this corridor (10 mph faster than current speeds).
- Road vehicle travel time savings: Faster train speeds through four of the crossings translates into decreased time that roadways are blocked, which minimizes idling and allows commuters to reach their destinations more quickly.
- Road vehicle operating cost savings: Reduced idling means less fuel wasted and less wear and tear on road vehicle engines. The resulting cost savings can be viewed as additional disposable income for vehicle owners.
- Road vehicle emissions reduction: Less fuel consumption as a result of reduced idling translates into less air pollution from road vehicles.

Table 3 shows the overall results of the BCA in terms of Net Present Value and as a Benefit-Cost (B/C) ratio:

- **Net Present Value (NPV)** provides the present value of the project's benefits minus the present value of the project's costs. The NPV provides a sense of the overall benefits of the project in today's dollar terms.

- **Benefit Cost (B/C) ratio** represents the present value of benefits divided by the present value of project costs. The B/C ratio is a measure of the extent to which a project's benefits either exceed or fall short of their associated costs.

At a 7 percent discount rate, the project yields a net present value of $28.9 million and a benefit-cost ratio of 3.79 over a 20-year analysis period. Using a 3 percent discount rate, the net present value and benefit-cost ratio are $54.0 million and 5.69 respectively. The rest of this Technical Memo describes the methodology and assumptions used to develop these numbers.

Table 3: Benefit-Cost Analysis Summary Results

Category	Present Value at 7%	Present Value at 3%
Evaluated Costs		
Capital Costs	$10,405,629	$11,565,153
Maintenance Costs	($33,137)	($54,196)
TOTAL COSTS	**$10,372,493**	**$11,510,957**
Evaluated Benefits		
Accident Reduction	$32,993,442	$54,590,541
Rail Emissions Reduction	$1,082,160	$1,813,552
Rail Operating Cost Savings	$448,391	$751,441
Road Vehicle Travel Time Savings	$4,516,280	$7,876,786
Road Vehicle Operating Cost Savings	$210,961	$362,432
Road Vehicle Emissions Reduction	$54,379	$94,782
TOTAL BENEFITS	**$39,305,613**	**$65,489,534**
NET PRESENT VALUE	**$28,933,120**	**$53,978,577**
BENEFIT/COST RATIO	**3.79**	**5.69**

Traffic Growth Assumptions

This project considers two forms of vehicular traffic: road traffic and rail traffic. In both cases, the growth rates of train and vehicle miles are assumed to grow at the same rate in the No Build and Build scenarios. In other words, the project is not expected to have an impact on total rail or road vehicle miles traveled (VMT).

The growth in vehicle traffic expected as population rises is an important consideration because there are accident rate and travel time implications. As travel demand increases (provided the infrastructure has the capacity to accommodate the incremental demand), the number of accidents will increase and so will the number of vehicles experiencing delay at rail grade crossings. Growth in rail traffic will also increase the potential for accidents at grade crossings and the number of road vehicles experiencing delay.

Road traffic at each of the crossings for the year 2014 was provided by ODOT. For 2015-2038, road traffic was assumed to increase at 2 percent per year, in keeping with average annual daily traffic (AADT) growth rates seen across the United States.

Similarly, rail traffic at each of the crossings was supplied for the year 2014 by ODOT. The growth rate for rail traffic is based on the growth of ton-miles of freight shipped by rail in the United States, which is also approximately 2 percent per year.

In addition to the above assumptions about travel demand, a sensitivity analysis was used to test a +/- 10 percent sensitivity on all travel demand figures. The results of the sensitivity analysis are presented at the end of this Technical Memo.

Economic Benefits Included

The following section identifies and classifies the benefits monetized in this BCA. It provides descriptions of the assumptions and valuations used in assessing each benefit category. In addition, model output summary tables of all benefit valuations for each year of the analysis are available in the Benefit-Cost Model Detail Tables at the end of this Technical Memo.

Safety – Accident Reduction

The cost savings that arise from a reduction in the number of accidents include both direct savings (e.g., reduced personal medical expenses and lost wages, and reduced vehicle damage costs), as well as significant avoided costs to society (e.g., reduced insurance premiums, emergency response costs, incident congestion costs, litigation costs, and economic productivity losses due to worker inactivity).

