Benefit-Cost Analysis Supplementary Documentation

BUILD Grant Program

KY 249 Interchange

Kentucky Transportation Cabinet

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

The Cost-Benefit Analysis conducted for this grant application compares the costs associated with the proposed investment to the benefits of the project. To the extent possible, benefits have been monetized. A qualitative discussion is also provided when a benefit is anticipated to be generated but is not easily monetized or quantified.

The KY 249 interchange project is located at the crossover of KY 249 with the Louis B. Nunn Cumberland Parkway (a major east-west control access highway) in central Barren County, south of the city of Glasgow, Kentucky. KY 249 is a rural two-lane state route which runs north-south and provides a direct connection between Glasgow and the southern areas of Barren County. Currently, KY 249 passes over the Parkway and has no direct connection to it.

This project would add a much needed interchange to the Louis B. Nunn Cumberland Parkway in Barren County, Kentucky. The Parkway serves the city of Glasgow and Barren County via four existing interchanges. However, they are located further away from KY 249, are becoming more and more congested, and experience a high frequency of crashes.

The project would also include roadway improvements north and south of the Parkway, replacement of the deficient South Fork Beaver Creek Bridge over the Parkway, and spot traffic calming improvements on area roads.

A table summarizing the changes expected from the project and the associated benefits is provided below.

Table ES-1: Summary of Infrastructure Improvements and Associated Benefits

Current Status or Baseline & Problems to Be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Benefits	Summary of Results (millions of $2017)	Page #
KY 249 is a rural two-lane state route which runs north-south and provides a direct connection between Glasgow and the southern areas of Barren County. Currently, KY 249 passes over the Louis B. Nunn Cumberland Parkway, a major east-west highway with no direct connection. The Parkway serves the city of Glasgow and Barren County via four existing interchanges. However, they are located further away from KY 249, are becoming more and more congested, and experience a high frequency of crashes.	This project would construct an interchange between KY 249 and the Louie B. Nunn Cumberland Parkway. Project scope also includes replacement of deficient bridge and traffic calming road improvements.	Safety Improvements	Reductions in fatalities, injuries, and property losses, reduction in accident costs on highway segment.	$6.02	13-14
		Economic Competitiveness: improvement in efficiency of movement of goods and people.	Reduction in travel time; travel time savings.	$10.05	15-16

Note: All monetary values in the table above are in millions of 2017 dollars over the period 2019-2042 discounted using a real discount rate of 7 percent.

The period of analysis used in the estimation of benefits and costs corresponds to 23 years, including 4 years of construction and 20 years of operation. The total (undiscounted) project costs are $20.49 million dollars according to the distribution shown in Table ES-2.

Table ES-2: Summary of Project Costs, in Millions of Dollars of 2017

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Construction & Development Costs	$19.69	$16.52
Operations and Maintenance	$0.80	$0.31
Total	**$20.49**	**$16.83**

A summary of the relevant data and calculations used to derive the benefits and costs of the project are shown in the Benefit-Cost Analysis (BCA) model (in dollars of 2017). Based on the analysis presented in the rest of this document, the project is expected to generate $16.07 million in discounted benefits and $16.83 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Benefit/Cost Ratio of 0.95.

In addition to the monetized benefits, the project would generate benefits that are difficult to quantify. A brief description of those benefits is provided below.

Safety

- The new interchange will offer improved and more effective emergency response/evacuation routes for local schools and industrial facilities with nearly a thousand employees.

State of Good Repair

- The new KY 249 Interchange will divert traffic away from the congested US 31E interchange. This reduction in traffic along US 31E will reduce the daily wear on the infrastructure thus decreasing the expected annual maintenance costs.

Economic Competitiveness

- The new interchange will allow a more direct access to the Louie B. Nunn Cumberland Parkway from areas along KY 249 reducing the requirements to travel along circuitous routes to the east or west. This may create benefits that go over and above travel time savings through improved connectivity to markets that can encourage local economic development. In particular, the interchange would improve connectivity of areas targeted for development in Barren County Comprehensive Plan.

