Benefit-Cost Analysis Supplementary Documentation

RAISE Program

Hampton Harbor Bridge Replacement

New Hampshire Department of Transportation

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

The Benefit-Cost Analysis (BCA) 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. Where not possible to assign a dollar value to a benefit, efforts have been made to quantify it. A qualitative discussion is also provided when a benefit is anticipated to be generated but is not easily monetized or quantified.

To complete funding to replace the Hampton Harbor Bridge, which is listed on the New Hampshire "Red-List" of structurally deficient bridges, the New Hampshire Department of Transportation (NHDOT) is pursuing a Rebuilding American Infrastructure With Sustainability and Equity (RAISE) grant to replace the existing bascule lift bridge between Hampton and Seabrook on Route 1A with a fixed bridge. This project will include two vehicle traffic lanes with wider shoulders and sidewalks compared to the existing bridge configuration. This will improve bicycle and pedestrian facilities and is designed to provide a high enough underclearance to allow existing maritime traffic to pass underneath without having to wait for the bridge to lift.

If the bridge is not replaced, operations and maintenance costs are likely to be significant over time, and traffic will be required to divert 12 miles to access Seabrook from Hampton and vice versa. The Hampton Harbor Bridge Replacement project is anticipated to have substantial impacts, which include the following:

- Provide significant travel time savings for private and commercial drivers along Route 1A between Hampton and Seabrook by avoiding a lengthy diversion;
- Achieve a reduction in bicycle and pedestrian traffic fatalities and injuries by improving facilities available to those travelers;
- Improve the movement of people along the corridor by reducing congestion and delays due to bridge lifts and delays caused by mechanical failure; and
- Reduce emissions for pollutants such as carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), fine particulate matter (PM2.5), sulfur dioxide (SO_x), and carbon dioxide (CO_2).

Table ES-1 summarizes the changes expected from the project and the associated benefits. Monetized and non-monetized benefits are provided.

Table ES-1: Merit Criteria and Cost-Effectiveness - Summary of Infrastructure Improvements and Associated Benefits, Millions of 2019 Dollars

Current Status or Baseline & Problems to be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Economic Benefit	Summary of Results Discounted at 7% (millions)
Travel Delays for vehicles, bicycles and pedestrians, and maritime vessels traveling over and under the bridge. Safety benefits for bicycles and pedestrians. O&M costs associated with lift bridge. Bridge is beyond its useful service life and is structurally deficient.	Replace the Hampton Harbor Bridge with a fixed bridge with an appropriate underclearance to accommodate maritime traffic and improved bicycle and pedestrian facilities.	Improved travel speeds, reduced congestion and closure delays, improved safety due to improved bicycle and pedestrian facilities.	Safety Benefits	$0.26
			Travel Time Savings-Vehicles	$4.91
			Travel Time Savings - Bicycles and Pedestrians	$0.20
			Travel Time Savings - Averted Diversions	$25.99
			Travel Time Reliability	Not Monetized
			Vehicle Operating Costs - Diverted Trucks	$20.63
			Journey Quality Benefits	$0.35
			Emissions Benefits due to Delays	$0.10
			Emissions Benefits due to Diversions	$5.94
			O&M Cost Savings	$0.77
			Residual Value	$3.63

The Hampton Harbor Bridge is an important link between Hampton and Seabrook along 1A and is used heavily by both weekday commuters and weekend beach goers. The proposed bridge replacement will improve travel time and reliability, improve safety, reduce emissions and spur economic growth and additional investments in the region.

The period of analysis used in the estimation of benefits and costs corresponds to 20 years, including 5 years of construction and project support and 20 years of operation. The total project capital costs are $57.3 million in 2019 dollars and are expected to be financed by federal and state funds.

Operations & Maintenance (O&M) costs and cyclical repaving costs for an operational period of 20 years in the Build scenario will save a net total $0.77 million.[1] The primary and most significant source of these savings is maintenance associated with the mechanical components of a bascule bridge, and the labor costs required to operate the lifts. The fixed bridge in the Build scenario will not have any of these costs.

[1] Per USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (February 2021), for the purposes of this BCA the net O&M costs between the build and no-build baseline should be included in the numerator along with other project benefits when calculating a benefit-cost ratio for a project proposed for funding under the discretionary grant programs.

Based on the analysis presented in the rest of this document, the project is expected to generate $62.8 million in discounted benefits and $39.0 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value of $22.8 million and a Benefit-Cost Ratio of 1.61, as presented in Table ES-2.