Accident rates for this analysis were derived using the U.S. DOT Accident Prediction Model (APM). Crossing-specific data in the No Build and Build scenarios was supplied by ODOT and used as input to the APM along with historical accident reports from the FRA grade crossing database. As an output from the model, two sets of accident rates were generated for each crossing – one set for the No Build and one for the Build. The difference between the two rates represents the anticipated accident reduction that will result from the project. The accident prediction formulas used in the calculations are described in Figure 5.

Results from the accident prediction model were broken down into fatalities versus non-fatalities using the accident details shown in the BTS Highway-Rail Grade Crossing Incidents (2012).[6] The non-fatal accident rates were further broken down into the AIS categories following the percentages indicated in the TIGER BCA Resource Guide. Table 4 summarizes the full breakout of accident rates by category of severity.

Table 4: Distribution of Accidents by Category (Severity Level)

Category	Percentage
Fatality	11.7%
AIS 5	0.2%
AIS 4	0.5%
AIS 3	4.3%
AIS 2	7.8%
AIS 1	36.8%
Property Damage Only	38.5%

[6] Bureau of Transportation Statistics Table 2-11: Highway-Rail Grade Crossing Incidents (2012) http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2014/index.html/chapter2/table2-11

Figure 5: Accident Prediction Model Formulas

Basic Accident Prediction Formula: $a = K * EI * MT * DT * HP * MS * HT * HL$

Crossing Category	Formula Constant **K**	Exposure Index Factor **EI**	Main Tracks Factor **MT**	Day Thru Trains Factor **DT**	Highway Paved Factor **HP**	Maximum Speed Factor **MS**	Highway Type Factor **HT**	Highway Lanes Factor **HL**
Passive	0.002268	$\left(\frac{c * t + 0.2}{0.2}\right)^{0.3334}$	$e^{0.2094mt}$	$\left(\frac{d + 0.2}{0.2}\right)^{0.1336}$	$e^{-0.616(hp-1)}$	$e^{0.0077ms}$	$e^{-0.1(ht-1)}$	1.0
Flashing Lights	0.003646	$\left(\frac{c * t + 0.2}{0.2}\right)^{0.2953}$	$e^{0.1088mt}$	$\left(\frac{d + 0.2}{0.2}\right)^{0.0470}$	1.0	1.0	1.0	$e^{0.1380(hl-1)}$
Gates	0.001088	$\left(\frac{c * t + 0.2}{0.2}\right)^{0.3116}$	$e^{0.2912mt}$	1.0	1.0	1.0	1.0	$e^{0.1036(hl-1)}$

c = annual average number of highway vehicles per day
t = average total train movements per day
mt = number of main tracks
d = average number of thru trains per day during daylight
hp = highway paved, yes = 1.0, no = 2.0
ms = maximum timetable speed, mph
ht = highway type factor value
hl = number of highway lanes

Final Accident Prediction Formula: $B = \frac{T_0}{T_0+T} * a + \frac{T}{T_0+T} * \frac{N}{T}$

B = collisions per year at the crossing (used in BCA)
a = initial collisions prediction using the basic accident prediction formula
N/T = collisions per year, where N is the number of observed collisions in T years
T_0 = formula weighting factor equal to $(0.05 + a)^{-1}$

Monetized values for fatalities and accidents categorized on the AIS scale are taken from U.S. DOT's guidance for "Treatment of the Economic Value of a Statistical Life,"[7] including the low and high ranges used for the sensitivity analysis. Values pertaining to "property damage only" accidents were reported by the National Highway Traffic and Safety Administration,[8] and have subsequently been updated to 2014 dollars by U.S. DOT. Table 5 lists the range of values used in the sensitivity analysis for each accident type.

[7] Office of the Secretary of Transportation, *Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses* (2013 update), Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses.

[8] National Highway Traffic Safety Administration (2002*), The Economic Impact of Motor Vehicle Crashes, 2000*, p. 62, Table 3.

Table 5: Monetized Accident Values (per U.S. DOT 2015)

Category	Unit Value Low	Unit Value Likely	Unit Value High
Fatality	$8,597,237	$9,552,486	$10,507,734
AIS 5	$5,098,162	$5,664,624	$6,231,086
AIS 4	$2,286,865	$2,540,961	$2,795,057
AIS 3	$902,710	$1,003,011	$1,103,312
AIS 2	$404,070	$448,967	$493,864
AIS 1	$25,792	$28,657	$31,523
Property Damage Only	$3,592	$3,991	$4,390

The resulting present value of accident reduction is $33.0 million at a 7 percent discount rate, and $54.6 million at a 3 percent discount rate.