Quality of Life

- The project would contribute to enhancing quality of life in the study area through improving the connectivity of the local residents to various destinations within the region which currently can be accessed through a much less direct route. This may increase access to employment opportunities, health care and other services.

Innovation

- The KY 249 interchange project includes an innovative approach to right-of-way acquisition and funding with local individuals taking the lead and Barren County providing the guarantee on their donations.

Partnership

- A diverse range of partners is involved in the development and funding of this project, including local government and other public, private and nonprofit organizations representing industrial sectors such as manufacturing, education, and community services.

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the Cumberland Parkway and KY249 Interchange project.

Section 3 introduces the conceptual framework used in the BCA. Section 4 provides an overview of the project, including a brief description of existing conditions and proposed alternatives; a summary of cost estimates and schedule; and a description of the types of effects that the project is expected to generate. Section 5 discusses the general assumptions used in the estimation of project costs and benefits, while estimates of travel demand and traffic growth can be found in Section 6. Specific data elements and assumptions pertaining to the long-term outcome selection criteria are presented in Section 0 along with associated benefit estimates. Estimates of the project's Net Present Value (NPV), its Benefit/Cost ratio (BCR) and other project evaluation metrics are introduced in Section 8. Next, Section 9 provides the results of the sensitivity analysis. Additional data tables are provided within the BCA model including annual estimates of benefits and costs to assist the U.S. Department of Transportation (USDOT) in its review of the application.[1]

3. Methodological Framework

The BCA conducted for this project includes the monetized benefits and costs measured using USDOT guidance, as well as the quantitative and qualitative merits of the project. A BCA provides estimates of the benefits that are expected to accrue from a project over a specified period and compares them to the anticipated costs of the project. Costs include both the resources required to develop the project and the costs of maintaining the new or improved asset over time. Estimated benefits are based on the projected impacts of the project on both users and non-users of the facility, valued in monetary terms.[2]

[1] While the models and software themselves do not accompany this appendix, they are provided separately as part of the application.
[2] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, June 2018.

While BCA is just one of many tools that can be used in making decisions about infrastructure investments, USDOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments.[3]

The specific methodology developed for this application was developed using the BCA guidance developed by USDOT and is consistent with the BUILD program guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the build and no-build scenarios;
- Assessing benefits with respect to merit criteria identified in the NOFO;
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using USDOT guidance for the valuation of travel time savings, safety benefits and reductions in air emissions, while relying on industry best practice for the valuation of other effects;
- Discounting future benefits and costs with the real discount rates recommended by USDOT (7 percent, and 3 percent for sensitivity analysis); and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