Table ES-2: Overall Results of the Benefit Cost Analysis, Millions of 2019 Dollars

Project Evaluation Metric	7% Discount Rate
Total Discounted Benefits	$62.77
Total Discounted Costs	$39.02
Net Present Value	$22.76
Benefit-Cost Ratio	1.61

A summary of the relevant data and calculations used to derive the total monetized benefits and costs of the project (discounted at 7 percent) are shown in Table ES-3.The largest source of benefits is from travel time savings. Travel time benefits are expected to total $31.1 million discounted at 7 percent over the 20-year analysis period. Currently, vehicles, trucks, bicycles and pedestrians are delayed every time the bridge is raised to accommodate maritime traffic, which can cause stopping and queuing while the bridge is in the up position. In addition, our No-Build scenario assumes that trucks will divert around the bridge due to weight restrictions. Avoiding this diversion in the Build scenario generates additional time savings.

Table ES-3: Summary of Pertinent Data, Quantifiable Benefits and Costs, Millions of 2019 Dollars, Discounted at 7% (3% for Carbon Dioxide)

Calendar Year	Project Year	Travel Time Savings	Accident Cost Savings	Vehicle Operating Cost Savings	Emissions Cost Savings	Journey Quality Benefits	O&M Cost Savings	Residual Value	Total Benefits	Total Costs
2019	1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	2	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2021	3	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$3.21
2022	4	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.86
2023	5	$0.00	$0.00	$1.45	$0.00	$0.00	$0.00	$0.00	$1.45	$2.26
2024	6	$0.00	$0.00	$1.37	$0.00	$0.00	$0.00	$0.00	$1.37	$10.01
2025	7	$0.00	$0.00	$1.30	$0.00	$0.00	$0.00	$0.00	$1.30	$11.99
2026	8	$0.00	$0.00	$1.24	$0.00	$0.00	$0.00	$0.00	$1.24	$7.29
2027	9	$0.00	$0.00	$1.17	$0.00	$0.00	$0.00	$0.00	$1.17	$3.40
2028	10	$2.41	$0.02	$1.11	$0.38	$0.03	$0.08	$0.00	$4.03	$0.00
2029	11	$2.29	$0.02	$1.05	$0.37	$0.03	$0.06	$0.00	$3.82	$0.00
2030	12	$2.18	$0.02	$1.00	$0.36	$0.02	$0.07	$0.00	$3.64	$0.00
2031	13	$2.07	$0.02	$0.95	$0.35	$0.02	$0.05	$0.00	$3.46	$0.00
2032	14	$1.97	$0.02	$0.90	$0.33	$0.02	$0.06	$0.00	$3.30	$0.00
2033	15	$1.87	$0.02	$0.85	$0.32	$0.02	$0.04	$0.00	$3.12	$0.00
2034	16	$1.78	$0.02	$0.81	$0.31	$0.02	$0.05	$0.00	$2.99	$0.00
2035	17	$1.69	$0.01	$0.77	$0.30	$0.02	$0.04	$0.00	$2.84	$0.00
2036	18	$1.61	$0.01	$0.73	$0.30	$0.02	$0.04	$0.00	$2.71	$0.00
2037	19	$1.53	$0.01	$0.69	$0.29	$0.02	$0.02	$0.00	$2.56	$0.00
2038	20	$1.45	$0.01	$0.66	$0.29	$0.02	$0.04	$0.00	$2.46	$0.00
2039	21	$1.38	$0.01	$0.62	$0.28	$0.02	$0.03	$0.00	$2.34	$0.00
2040	22	$1.31	$0.01	$0.59	$0.28	$0.01	$0.03	$0.00	$2.24	$0.00
2041	23	$1.25	$0.01	$0.56	$0.28	$0.01	$0.03	$0.00	$2.14	$0.00
2042	24	$1.19	$0.01	$0.53	$0.28	$0.01	$0.03	$0.00	$2.05	$0.00