Sustainability – Rail Emissions Reduction

The project will have environmental and sustainability benefits relating to reducing air pollution associated with train travel. Three forms of emissions were identified, measured and monetized for rail vehicles, including carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulate matter (PM).

Since rail vehicle miles traveled (VMT) are not impacted by the Build scenario, emissions rates on a per-hour basis were used in the BCA. The emissions rates used were stated in terms of dollars per locomotive-hour, so that it was not necessary to first calculate short tons of emissions before converting the avoided tons of emissions into dollar values. These rates, summarized in Table 6, were derived from a report prepared by researchers at the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign.[9]

Table 6: Rail Emissions Rates

Emissions Type	Cost per locomotive-hour Low	Cost per locomotive-hour Likely	Cost per locomotive-hour High
CO_2	$22.82	$25.35	$27.88
NO_x	$92.72	$103.02	$113.32
PM	$157.88	$175.42	$192.96

These rates are based on the premise that the longer trains are in operation, the less efficiently they operate and the more emissions they will produce; and they consider the total social cost of emissions, including potential impacts to health, property value and climate change. The rates are based on an average hour of locomotive operation for an SD-70 locomotive, with fuel efficiency considerations at various speeds aggregated into a single set of cost per locomotive-hour figures.

[9] RailTEC: Determining Freight Train Delay Costs on Railroad Lines in North America http://railtec.illinois.edu/articles/Files/Conference%20Proceedings/2015/Lovett-et-al-2015-IAROR.pdf

Economic Competitiveness – Rail Operating Cost Savings

Rail vehicle operating costs include railcar rental, locomotive operation, fuel, crew wages, repairs and maintenance, as well as the depreciation of the vehicle over time. The per-hour factors of these costs were estimated by researchers at RailTEC at the University of Illinois at Urbana-Champaign.[10] These values are presented as train delay costs per train-hour, assuming the train is of average specifications and travels at average operating speeds. The values per train-hour are as follows: $226.58 in the "low" scenario, $251.75 in the "likely" scenario, and $276.92 in the "high" scenario. Other studies, also by RailTEC, suggest the value could be much higher at over $1,000 per train-hour, but the lower value was chosen to be conservative. As a result, it is possible that the present value of the rail operating cost savings benefit has been underestimated.

Livability / Economic Competitiveness – Road Vehicle Travel Time Savings

Road vehicle travel time savings includes in-vehicle travel time savings for auto drivers, bus passengers, and truck drivers. Travel time is a cost to users, and its value depends on the disutility that travelers attribute to time spent traveling. A reduction in travel time translates into more time available for work, leisure, or other activities. As there is great variance among the purposes of road travel, this benefit can be classified as both a livability and an economic competitiveness benefit.

Travel time savings is valued as a percentage of the average wage rate, with different percentages assigned to different trip purposes (Table 7). As recommended by U.S. DOT,[11] values are broken down as low, likely, and high for use in the BCA analysis, based on the percentages shown in Table 7.

Table 7: U.S. DOT Recommended Values of Time

(per person-hour as a percentage of total earnings)

Category	Low	Likely	High
Local Travel			
Personal	35%	50%	60%
Business	80%	100%	120%
Intercity Travel			
Personal	60%	70%	90%
Business	80%	100%	120%
Vehicle Operators			
All	80%	100%	120%

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[10] RailTEC: A Prediction Model for Broken Rails and an Analysis of their Economic Impact http://railtec.illinois.edu/articles/Files/Conference%20Proceedings/2008/Schafer-et-al-2008-AREMA.pdf

[11] Office of the Secretary of Transportation. (2014). *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis,* p. 11-12. (http://www.dot.gov/sites/dot.gov/files/docs/USDOT%20VOT%20Guidance_0.pdf)

Table 8: U.S. DOT Recommended Hourly Values of Time

Category	Low	Likely	High
Local Travel			
Personal	$11.43	$12.70	$13.97
Business	$22.32	$24.80	$27.28
All Purposes	$11.93	$13.26	$14.59
Intercity Travel			
Personal	$16.00	$17.78	$19.56
Business	$22.32	$24.80	$27.28
All Purposes	$17.35	$19.28	$21.21
Vehicle Operators			
Truck Drivers	$23.60	$26.22	$28.84
Bus Drivers	$24.42	$27.13	$29.84

Because the exact division between personal and business travel is not known for all trips potentially impacted by this project, the values of time for "all purposes" are used. These values (shown in Table 8) represent a weighted national average of the personal and business values of time calculated by U.S. DOT.[12]

Additionally, U.S. DOT guidance accepts the use of a real growth rate of 1.2 percent a year for the value of time.[13]

Economic Competitiveness – Road Vehicle Operating Cost Savings

Road vehicle operating costs include fuel, maintenance, repair, replacement of tires, and the depreciation of the vehicle over time. The per-hour factors of these costs were estimated by the Federal Highway Administration for the specific case of vehicle idling.[14] These values are shown below in Table 9.

