Oklahoma Rural Railroad Crossing
Safety Improvement Project

Benefit Cost Analysis Technical Memo

TIGER VII Grant Application
Oklahoma Department of Transportation

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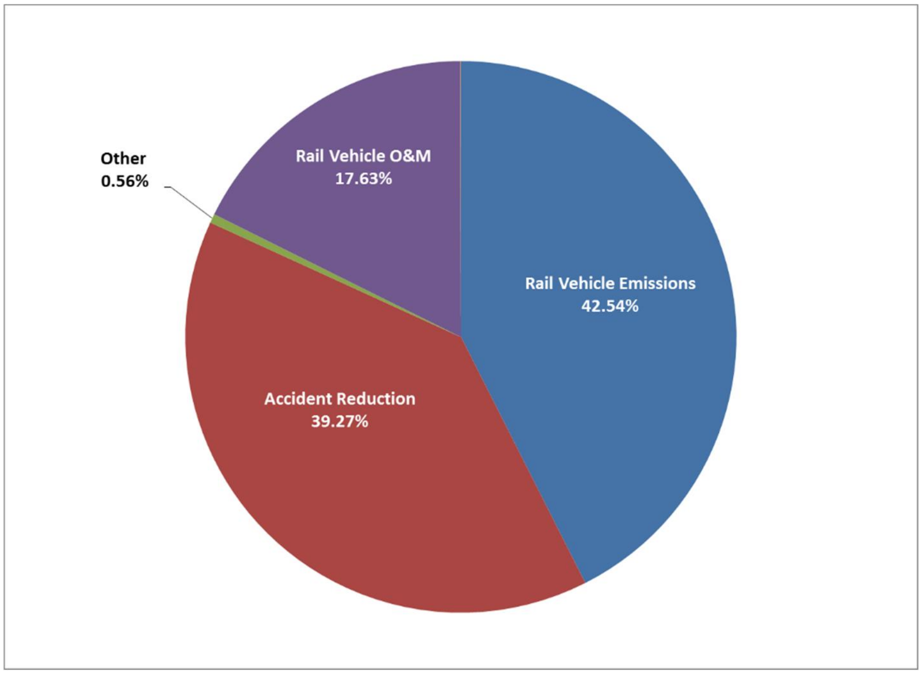
Executive Summary

A formal benefit-cost analysis (BCA) was conducted for the modernization and improvement of rail safety infrastructure at 12 rural railroad crossings in 11 different Oklahoma counties. 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 $3.0 million and will provide an estimated $24.5 million in total benefits, predominantly as a result of accident and rail emissions reductions (Figure 1). The resulting net present value is $21.5 million and the **benefit/cost ratio is 8.07**.

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 second 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)