Calendar Year	Project Year	Travel Time Savings	Accident Cost Savings	Vehicle Operating Cost Savings	Emissions Cost Savings	Journey Quality Benefits	O&M Cost Savings	Residual Value	Total Benefits	Total Costs
2043	25	$1.13	$0.01	$0.50	$0.27	$0.01	$0.02	$0.00	$1.95	$0.00
2044	26	$1.08	$0.01	$0.48	$0.27	$0.01	$0.03	$0.00	$1.87	$0.00
2045	27	$1.02	$0.01	$0.45	$0.26	$0.01	$0.02	$0.00	$1.78	$0.00
2046	28	$0.97	$0.01	$0.43	$0.26	$0.01	$0.02	$0.00	$1.70	$0.00
2047	29	$0.93	$0.01	$0.41	$0.26	$0.01	$0.01	$3.63	$5.24	$0.00
2048	30	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total		**$31.10**	**$0.26**	**$20.63**	**$6.04**	**$0.35**	**$0.77**	**$3.63**	**$62.77**	**$39.02**

*Total costs include construction costs and miscellaneous costs (e.g., utilities, permits, incentives, design, and construction engineering).

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the Hampton Harbor Bridge Replacement project.

- Section 3, Methodological Framework, introduces the conceptual framework used in the Benefit-Cost Analysis;
- Section 4, Project Overview, 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. Monetized, quantified, and qualitative effects are highlighted;
- Section 5, General Assumptions, discusses the general assumptions used in the estimation of project costs and benefits;
- Estimates of travel demand and traffic growth can be found in Section 6, Demand Projections:
- Specific data elements and assumptions pertaining to the merit criteria are presented in Section 7, Estimation of Economic Benefits, 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, Summary of Findings and BCA Outcomes;
- Section 9, BCA Sensitivity Analysis, provides the outcomes 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.

3. Methodological Framework

The Benefit-Cost Analysis (BCA) conducted for Hampton Harbor Bridge Replacement project includes monetized benefits and costs that are measured using USDOT guidance, as well as quantitative and qualitative merits of the proposed project. A BCA provides estimates of the benefits that are expected to accrue from a project over a specific period and compares them to the anticipated costs of the project. Estimated benefits are based on the projected impacts of the project on both users and non-users of the facility, valued in monetary terms.[3]

The specific methodology utilized in this application was developed based on the USDOT BCA Guidance released in February 2021. The analysis is consistent with all RAISE program guidelines, specifically:

- Establishing existing and future conditions under the "Build" and "No-Build" scenarios;
- Assessing benefits with respect to the criteria identified in the Notice of Funding Opportunity (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, vehicle operating costs, 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 of 7 percent generally and 3 percent for benefits related to carbon dioxide emissions; and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

The BCA measures benefits against costs throughout a period of analysis beginning at the start of project development and including 20 years of operation. The monetized benefits and costs are estimated in 2019 dollars with future dollars discounted at 7 percent and CO2 discounted at 3 percent in compliance with RAISE requirements. The analysis period totals 28 years, beginning in 2019 and ending in 2047; this includes project development and construction from 2019-2027 and operations from late 2028 to 2047.[4] The 20-year analysis period was utilized in compliance with USDOT recommendations that "projects aimed primarily at capacity expansion or to address other operating deficiencies should use an operating period of 20 years."[5] This horizon also corresponds to the project design year traffic projections.

4. Project Overview

The New Hampshire Department of Transportation (NHDOT) requests $20 million in Rebuilding American Infrastructure with Sustainability and Equity (RAISE) funds to support the Hampton Harbor Bridge Replacement Project, which includes reconstructing the Hampton Harbor Bridge, also known as the Neil R. Underwood Bridge, and associated access roadways and is estimated to cost $57.3 million in 2019 dollars. This bascule bridge reconstruction will result in a fixed bridge structure that improves vehicular, pedestrian, bicycle and marine traffic efficiency and safety, while reducing lifecycle operations and maintenance (O&M) costs. Specifically, the Hampton Harbor Bridge Replacement Project will replace the existing bascule structure with a fixed bridge and reconstruct associated access roadways and sidewalks.

This bridge has been on NHDOT's Red List of deficient bridges since 1999 due to the poor condition of the superstructure. It is considered New Hampshire's number one priority Red-Listed bridge. It is a steel and concrete structure and located on Route 1A along the New Hampshire

Seacoast. It spans the Hampton River near Hampton Beach, New Hampshire, and is a vital connection between the Village of Hampton Beach and Seabrook Village.

The bridge itself is approximately 1,199 feet long and approximately 33 feet wide (53 feet wide at the barrier gates). It includes a 24-foot-wide roadway, a one-foot-wide shoulder on either side, and a four-and-a-half-foot-wide sidewalk on the east side. The bridge carries up to 18,000 vehicles per day during peak summer traffic. This segment of NH Route 1A is also the on-road route for the East Coast Greenway in NH and, as such, the roadway handles vehicular, bicycle, and pedestrian traffic. Preserving access for multiple modes of transportation is a high priority for this proposed bridge replacement.