Table 9: Vehicle O&M Costs

Vehicle Type	Idling Costs per hour Low	Idling Costs per hour Likely	Idling Costs per hour High
Automobile	$1.00	$1.11	$1.22
Truck	$1.13	$1.25	$1.37
Bus	$1.13	$1.25	$1.37

Sustainability – Road Vehicle Emissions Reduction

The project will have environmental and sustainability benefits relating to reductions in the air pollution associated with automobile, truck and bus travel. Four forms of emissions were

[12] Ibid

[13] Office of the Secretary of Transportation. (2014). *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis (Revision 2)*, p. 14. (http://www.dot.gov/sites/dot.gov/files/docs/USDOT%20VOT%20Guidance%202014.pdf)

[14] Federal Highway Administration: Work Zone Road User Costs – Concepts and Applications http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/sec2.htm

identified, measured and monetized for road vehicles, including CO_2, NO_x, PM, and volatile organic compounds (VOC).

Since road VMT is not impacted by the project, emissions rates on a per vehicle-hour basis were used. Specifically, idling emissions rates were used, as the reduced vehicle-hours in the Build scenario are a result of reduced idling time. These rates were derived from a report by the U.S. Environmental Protection Agency.[15] The rates were used to calculate total tons of emissions reduced, which was converted into dollars using the values shown in Tables 10 and 11.

Table 10: Emissions Reduction Values for NOx, PM, and VOC

Emissions Type	Value per Ton Low	Value per Ton Likely	Value per Ton High
NO_x	$7,204	$8,005	$8,805
PM	$329,606	$366,229	$402,852
VOC	$1,828	$2,031	$2,235

Table 11: Social Cost of Carbon at 3% Discounting

	Base Year of Analysis 2014	First Year of Benefits 2019	Final Year of Benefits 2038
Social Cost of CO_2 Low	$40.24	$46.64	$65.85
Social Cost of CO_2 Likely	$44.71	$51.83	$73.17
Social Cost of CO_2 High	$49.19	$57.01	$80.48

These conversion multipliers for NOx, PM, and VOC were sourced from reports by the National Cooperative Highway Research Program,[16] the National Highway Traffic and Safety Administration[17], and the CAL B/C tool.[18] In the case of CO_2, the per-ton costs were derived from the Interagency Working Group on the Social Cost of Carbon,[19] and the analysis conducted by U.S. DOT in the TIGER Benefit-Cost Analysis Resource Guide. The values used for the CO_2

[15] US Environmental Protection Agency: Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks http://www.epa.gov/otaq/consumer/420f08025.pdf

[16] NCHRP Project 08-36, Task 61: Monetary Valuation per Dollar of Investment in Different Performance Measures (2007) http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36%2861%29_FR.pdf

[17] National Highway Traffic and Safety Administration (August 2012), *Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks*, page 922, Table VIII-16, "Economic Values Used for Benefits Computations (2010 Dollars)", http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf

[18] California Environmental Protection Agency Air Resources Board. (2011). EMFAC2011 Emissions Database. (http://www.arb.ca.gov/emfac/)

[19] U.S. Environmental Protection Agency, Interagency Working Group on Social Cost of Carbon (2013), *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, p.18., Table A1, (https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf).

analysis were discounted at the U.S.DOT-recommended 3 percent rate. To account for change in the social cost of carbon over time, the compounded annual growth rate (CAGR) for the "likely" value (from 2019-2038) is applied to each case. This allows the social cost of carbon to grow over time, in keeping with EPA guidance.[20]

Economic Costs Included

In the benefit-cost analysis, the term "cost" refers to the additional resource costs or expenditures required to implement and maintain the investments associated with the project. The costs assessed in this BCA include the initial project investment (capital) expenditures for the years 2016 to 2018, and the operating and maintenance expenditures starting the first year of benefits, 2019, and continuing through the 20-year analysis period to the end of 2038.