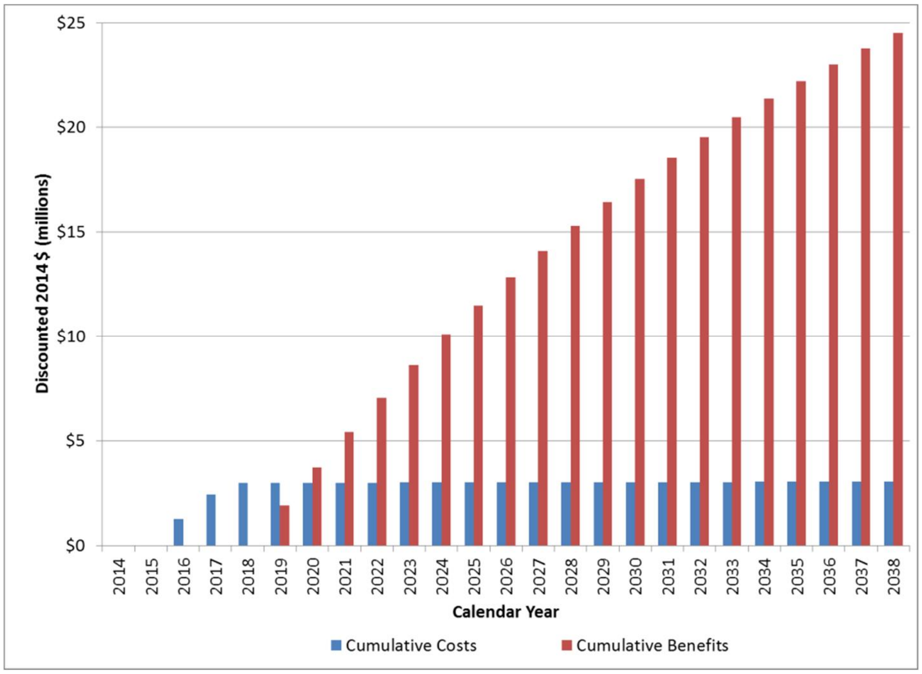


Table 1: Project Impact and Benefits Matrix

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	$9.7 million	$16.1 million	pp. 8-10
Delay at road/rail grade crossings	Lengthened circuit approaches at 2 crossings, resulting in faster train speeds	Improved diesel fuel efficiency for rail transport	Society and surrounding communities	Reductions in rail vehicle emissions	$10.4 million	$17.4 million	pp. 10-11
Delay at road/rail grade crossings	Lengthened circuit approaches at 2 crossings, resulting in faster train speeds	Faster train speeds	Railroad companies, shippers, end consumers of bulk commodities	Reductions in rail operating costs	$4.3 million	$7.2 million	p. 11
Delay at road/rail grade crossings	Lengthened circuit approaches at 2 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	$124,200	$216,700	pp. 11-12
Delay at road/rail grade crossings	Lengthened circuit approaches at 2 crossings, resulting in faster train speeds	Reduced idling at grade crossings	Automobile owners, trucking and bus companies	Reductions in road vehicle operating costs	$5,800	$10,000	pp. 12-13
Delay at road/rail grade crossings	Lengthened circuit approaches at 2 crossings, resulting in faster train speeds	Reduced idling at grade crossings	Society and surrounding communities, due to less idling	Reductions in road vehicle emissions	$1,500	$2,600	pp. 13-14