4.1 Base Case and Alternatives

For the purposes of this analysis, the proposed project improvements are considered a "Build" scenario, whose benefits and costs will be weighed against a "No-build" scenario that retains the existing conditions. The "Build" Scenario includes Fixed Bridge replacement to allow vehicular, bicycle and pedestrian and maritime vessel traffic flow through the area without delays caused by bridge lifts as well as improved pedestrian/bicycle facilities to facilitate access and travel. Figure 1 shows the current Hampton Harbor Bridge Section, and Figure 2 shows the proposed reconfiguration of the roadway across the bridge.

Figure 1: Schematic Representation of the Hampton Harbor Bridge No-Build Scenario Lane Configuration

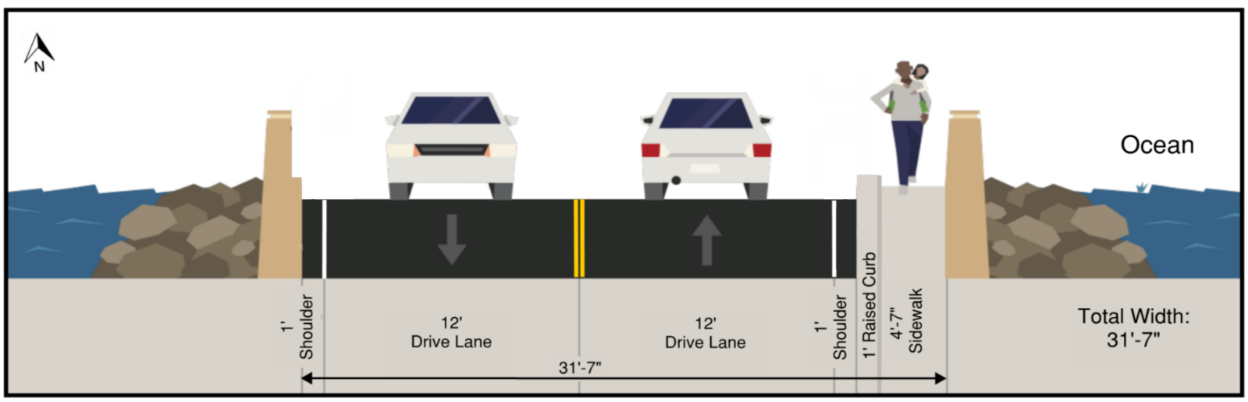
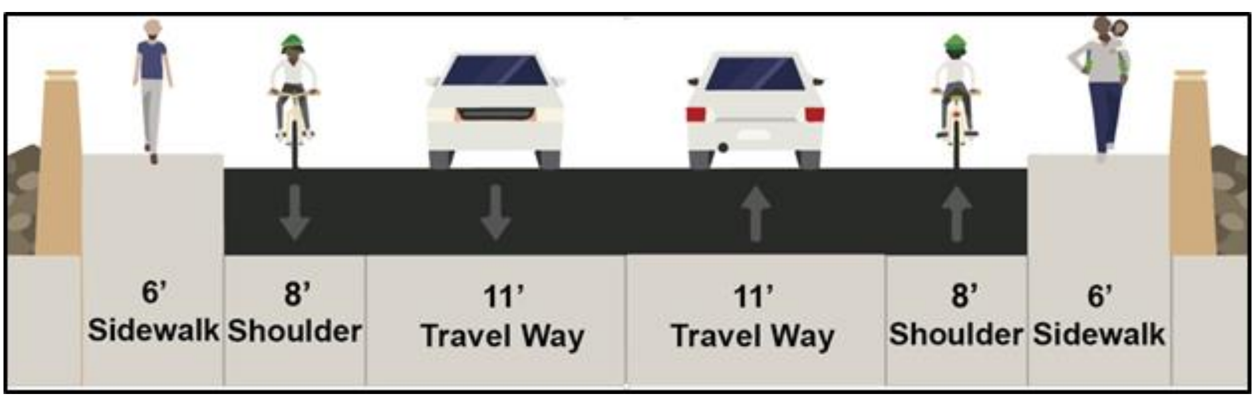


Figure 2: Schematic Representation of the Hampton Harbor Bridge Build Scenario Lane Configuration



4.2 Types of Impacts

The project will benefit the following categories of population:

- People that use the bridge or pass under it in their everyday personal or business travel will see the travel time savings resulting from removing the need for bridge lifts to accommodate maritime traffic.
- Truck drivers and trucking companies will benefit from reduced delays and any future diversions created by potential load restrictions on the bridge.
- Bicyclists and pedestrians will benefit from safety improvements to the bridge.
- Local communities in general, not only drivers, will enjoy less air pollution due to decreased congestion and unnecessary diversions associated with a weight-restricted bridge.