The overall cost of the project is expected to be $12.56 million in undiscounted 2014 dollars through 2018. At a 7 percent discount rate, the total costs through 2038 are $10.37 million, while at a 3 percent discount rate the total costs are $11.51 million.

Initial Project Investment Costs

Initial project investment costs total $10.41 million. This includes engineering and design, materials, construction services, and contingency factors. Right-of-way (ROW) costs are not included as no new ROW is required for this project. These costs were estimated by ODOT and include costs beginning in 2016 and ending in 2018.

State of Good Repair – Annual Operating and Maintenance Costs

The annual costs of operating and maintaining the project are included in the analysis and, after netting out the operating and maintenance (O&M) costs for the existing crossings, result in a net savings. O&M expenses apply to all 23 crossings and are assumed to occur annually beginning in 2019.

Relative to the No Build scenario, this project will result in cost savings for the 16 crossings which currently have active warning devices. O&M costs are expected to decrease by $1,000 yearly at each of these crossings because the existing crossing infrastructure is old, and is more costly to repair. These savings are partially offset by cost increases expected for the 7 crossings which currently do not have active warning devices, relying solely on crossbuck signs. Improvements at these crossings are expected to cost an additional $1,700 per year to maintain.

Table 12 illustrates the projects O&M cost impacts, showing net annual savings of $4,100. Over the entire 20-year analysis period, this translates into $82,000 of cost savings in undiscounted 2014 dollars. At a 7 percent discount rate, the cost savings are $33,137, while at a 3 percent discount rate the cost savings are $54,196.

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[20] U.S. Environmental Protection Agency, Interagency Working Group on Social Cost of Carbon (2010), *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,* p.2., Table 19, (http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf).

Table 12: Annual O&M Cost Impacts

		NO BUILD SCENARIO		BUILD SCENARIO		CHANGE
Existing Infrastructure	**# of Crossings [A]**	**Annual O&M per crossing [B]**	**Annual O&M all crossings [C] = [A] x [B]**	**Annual O&M per crossing [D]**	**Annual O&M all crossings [E] = [A] x [D]**	**Annual Cost Savings [F] = [C] – [E]**
Active devices	16	$2,750	$44,000	$1,750	$28,000	$16,000
Passive devices	7	$50	$350	$1,750	$12,250	($11,900)
Total	**23**	n/a	**$44,350**	n/a	**$40,250**	**$4,100**

Benefit-Cost Model Detail Tables

Table 13 below shows some of the inputs and assumptions used in the BCA for the Oklahoma Urban Railroad Crossing Safety Improvement Project. Following this are detailed tables showing yearly values for each of the project benefits and costs described above.

Table 13: Summary of Key Assumptions

Input Name	Units	Value	Source
Expected Annual Growth in Rail/Road Traffic	%	2.0%	Bureau of Transportation Statistics
Fatalities as a Share of Total Accidents	%	11.7%	Bureau of Transportation Statistics
Track Length Benefiting from Sooner Subdivision Speed Increase	Miles	96.9	ODOT
Percent of Sooner Subdivision Speed Increase Attributable to Project	$	20%	ODOT
Hourly Cost of Rail Operation	$/train-hour	251.75	RailTEC at the University of Illinois at Urbana-Champaign
Percentage of Automobiles of Total Traffic	%	90.5%	U.S. DOT
Percentage of Trucks of Total Traffic	%	9.0%	U.S. DOT
Percentage of Buses of Total Traffic	%	0.5%	U.S. DOT
Lead and Lag Time for a Passing Train	Minutes	0.6	Federal Railroad Administration
Passengers Per Automobile	Passengers	1.38	Bureau of Transportation Statistics
Passengers Per Truck	Passengers	1.02	Bureau of Transportation Statistics
Passengers Per Bus	Passengers	21.79	Bureau of Transportation Statistics
Idling Cost – Automobile	$/vehicle-hour	1.11	Federal Highway Administration
Idling Cost – Truck/Bus	$/vehicle-hour	1.25	Federal Highway Administration
Rail Emissions Cost – CO_2	$/locomotive-hour	25.35	RailTEC at the University of Illinois at Urbana-Champaign
Rail Emissions Cost – NO_x	$/locomotive-hour	103.02	RailTEC at the University of Illinois at Urbana-Champaign
Rail Emissions Cost – PM	$/locomotive-hour	175.42	RailTEC at the University of Illinois at Urbana-Champaign
Average Train Length	Feet	7,700	PB assumption: 110 cars * 70 ft/car
Trains Per Year (all crossings)	Trains/year	49,275	ODOT
Average Train Speed (No Build case)	Mph	29.41	ODOT (weighted average of all crossings)
Average Train Speed (Build case)	Mph	31.19	ODOT (weighted average including 10 mph increases on the Sooner Subdivision)