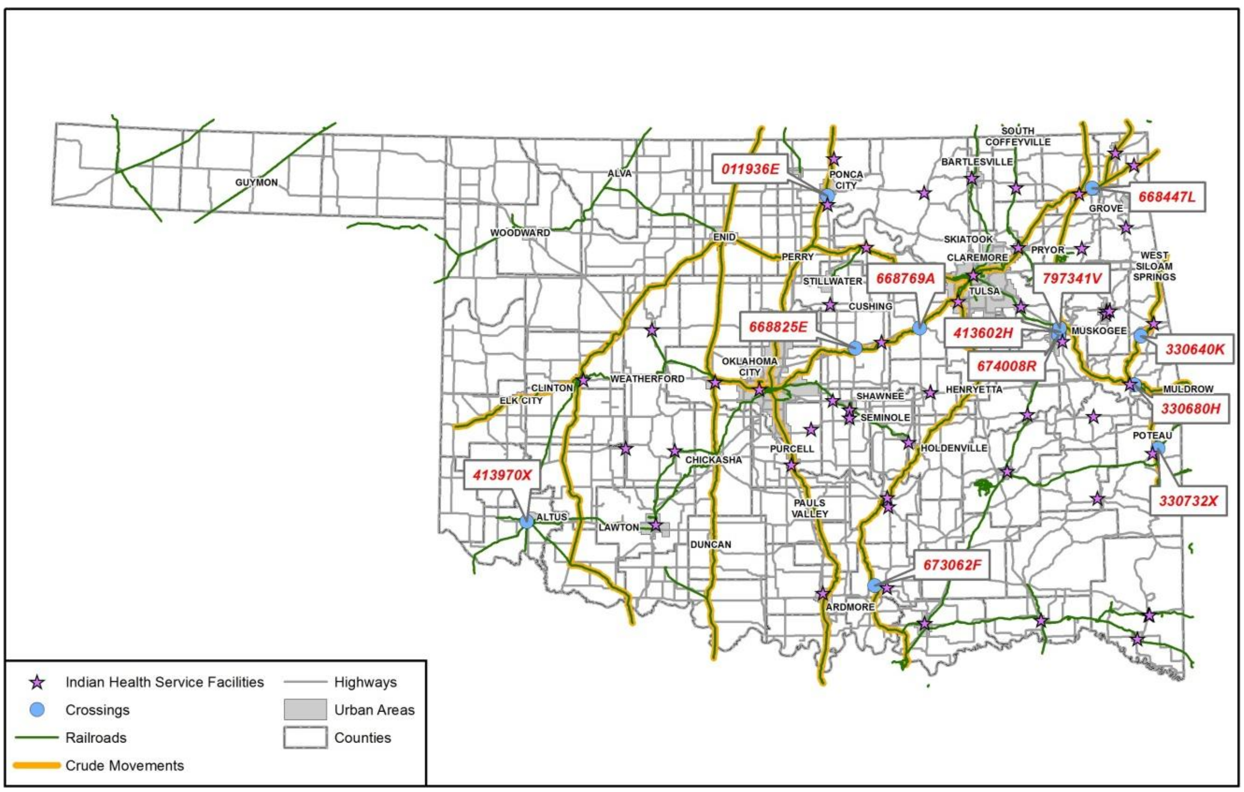
Background

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.

Because of the 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 Oklahoma



This project will modernize and improve rail safety infrastructure at 12 rural railroad crossings that either experience high volumes of unit trains transporting crude oil, or which intersect highway routes that serve Indian Health Service Facilities (Figure 3).

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]

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.

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[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

[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).

Project Region

This proposed multi-location, multi-jurisdictional project will upgrade 12 rural railroad crossings in 11 different Oklahoma counties. New gated signal installations and other crossing improvements will enhance the safety of motor vehicle and railroad operations at the locations shown in Figure 3. Two of the project crossings, both 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 77 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.

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

Category (Units)	Quantity
Rail travel time (train-hours)	▼ 44,209
Rail vehicle emissions (tons of CO_2, NOx, and PM)	▼ 37,244
Road vehicle travel time (person-hours)	▼ 20,227
Road vehicle travel time (vehicle-hours)	▼ 13,919
Road vehicle emissions (tons of CO_2, NOx, PM, and VOC)	▼ 42
Total accidents (number)	▼ 20
Total fatalities (number)	▼ 2

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 two 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 two 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 $21.5 million and a benefit-cost ratio of 8.07 over a 20-year analysis period. Using a 3 percent discount rate, the net present value and benefit-cost ratio are $37.5 million and 12.02 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	$2,982,505	$3,314,853
Maintenance Costs	$55,767	$91,207
TOTAL COSTS	**$3,038,272**	**$3,406,060**
Evaluated Benefits		
Accident Reduction	$9,682,826	$16,071,536
Rail Emissions Reduction	$10,388,740	$17,410,100
Rail Operating Cost Savings	$4,304,550	$7,213,834
Road Vehicle Travel Time Savings	$124,235	$216,676
Road Vehicle Operating Cost Savings	$5,803	$9,970
Road Vehicle Emissions Reduction	$1,496	$2,607
TOTAL BENEFITS	**$24,507,649**	**$40,924,723**
NET PRESENT VALUE	**$21,469,377**	**$37,518,663**
BENEFIT/COST RATIO	**8.07**	**12.02**

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 2007 was provided by ODOT. For 2008-2038, 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 4.