4. Project Overview

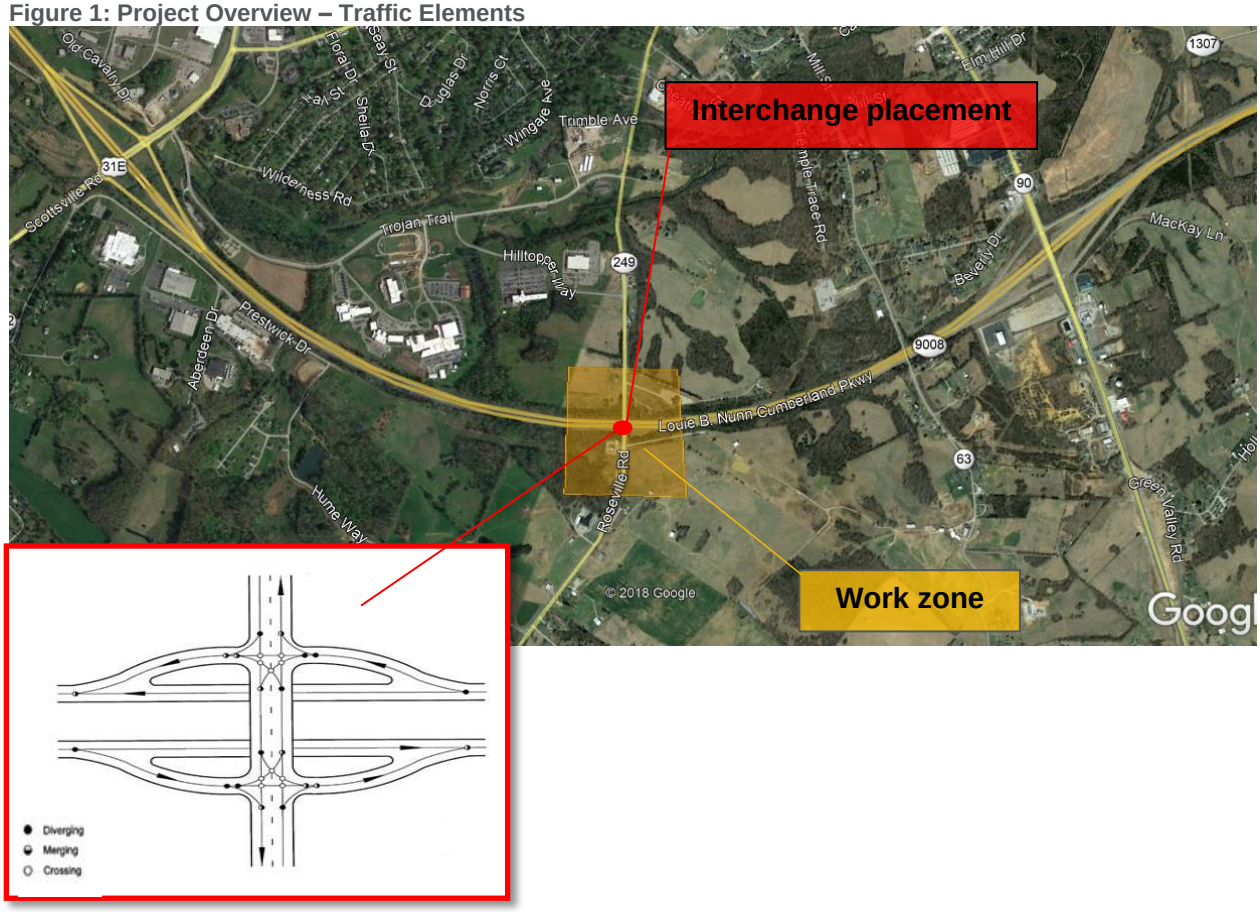
KY 249 is a rural highway between US 31E and KY 90 providing connectivity to the rural southern portions of Barren Country to Glasgow, Kentucky. KY 249 terminates in downtown Glasgow and provides access to Barren County High School, Middle School and Technology campuses as well as the Western Kentucky University Glasgow Campus on Trojan Trail. KY 249 is a key spoke in the transportation system linking rural/urban population concentrations to commercial, educational, and health services in Glasgow. This project would add a much needed interchange to the Louie B. Nunn Cumberland Parkway in Barren County. It would also include roadway improvements north and south of the Parkway, replacement of the deficient South Fork Beaver Creek Bridge, and spot traffic calming improvements near the school facilities along Trojan Trail.

The Parkway serves the city of Glasgow and Barren County via four existing interchanges, two of which provide linkage to a bypass across the northern side of the city. The other two interchanges are with the rural highways of US 31E and KY 90 which are the primary access points for Glasgow and much of Barren County. While the parkway, bypass and the existing interchanges provide reasonable connectivity, the area of Trojan Trail and US 31E Interchange have become known for its high frequency of crashes and slow travel, particularly during peak times. A new interchange at KY 249 would provide much needed congestion relief and connectivity within the southern area of Glasgow, and road improvements and upgrades would help improve safety.

Figure 1 below provides a map of the key roads mentioned above the the project location.

[3] Ibid.

Figure 1: Project Overview – Traffic Elements



4.1 Base Case and Alternatives

The No Build scenario maintains the existing general roadway network conditions. In particular, the interchange on KY 249 will not be built, and the road and existing interchanges in the area will continue with the existing traffic volumes and traffic challenges.