Table 14: Detailed Benefits Forecast – Accident Reduction

Year	Fatality Reduction	Accident Reduction (incl. fatalities)	Value of Accident Reduction, Undiscounted	Value of Accident Reduction, Discounted
	# of fatalities	# of accidents	2014$	2014$, disc. 7%
2019	0.36	3.06	3,798,542	2,708,308
2020	0.36	3.09	3,836,165	2,556,199
2021	0.37	3.12	3,874,017	2,412,543
2022	0.37	3.16	3,912,098	2,276,876
2023	0.37	3.19	3,950,404	2,148,758
2024	0.38	3.22	3,988,933	2,027,771
2025	0.38	3.25	4,027,684	1,913,524
2026	0.39	3.28	4,066,655	1,805,643
2027	0.39	3.31	4,105,842	1,703,778
2028	0.39	3.34	4,145,244	1,607,597
2029	0.40	3.38	4,184,857	1,516,785
2030	0.40	3.41	4,224,680	1,431,045
2031	0.40	3.44	4,264,710	1,350,098
2032	0.41	3.47	4,304,944	1,273,678
2033	0.41	3.50	4,345,379	1,201,533
2034	0.42	3.54	4,386,011	1,133,429
2035	0.42	3.57	4,426,839	1,069,140
2036	0.42	3.60	4,467,859	1,008,455
2037	0.43	3.64	4,509,067	951,174
2038	0.43	3.67	4,550,460	897,108
TOTAL	**8.02**	**67.25**	**83,370,390**	**32,993,442**

Table 15: Detailed Benefits Forecast – Road Vehicle Travel Time Savings

Year	Travel Time Savings per Vehicle	Travel Time Savings per Person	Value of Travel Time Savings, Undiscounted	Value of Travel Time Savings, Discounted
	Vehicle-hours	Person-hours	2014$	2014$, disc. 7%
2019	16,910	24,573	367,328	261,900
2020	17,594	25,567	386,760	257,728
2021	18,306	26,602	407,263	253,523
2022	19,047	27,679	428,831	249,583
2023	19,818	28,799	451,540	245,608
2024	20,620	29,965	475,453	241,696
2025	21,454	31,177	500,632	237,846
2026	22,323	32,439	527,144	234,058
2027	23,226	33,752	555,060	230,330
2028	24,166	35,118	584,454	226,661
2029	25,144	36,539	615,405	223,051
2030	26,162	38,018	647,996	219,499
2031	27,221	39,557	682,312	216,002
2032	28,322	41,158	718,445	212,562
2033	29,468	42,823	756,492	209,176
2034	30,661	44,556	796,554	205,845
2035	31,902	46,360	838,737	202,566
2036	33,193	48,236	883,155	199,340
2037	34,537	50,188	929,924	196,165
2038	35,934	52,219	979,170	193,040
TOTAL	**506,007**	**735,326**	**12,532,676**	**4,516,280**

Table 16: Detailed Benefits Forecast – Rail Emissions Reduction

Year	Rail Transport Time Savings	Value of Rail Emissions Reduction, Undiscounted	Value of Rail Emissions Reduction, Discounted
	Hours	2014$	2014$, disc. 7%
2019	189.4	115,074	82,046
2020	193.2	117,383	78,218
2021	197.1	119,739	74,568
2022	201.0	122,143	71,088
2023	205.1	124,594	67,771
2024	209.2	127,095	64,608
2025	213.4	129,645	61,594
2026	217.7	132,247	58,719
2027	222.0	134,902	55,979
2028	226.5	137,609	53,367
2029	231.0	140,371	50,877
2030	235.7	143,188	48,503
2031	240.4	146,062	46,240
2032	245.2	148,994	44,082
2033	250.1	151,984	42,025
2034	255.2	155,034	40,064
2035	260.3	158,146	38,194
2036	265.5	161,320	36,412
2037	270.8	164,558	34,713
2038	276.3	167,860	33,093
TOTAL	**4,605.1**	**2,797,949**	**1,082,160**