Figure 4: 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	$\frac{c * t + 0.2^{0.3334}}{0.2}$	$e^{0.2094mt}$	$\frac{d + 0.2^{0.1336}}{0.2}$	$e^{-0.616(hp-1)}$	$e^{0.0077ms}$	$e^{-0.1(ht-1)}$	1.0
Flashing Lights	0.003646	$\frac{c * t + 0.2^{0.2953}}{0.2}$	$e^{0.1088mt}$	$\frac{d + 0.2^{0.0470}}{0.2}$	1.0	1.0	1.0	$e^{0.1380(hl-1)}$
Gates	0.001088	$\frac{c * t + 0.2^{0.3116}}{0.2}$	$e^{0.2912mt}$	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 $(0.05 + a)^{-1}$

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.

[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

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%

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.

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 $9.7 million at a 7 percent discount rate, and $16.1 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

[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.

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
NOx	$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.

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.

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[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

[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

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.

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%

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

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[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)
[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)

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 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 2014 dollars using the values shown in Table 10 and Table 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
NOx	$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

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

[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

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 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 $3.60 million in undiscounted 2014 dollars through 2018. At a 7 percent discount rate, the total costs through 2038 are $3.04 million, while at a 3 percent discount rate the total costs are $3.41 million.

Initial Project Investment Costs

Initial project investment costs total $2.98 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 total $56,000 in present value. Operations and maintenance (O&M) expenses apply to all 12 crossings and are assumed to occur annually beginning in 2019.

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[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).

[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).

Relative to the No Build scenario, this project will result in cost savings for the 5 crossings which currently have active warning devices. These savings (averaging $1,000 annually per crossing) result from bringing the infrastructure to a state of good repair. These savings are offset by cost increases on the 7 crossings which currently do not have active warning devices, relying solely on crossbuck signs. These improvements will cost an extra $1,700 in O&M annually per crossing.

Table 12 illustrates the project's O&M cost impacts, showing net additional costs of $6,900 per year. Over the entire 20-year analysis period, this translates into $138,000 of additional undiscounted costs. At a 7 percent discount rate, the costs are $55,767, while at a 3 percent discount rate the costs are $91,207.

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	5	$2,750	$13,750	$1,750	$8,750	$5,000
Passive devices	7	$50	$350	$1,750	$12,250	($11,900)
Total	**12**	n/a	**$14,100**	n/a	**$21,000**	**($6,900)**

Benefit-Cost Model Detail Tables

Table 13 below shows some of the inputs and assumptions used in the BCA for the Oklahoma Rural 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	$	80%	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 – NOx	$/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	66,795	ODOT
Average Train Speed (No Build case)	Mph	45.42	ODOT (weighted average of all crossings)
Average Train Speed (Build case)	Mph	46.07	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	0.10	0.88	1,093,434	779,604
2020	0.10	0.89	1,106,999	737,640
2021	0.11	0.90	1,120,702	697,917
2022	0.11	0.92	1,134,544	660,315
2023	0.11	0.93	1,148,525	624,722
2024	0.11	0.94	1,162,646	591,030
2025	0.11	0.95	1,176,908	559,140
2026	0.11	0.96	1,191,310	528,956
2027	0.11	0.97	1,205,855	500,387
2028	0.12	0.98	1,220,541	473,347
2029	0.12	1.00	1,235,370	447,755
2030	0.12	1.01	1,250,341	423,534
2031	0.12	1.02	1,265,456	400,611
2032	0.12	1.03	1,280,715	378,917
2033	0.12	1.05	1,296,118	358,388
2034	0.12	1.06	1,311,666	338,959
2035	0.13	1.07	1,327,359	320,575
2036	0.13	1.08	1,343,197	303,177
2037	0.13	1.10	1,359,180	286,715
2038	0.13	1.11	1,375.309	271,137
TOTAL	**2.33**	**19.85**	**24,606,176**	**9,682,826**