The Build scenario entails the construction of the interchange, overpass bridge replacement and several road improvements. The new KY 249 interchange will divert traffic away from the congested US 31E interchange improving road conditions along that road. Providing direct connection between KY 249 and the Cumberland Parkway will provide efficient and increased connectivity for Glasgow and rural Barren County increasing opportunities for economic development within the area. The improvements included in project scope will improve road safety and reduce the number of accidents,

4.2 Types of Impacts

The KY 249 Interchange project will improve road network connectivity to residents and businesses in southern Barren County as well as improve safety, or reduce the risk of crashes, along the route.

This can be expected to create impacts in the form of a reduction in number of accidents in the area, travel time savings for commuting, personal, and business/commercial trips, and related

benefits, including increased economic competitiveness of the local area, increased economic development incentives, and increased quality of life.

This project is consistent with all state, local, and regional plans and efforts to maintain and improve the current transportation system.

4.3 Project Cost and Schedule[4]

Total project construction costs are estimated at $19.7 million in 2017 dollars. The project is planned to start in 2019 and be completed by 2023. 2023 would be the year of project opening and the first year of benefits.

The incremental annual operation and maintenance costs for the improved facility are estimated at $0.04 million annually in 2017 dollars for a total of $0.80 million over the project life (in 2017 undiscounted dollars).

4.4 Effects on Selection Criteria

The main benefit categories associated with the project are mapped into the eight merit criteria set forth by USDOT in the table below.

[4] All cost estimates in this section are in millions of dollars of 2017, discounted to this year using a 7 percent real discount rate.

Table 1: Benefit Categories and Expected Effects on Selection Criteria

Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
Safety	Reduction in number of traffic crashes, fatalities and injuries	Interchange on KY 249 will divert traffic from US 31E known for a high frequency of crashes. Project also involves replacement of the South Fork Beaver Creek Bridge and other road improvements expected to reduce accident rates.	Yes		Yes
State of Good Repair	Diversion of traffic away from US 31E and reduction in annual maintenance cost for that road	KY 249 Interchange will divert traffic away from congested US 31E. This reduction in traffic along the US 31E will reduce daily wear on the infrastructure. Project also involves replacement of a deficient bridge.			Yes
Economic Competitiveness	Improved efficiency of movements of goods and people; reduction in the cost of doing business	This project will increase the connectivity within the area and decrease travel times due to both alleviating congestion and lowering the vehicle miles traveled (VMT) by residents and commuters in this area.	Yes		
Quality of Life	Improve the connectivity options	The proposed interchange project and the additional bridge improvements will greatly improve the connectivity options to residents of Barren county to various destinations within the county. This will improve access to employment opportunities, education, health care, and services.			Yes
Innovation	Innovative approach to right-of-way acquisition	The project includes an innovative approach to right-of-way acquisition and funding with local individuals taking the lead and Barren County providing the guarantee on their donations.			Yes
Partnership	Diverse range of partners supporting the project	A diverse multitude of partners are involved in the development and funding for the Project, including local government and other public, private and nonprofit entities.			Yes

5. General Assumptions

The BCA measures benefits against costs throughout a period of analysis beginning at the start of construction and including 20 years of operations.

The monetized benefits and costs are estimated in 2017 dollars with future costs and benefits discounted in compliance with BUILD requirements using a 7 percent real rate, and sensitivity testing at 3 percent.

The methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are expressed in 2017 dollars;
- The period of analysis begins in 2019 and ends in 2042. It includes project development and construction years (2019 - 2023) and 20 years of operations (2023 - 2042);
- A constant 7 percent real discount rate is assumed throughout the period of analysis. A 3 percent real discount rate is used for sensitivity analysis;
- Opening year demand is an input to the BCA and is assumed to be fully realized in Year 1 in 2023 (no ramp-up); and
- Unless specified otherwise, the results shown in this document correspond to the effects of the Full Build alternative, the construction of an interchange on KY 249.