Table 17: Detailed Benefits Forecast – Rail Operating Cost Savings

Year	Rail Transport Time Savings	Value of Rail Operating Cost Savings, Undiscounted	Value of Rail Operating Cost Savings, Discounted
	Hours	2014$	2014$, disc. 7%
2019	189.4	47,681	33,996
2020	193.2	48,638	32,409
2021	197.1	49,614	30,897
2022	201.0	50,609	29,455
2023	205.1	51,625	28,081
2024	209.2	52,661	26,770
2025	213.4	53,718	25,521
2026	217.7	54,796	24,330
2027	222.0	55,896	23,195
2028	226.5	57,018	22,113
2029	231.0	58,162	21,081
2030	235.7	59,330	20,097
2031	240.4	60,521	19,159
2032	245.2	61,735	18,265
2033	250.1	62,974	17,413
2034	255.2	64,238	16,600
2035	260.3	65,527	15,826
2036	265.5	66,843	15,087
2037	270.8	68,184	14,383
2038	276.3	69,553	13,712
TOTAL	**4,605.1**	**1,159,323**	**448,391**

Table 18: Detailed Benefits Forecast – Road Vehicle Operating Cost Savings

Year	Reduced Idling – Automobiles	Reduced Idling – Trucks	Reduced Idling – Buses	Value of Road Vehicle Cost Savings, Undiscounted	Value of Road Vehicle Cost Savings, Discounted
	Vehicle-hours	Vehicle-hours	Vehicle-hours	2014$	2014$, disc. 7%
2019	15,297	1,528	84	19,051	13,583
2020	15,916	1,590	87	19,822	13,208
2021	16,560	1,654	91	20,624	12,844
2022	17,231	1,721	95	21,459	12,489
2023	17,928	1,791	98	22,327	12,144
2024	18,654	1,864	102	23,231	11,809
2025	19,409	1,939	107	24,171	11,483
2026	20,194	2,017	111	25,149	11,166
2027	21,011	2,099	115	26,167	10,858
2028	21,862	2,184	120	27,226	10,559
2029	22,747	2,272	125	28,328	10,267
2030	23,667	2,364	130	29,474	9,984
2031	24,625	2,460	135	30,667	9,708
2032	25,622	2,560	141	31,908	9,441
2033	26,659	2,663	146	33,200	9,180
2034	27,738	2,771	152	34,543	8,927
2035	28,860	2,883	159	35,941	8,680
2036	30,028	3,000	165	37,396	8,441
2037	31,243	3,121	172	38,909	8,208
2038	32,508	3,248	179	40,484	7,981
TOTAL	**457,760**	**45,732**	**2,515**	**570,077**	**210,961**

Table 19: Detailed Benefits Forecast – Road Vehicle Emissions Reduction

Year	Emissions Reduction – CO_2 only	Emissions Reduction – total incl. CO_2	Value of Road Vehicle Emissions Reduction, Undiscounted	Value of Road Vehicle Emissions Reduction, Discounted
	Tons	Tons	2014$	2014$, disc. 7%
2019	50.37	50.56	4,446	3,170
2020	52.41	52.60	4,679	3,118
2021	54.53	54.73	4,869	3,032
2022	56.74	56.95	5,181	3,015
2023	59.03	59.25	5,451	2,965
2024	61.42	61.65	5,734	2,915
2025	63.91	64.15	6,031	2,865
2026	66.49	66.74	6,342	2,816
2027	69.18	69.44	6,740	2,797
2028	71.98	72.25	7,085	2,748
2029	74.90	75.18	7,448	2,700
2030	77.93	78.22	7,829	2,652
2031	81.08	81.39	8,146	2,579
2032	84.36	84.68	8,647	2,558
2033	87.78	88.11	9,086	2,512
2034	91.33	91.67	9,547	2,467
2035	95.03	95.38	10,030	2,422
2036	98.87	99.24	10,536	2,378
2037	102.87	103.26	11,172	2,357
2038	107.04	107.44	11,732	2,313
TOTAL	**1,507.25**	**1,512.89**	**150,730**	**54,379**