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	465	676	10,105	7,204
2020	484	703	10,640	7,090
2021	504	732	11,203	6,977
2022	524	761	11,796	6,866
2023	545	792	12,421	6,756
2024	567	824	13,079	6,649
2025	590	858	13,771	6,543
2026	614	892	14,501	6,439
2027	639	928	15,269	6,336
2028	665	966	16,077	6,235
2029	692	1,005	16,929	6,136
2030	720	1,046	17,825	6,038
2031	749	1,088	18,769	5,942
2032	780	1,132	19,763	5,847
2033	811	1,178	20,810	5,754
2034	843	1,226	21,912	5,662
2035	878	1,275	23,072	5,572
2036	913	1,327	24,294	5,483
2037	950	1,381	25,581	5,396
2038	988	1,436	26,935	5,310
TOTAL	**13,919**	**20,227**	**344,751**	**124,235**

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	1,818	1,104,709	787,642
2020	1,855	1,126,881	750,888
2021	1,892	1,149,497	715,849
2022	1,930	1,172,568	682,445
2023	1,969	1,196,102	650,600
2024	2,008	1,220,108	620,241
2025	2,048	1,244,596	591,299
2026	2,090	1,269,575	563,707
2027	2,131	1,295,056	537,402
2028	2,174	1,321,048	512,325
2029	2,218	1,347,562	488,418
2030	2,262	1,374,608	465,627
2031	2,308	1,402,197	443,900
2032	2,354	1,430,339	423,186
2033	2,401	1,459,046	403,438
2034	2,450	1,488,330	384,613
2035	2,499	1,518,201	366,665
2036	2,549	1,548,672	349,556
2037	2,600	1,579,754	333,244
2038	2,652	1,611,460	317,694
TOTAL	**44,209**	**26,860,309**	**10,388,740**

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	1,818	457,733	326,358
2020	1,855	466,920	311,129
2021	1,892	476,292	296,610
2022	1,930	485,851	282,770
2023	1,969	495,602	269,575
2024	2,008	505,549	256,995
2025	2,048	515,695	245,003
2026	2,090	526,045	233,570
2027	2,131	536,603	222,671
2028	2,174	547,373	212,281
2029	2,218	558,359	202,375
2030	2,262	569,565	192,932
2031	2,308	580,997	183,929
2032	2,354	592,658	175,346
2033	2,401	604,552	167,164
2034	2,450	616,686	159,363
2035	2,499	629,063	151,927
2036	2,549	641,688	144,838
2037	2,600	654,567	138,079
2038	2,652	667,705	131,636
TOTAL	**44,209**	**11,129,505**	**4,304,550**

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	420.8	42.0	2.3	524	374
2020	437.8	43.7	2.4	545	363
2021	455.6	45.4	2.5	567	353
2022	474.0	47.4	2.6	590	344
2023	493.2	49.3	2.7	614	334
2024	513.1	51.3	2.8	639	325
2025	533.9	53.3	2.9	665	316
2026	555.5	55.5	3.1	692	307
2027	578.0	57.7	3.2	720	299
2028	601.4	60.1	3.3	749	290
2029	625.7	62.5	3.4	779	282
2030	651.0	65.0	3.6	811	275
2031	677.4	67.7	3.7	844	267
2032	704.8	70.4	3.9	878	260
2033	733.3	73.3	4.0	913	253
2034	763.0	76.2	4.2	950	246
2035	793.9	79.3	4.4	989	239
2036	826.0	82.5	4.5	1,029	232
2037	859.5	85.9	4.7	1,070	226
2038	894.2	89.3	4.9	1,114	220
TOTAL	**12,592.1**	**1,258.0**	**69.2**	**15,682**	**5,803**