6. Demand Projections

When quantifying the benefits of transportation infrastructure improvements, current, and future demand facing the facility modeled needs to be analyzed and quantified.

The Kentucky Transportation Cabinet Database and the Warren County Transportation model was used to compile and calibrate traffic data, average annual daily traffic (AADT), for the road links in the road network that could be affected by the project, a total of 22 links. The most recent data available was for 2015 to 2017. This traffic data was extrapolated to the project opening year of 2023 assuming a rate of growth of 1.5% and a rate of 1.2% for years between 2023 and 2042 (based on travel demand model outputs). The resulting traffic projections for key years in this project are presented in the table below.

Table 2: Demand Projections, Sum across Links in Study Area

	Total AADT
Traffic across Links	
2023	210,820
2042	258,887

7. Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each benefit or impact category identified in Table 2 and provides an overview of the associated methodology, assumptions, and estimates.

The key quantified benefits are safety benefits and travel time savings while other project benefits are presented in a qualitative manner.

The safety and travel time savings benefits are estimated on the basis of outputs from a regional travel demand model, the Warren County Model, obtained from the Kentucky Transportation Commission. This model divides the road network in the study area into segments and then simulates traffic volumes on these segments under the no-build scenario and under the build scenario with the proposed interchange in place, both for 2023 (project opening year) and 2042 (last year of the analysis period). After the interchange is built, traffic volumes on some segments change reflecting diversion to more convenient routing to reach the new interchange. Volume of traffic across all links decreases as some trips will take place over fewer links. This will lead to a reduction in both travel time (vehicle hours of travel, VHT) and a reduction in number of accidents due to lower travel volume and lower risk exposure.

The number of accidents and travel times are tracked for each section and summed across. The difference between build and no-build represents the benefit of the project.

7.1 Safety

The proposed project would contribute to promoting USDOT's safety long-term outcome through two key effects: 1) Upgrading KY 249 leading to/from the interchange (including a high crash bridge), and 2) Shifting traffic to lower crash routes and/or more direct routes. The first component will reduce the crash rates while the second will reduce exposure. In addition, this project will offer improved and more effective emergency response/evacuation routes for local schools and industrial facilities with nearly a thousand employees, in particular those located on Trojan Trail. This last effect is considered as a qualitative impact.

7.1.1 METHODOLOGY AND ASSUMPTIONS

The number of accidents is estimated for each link based on the crash/accident rate (number of crashes per 1 million vehicle miles) and volume of travel outputs from the transportation model.

For the no-build scenario the number of accidents is estimated on the basis of the actual accident data, by type, converted into accident rates. For the build scenario, the accident rate is reduced for certain links where improvements covered under this project would be taking place. Specifically, this included three critical links, where accident rate was reduced by 28 percent to 34 percent based on crash modification factors (CMF) sources from the Crash Modification Factors Clearinghouse inventory.

The difference between no-build and build gives then the number of accidents avoided. These are then monetized using the average cost per accident derived from unit values of injuries, property damage accidents, and value of statistical life recommended by US DOT. Average cost per accident is calculated as a weighted average of these unit values with weights based on actual distribution of accident types.

The assumptions used in the estimation of safety benefits are summarized in the table below.

Table 4: Assumptions Used in the Estimation of Safety Benefits

Variable Name	Unit	Value	Source
Unit Accident Costs	$/Victim, PDO Crash		2018 BCA Guidance document from US DOT.
Fatality		$9,600,000	
Injury		$174,000	
No Injury/ PDO		$4,327	
No-Build accidents across links	Number of accidents/crashes		Regional Transportation Demand Model
2023		155.4	
2042		190.8	
Build accidents across links	Number of accidents/crashes		Regional Transportation Demand Model
2023		145.7	
2042		178.9	
Existing Crash Distribution	Crashes		5-year accident statistics for the study area.
Fatal		3	
Injury		146	
PDO		942	
Implied Average Crash/accident costs	$/accident	$70,986	

7.1.2 BENEFIT ESTIMATES

Table 5 shows that the proposed project will result in a life-cycle safety benefits of $6.02 million, discounted at 7%, or $15.27 million in undiscounted dollars.