Table 20: Detailed Costs Forecast

Year	Capital Costs, Undiscounted	Net O&M Costs, Undiscounted	Total Undiscounted Costs	Total Discounted Costs
	2014$	2014$	2014$	2014$, disc. 7%
2015	-	-	-	-
2016	5,024,000	-	5,024,000	4,388,156
2017	5,024,000	-	5,024,000	4,101,081
2018	2,512,000	-	2,512,000	1,916,393
2019	-	(4,100)	(4,100)	(2,923)
2020	-	(4,100)	(4,100)	(2,732)
2021	-	(4,100)	(4,100)	(2,553)
2022	-	(4,100)	(4,100)	(2,386)
2023	-	(4,100)	(4,100)	(2,230)
2024	-	(4,100)	(4,100)	(2,084)
2025	-	(4,100)	(4,100)	(1,948)
2026	-	(4,100)	(4,100)	(1,820)
2027	-	(4,100)	(4,100)	(1,701)
2028	-	(4,100)	(4,100)	(1,590)
2029	-	(4,100)	(4,100)	(1,486)
2030	-	(4,100)	(4,100)	(1,389)
2031	-	(4,100)	(4,100)	(1,298)
2032	-	(4,100)	(4,100)	(1,213)
2033	-	(4,100)	(4,100)	(1,134)
2034	-	(4,100)	(4,100)	(1,060)
2035	-	(4,100)	(4,100)	(990)
2036	-	(4,100)	(4,100)	(925)
2037	-	(4,100)	(4,100)	(865)
2038	-	(4,100)	(4,100)	(808)
TOTAL	**12,560,000**	**(82,000)**	**12,478,000**	**10,372,493**

Table 21: Costs and Benefits by Year

Year	Total Undiscounted Costs	Total Undiscounted Benefits	Net Undiscounted Benefits	Total Discounted Costs	Total Discounted Benefits	Net Discounted Benefits
	2014$	2014$	2014$	2014$ disc. 7%	2014$ disc. 7%	2014$ disc. 7%
2015	-	-	-	-	-	-
2016	5,024,000	-	(5,024,000)	4,388,156	-	(4,388,156)
2017	5,024,000	-	(5,024,000)	4,101,081	-	(4,101,081)
2018	2,512,000	-	(2,512,000)	1,916,393	-	(1,916,393)
2019	(4,100)	4,352,121	4,356,221	(2,923)	3,103,002	3,105,925
2020	(4,100)	4,413,467	4,417,567	(2,732)	2,940,880	2,943,612
2021	(4,100)	4,476,126	4,480,226	(2,553)	2,787,506	2,790,060
2022	(4,100)	4,540,320	4,544,420	(2,386)	2,642,508	2,644,894
2023	(4,100)	4,605,941	4,610,041	(2,230)	2,505,327	2,507,557
2024	(4,100)	4,673,106	4,677,206	(2,084)	2,375,570	2,377,655
2025	(4,100)	4,741,881	4,745,981	(1,948)	2,252,834	2,254,781
2026	(4,100)	4,812,334	4,816,434	(1,820)	2,136,734	2,138,554
2027	(4,100)	4,884,606	4,888,706	(1,701)	2,026,938	2,028,639
2028	(4,100)	4,958,637	4,962,737	(1,590)	1,923,045	1,924,635
2029	(4,100)	5,034,572	5,038,672	(1,486)	1,824,761	1,826,247
2030	(4,100)	5,112,497	5,116,597	(1,389)	1,731,780	1,733,169
2031	(4,100)	5,192,418	5,196,518	(1,298)	1,643,786	1,645,084
2032	(4,100)	5,274,673	5,278,773	(1,213)	1,560,585	1,561,799
2033	(4,100)	5,359,115	5,363,215	(1,134)	1,481,840	1,482,974
2034	(4,100)	5,445,928	5,450,028	(1,060)	1,407,331	1,408,391
2035	(4,100)	5,535,221	5,539,321	(990)	1,336,828	1,337,818
2036	(4,100)	5,627,108	5,631,208	(925)	1,270,112	1,271,038
2037	(4,100)	5,721,814	5,725,914	(865)	1,206,999	1,207,864
2038	(4,100)	5,819,260	5,823,360	(808)	1,147,247	1,148,056
TOTAL	**12,478,000**	**100,581,145**	**88,103,145**	**10,372,493**	**39,305,613**	**28,933,120**

Sensitivity Analysis

A sensitivity analysis was conducted for the BCA, utilizing a high case and a low case. The "likely" case results are the ones described above and summarized in the TIGER application.

The high case utilized high values of travel time and other categories as noted above, along with an assumption of 10% higher growth in traffic. The low case incorporated low values specified above, and assumed 10% lower traffic growth. The results of these two cases are shown in Table 22, indicating that the project benefits will substantially outweigh its costs.

Table 22: BCA Ratio Results from Sensitivity Analysis

	Using a 7% Discount Rate	Using a 3% Discount Rate
Low	3.41	5.12
Likely	3.79	5.69
High	4.17	6.26