Table 19: Detailed Benefits Forecast – Road Vehicle Emissions Reduction

Year	Emissions Reduction – CO2 only	Emissions Reduction – total incl. CO2	Value of Road Vehicle Emissions Reduction, Undiscounted	Value of Road Vehicle Emissions Reduction, Discounted
	Tons	Tons	2014$	2014$, disc. 7%
2019	1.39	1.39	122	87
2020	1.44	1.45	129	86
2021	1.50	1.51	134	83
2022	1.56	1.57	143	83
2023	1.62	1.63	150	82
2024	1.69	1.70	158	80
2025	1.76	1.76	166	79
2026	1.83	1.84	174	77
2027	1.90	1.91	185	77
2028	1.98	1.99	195	76
2029	2.06	2.07	205	74
2030	2.14	2.15	215	73
2031	2.23	2.24	224	71
2032	2.32	2.33	238	70
2033	2.41	2.42	250	69
2034	2.51	2.52	263	68
2035	2.61	2.62	276	67
2036	2.72	2.73	290	65
2037	2.83	2.84	307	65
2038	2.94	2.96	323	64
TOTAL	**41.46**	**41.62**	**4,146**	**1,496**

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	1,440,000	-	1,440,000	1,257,752
2017	1,440,000	-	1,440,000	1,175,469
2018	720,000	-	720,000	549,285
2019	-	6,900	6,900	4,920
2020	-	6,900	6,900	4,598
2021	-	6,900	6,900	4,297
2022	-	6,900	6,900	4,016
2023	-	6,900	6,900	3,753
2024	-	6,900	6,900	3,508
2025	-	6,900	6,900	3,278
2026	-	6,900	6,900	3,064
2027	-	6,900	6,900	2,863
2028	-	6,900	6,900	2,676
2029	-	6,900	6,900	2,501
2030	-	6,900	6,900	2,337
2031	-	6,900	6,900	2,184
2032	-	6,900	6,900	2,041
2033	-	6,900	6,900	1,908
2034	-	6,900	6,900	1,783
2035	-	6,900	6,900	1,666
2036	-	6,900	6,900	1,557
2037	-	6,900	6,900	1,456
2038	-	6,900	6,900	1,360
TOTAL	**3,600,000**	**138,000**	**3,738,000**	**3,038,272**

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	1,440,000	-	(1,440,000)	1,257,752	-	(1,257,752)
2017	1,440,000	-	(1,440,000)	1,175,469	-	(1,175,469)
2018	720,000	-	(720,000)	549,285	-	(549,285)
2019	6,900	2,666,627	2,659,727	4,920	1,901,269	1,896,349
2020	6,900	2,712,114	2,705,214	4,598	1,807,196	1,802,598
2021	6,900	2,758,395	2,751,495	4,297	1,717,790	1,713,493
2022	6,900	2,805,492	2,798,592	4,016	1,632,822	1,628,806
2023	6,900	2,853,414	2,846,514	3,753	1,552,068	1,548,315
2024	6,900	2,902,179	2,895,279	3,508	1,475,320	1,471,813
2025	6,900	2,951,801	2,944,901	3,278	1,402,380	1,399,101
2026	6,900	3,002,298	2,995,398	3,064	1,333,056	1,329,993
2027	6,900	3,053,688	3,046,788	2,863	1,267,172	1,264,309
2028	6,900	3,105,983	3,099,083	2,676	1,204,554	1,201,878
2029	6,900	3,159,203	3,152,303	2,501	1,145,041	1,142,540
2030	6,900	3,213,366	3,206,466	2,337	1,088,478	1,086,141
2031	6,900	3,268,487	3,261,587	2,184	1,034,719	1,032,535
2032	6,900	3,324,591	3,317,691	2,041	983,626	981,585
2033	6,900	3,381,690	3,374,790	1,908	935,065	933,158
2034	6,900	3,439,806	3,432,906	1,783	888,911	887,128
2035	6,900	3,498,959	3,492,059	1,666	845,044	843,378
2036	6,900	3,559,169	3,552,269	1,557	803,351	801,794
2037	6,900	3,620,459	3,613,559	1,456	763,725	762,269
2038	6,900	3,682,845	3,675,945	1,360	726,060	724,700
TOTAL	**3,738,000**	**62,960,568**	**59,222,568**	**3,038,272**	**24,507,649**	**21,469,377**

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's 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	7.26	10.81
Likely	8.07	12.02
High	8.87	13.22