Table 5: Estimates of Safety Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Monetary Value of Accident reduction	$15.27	$6.02

7.2 State of Good Repair

The new KY 249 Interchange will divert traffic away from the congested US 31E Interchange reducing the daily road wear of that regional road infrastructure element.

In addition to the new interchange, this project will replace the existing narrow bridge over the South Fork Beaver Creek. This existing bridge was built in 1934 and is nearing the end of its expected life. The existing structure has a clear width of less than 20-ft, which is insufficient for wide truck and bus traffic. Additionally, the bridge sits at the bottom of a steep hill with a grade of approximately 8% and has insufficient horizontal curvature.

7.3 Economic Competitiveness

The proposed project would contribute to enhancing the economic competitiveness of the Nation through improvements in the mobility of people and goods within and across the study area. In this analysis, this benefit is quantified using travel time savings (in hours) and monetized using the value of travel-time savings recommended by US DOT.

As explained earlier, this project will allow a more direct access to the Louie B. Nunn Cumberland Parkway from areas along KY 249 reducing the requirements to travel along circuitous routes to the east or west. This may create benefits that go over and above travel time savings through improved connectivity to markets that can encourage local economic development. In particular, the interchange would improve connectivity of areas targeted for development in Barren County Comprehensive Plan. This benefit is considered in a qualittative way.

7.3.1 METHODOLOGY AND ASSUMPTIONS

Travel time savings are estimated based on the difference in travel times across the network (links included in analysis) under build and no-build scenarios. For each scenario, the travel demand model simulates the vehicle flows along the links and estimates vehicle hours of travel time based on the traffic volume and prevalent speed. The difference between scenarios gives total annual vehicle hours of savings.

These are then split into auto and truck VHT. Auto VHT are valued using the personal value of travel time multiplied by average vehicle occupancy while truck VHT are valued using truck value of travel time.

Within this framework, it was not possible to break out from the traffic data school bus ADT by link and calculate VHT specific to school buses. The above approach does not account for these savings as school bus occupancy is much above the average auto occupancy. Therefore, travel time savings to student population are estimated as an additional element based on the estimated number of students affected and average travel time savings per trip. The value of bus driver time (over and above auto travel time value) is accounted for in a similar manner.

The assumptions used in the estimation of travel time savings are summarized in the table below.

Table 3: Assumptions Used in the Estimation of Travel Time Savings

Variable Name	Unit	Value	Source
Value of Time			Based on 2018 BCA Guidance document from DOT.
Auto	$/h	$14.20	
Trucks	$/h	$28.60	
Bus Drivers	$/h	$30.00	
Average Vehicle Occupancy	persons per vehicle	1.39	
Number of School Days	Number	180.00	

Variable Name	Unit	Value	Source
Student Population Affected by Change, all years	Number	350	Local school district. Future student enrolment projections are not known, a constant enrollment is assumed.
Number of bus drivers		10	
Travel time savings for student transportation	Min per trip	2.5	
Estimated VHT Reduction across all links	VHT, daily		Regional Transportation Demand Model
2023		154.2	
2042		167.1	

7.3.2 BENEFIT ESTIMATES

The estimated benefits of economics outcomes are shown in Table 8. Total economic outcomes benefits over the analysis period amount of $24.93 million in constant 2017 dollars or $10.05 in dollars discounted at 7 percent.

Table 4: Estimates of Economic Competitiveness Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Monetary Value of Travel Time Savings	$24.93	$10.05

7.4 Quality of Life

The project would contribute to enhancing quality of life in the study area through improving the connectivity of local residents to various destinations within the region which currently can be accessed only through a much less direct route. This may increase access to employment opportunities, health care, and other services.

7.5 Innovation

The KY 249 Interchange project includes an innovative approach to right-of-way acquisition and funding with local individuals taking the lead and Barren County providing the guarantee on their donations. In addition, the latest USDOT supported intersection control evaluation (ICE) methods will be applied to the design process. This may lead to the implementaiton of the first ever roundabouts in rural Barren County. .

7.6 Partnership

As presented in the Project Narrative document, a diverse range of partners are involved in the development and funding of this project, including local government and other public, private and nonprofit organizations representing industrial sectors such as manufacturing, education, and community services.

8. Summary of Findings and BCA Outcomes

The tables below summarize the BCA findings. Annual costs and benefits are computed over the lifecycle of the project (20 years). As stated earlier, construction is expected to be completed by 2023. Benefits accrue during the years 2023-2042.

Table 5: Overall Results of the Benefit Cost Analysis, Millions of 2017 Dollars*

Project Evaluation Metric	7% Discount Rate	3% Discount Rate
Total Discounted Benefits	$16.07	$26.44
Total Discounted Construction Costs	$16.52	$18.23
Total Incremental O&M Costs	$0.31	$0.52
Net Present Value	-$0.76	$7.69
Benefit / Cost Ratio	0.95	1.42
Internal Rate of Return (%)	6.5%	

** Unless Specified Otherwise*

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 6.5 percent. With a 7 percent real discount rate, the $16.83 million investment would result in $16.07 million in total benefits and a Benefit/Cost ratio of 0.95.

With a 3 percent real discount rate, the Net Present Value of the project would increase to $7.69 million, for a Benefit/Cost ratio of 1.42.

The next table compiles the results by category of benefits. The table shows that about 38 percent of the benefits are represented by safety benefits and remaining 62 percent by travel time savings.

Table 6: Benefit Estimates by Long-Term Outcome for the Full Build Alternative

Primary Selection Criteria	Benefit Categories	7% Discount Rate	3% Discount Rate
Safety	Reduction in number of traffic crashes, fatalities and injuries	$6.02	$9.98
Economic Competitiveness	Travel Time Saving	$10.05	$16.46
Total Benefit Estimates		**$16.07**	**$26.44**

Note: Economic Competitiveness excluding short-term employment impacts of the project

9. BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a large number of assumptions and long-term projections, both of which are subject to considerable uncertainty.

The primary purpose of the sensitivity analysis is to help identify the variables and model parameters whose variations have the greatest impact on the BCA outcomes: the "critical variables."

The sensitivity analysis can also be used to:

- Evaluate the impact of changes in individual critical variables – how much the final results would vary with reasonable departures from the "preferred" or most likely value for the variable; and
- Assess the robustness of the BCA and evaluate, in particular, whether the conclusions reached under the "preferred" set of input values are significantly altered by reasonable departures from those values.

The sensitivity analysis was conducted with respect to changes in the value of travel time, value of statistical life, and capital cost estimate. The changes in the capital cost estimate have the greater impact on the net present value.

The outcomes of the quantitative analysis using a 7 percent discount rate are summarized in the table below. The table provides the percentage changes in project NPV associated with variations in variables or parameters (listed in row), as indicated in the column headers.

Table 7: Quantitative Assessment of Sensitivity, Summary

Parameters	Change in Parameter Value	New NPV Discounted at 7%	Change in NPV	New B/C Ratio Discounted at 7%
Value of Travel Time	Lower Bound of Range Recommended by US DOT	-$4.28	463.08%	0.74
	Upper Bound of Range Recommended by US DOT	$0.15	-120.31%	1.01
Value of Statistical Life	Lower Bound of Range Recommended by US DOT ($5.4 million)	-$2.15	182.90%	0.87
	Upper Bound of Range Recommended by US DOT ($13.4 million)	-$0.43	-42.86%	0.97
Capital Cost Estimate	25% Increase	-$4.89	543.94%	0.76
	25% Reduction	$3.37	-543.94%	1.27
O&M Estimate	25% Increase	-$0.83	9.64%	0.95
	25% Reduction	-$0.68	-10.20%	0.96