4.3 Project Cost and Schedule[2]

Project construction engineering costs will be incurred between June 2023 and June 2024, and project construction is expected to begin June 2024 and extend through June 2027.[3] The total discounted capital costs of the project are approximately $39.0 million. Capital costs include construction costs and miscellaneous costs such as access for construction, bridge removal, fenders, cofferdams, mobilization and construction engineering. The breakdown of capital costs is provided in Table 1.

Although USDOT BCA guidance recommends that the difference between the build and the no build operation and maintenance (O&M) costs and cyclical repaving costs should be included as a disbenefit rather than a project cost.[4] Because replacement of the bascule bridge with a fixed structure reduces overall O&M costs, this BCA includes this cost savings as a benefit.

Table 1: Project Cost Summary, in Millions of 2019 Dollars

Cost Type	Cost, Discounted at 7 Percent
Construction Costs	$47.7
Project Support (Access for Construction, Bridge Removal, Fenders, Cofferdams, Mobilization, and Construction Engineering)	$9.6
TOTAL	**$57.3**

The tables below show the scheduling assumptions assumed for the BCA.

[2] All cost estimates in this section are in millions of 2019 dollars, discounted to 2019 using a 7 percent real discount rate.

[3] The BCA assumes that construction engineering begins in June 2023, construction begins June 2024 and ends in June 2027, with the first full year of benefits in 2028.

[4] USDOT, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* February 2021.

Table 2: Construction Schedule by Start and End

Construction Cost Schedule				
Stage	**Task**	**Duration**	**Stage Start**	**Stage End**
Stage 1	Construct Replacement Substructure	12 months	Jun-23	Jun-24
Stage 2: Phase 1	Phase 1 install superstructure on replacement bridge construct new bridge approaches and move traffic to the new bridge. One lane in each direction.	12 months	Jun-24	Jun-25
Stage 2: Phase 2	Phase 2 superstructure on replacement bridge, complete abutments, roadway approaches and remove existing bridge	12 months	Jun-25	Jun-26

Table 3 below presents the project schedule.

Table 3: Project Schedule

Activity	Date
Publish Environmental Assessment	Winter 2020
Finalize Environmental Assessment	Winter 2021
Finalize Design of Selected Alternative	Fall 2021 to Summer 2023
Construction	Summer 2024 to Summer 2027

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 2019 dollars with future dollars discounted in compliance with USDOT guidance using a 7 percent real rate generally, and a 3 percent real rate for benefits related to carbon dioxide emissions.

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

- Input prices are expressed in 2019 dollars;
- The period of analysis begins in 2019 and ends in 2047. It includes project development and construction years and 20 years of operations (2028-2047);
- A constant 7 percent real discount rate is assumed throughout the period of analysis, with a 3 percent real discount rate applied to benefits related to carbon dioxide emissions;
- Opening year demand is assumed to be fully realized in 2028; and
- The results shown in this document correspond to the effects of the Build alternative.

6. Demand Projections

As shown in the Type, Span & Location (TSL) Study Report, the fixed bridge alternative improves mobility, safety and emissions on this section of Route 1A. The fixed steel bride single alternative was identified as the preferred option by the report; this application assumes the estimated project costs for that bridge type, as well as a discussion of the range of benefits and impacts.

Route 1A is a major roadway used by commuters, beach goers and commercial vehicles between Hampton and Seabrook, New Hampshire, and is a vital link for traffic traveling locally and from urban centers in Portland, ME to the north and Boston, MA to the south. The bridge roadway is a two-lane divided configuration serving on average 9,466 vehicles daily and up to 18,000 vehicles per day during summer peak travel.

FUTURE YEAR GROWTH PROJECTIONS

Existing traffic conditions were recorded in July of 2018. The bridge carries an estimated average annual daily traffic of 9,466 vehicles and up to 18,000 on peak summer days. Traffic is expected to grow by 1.5 percent annually, based on the Type, Size & Location (TS&L) report, which would exacerbate travel delays in the No-Build scenario going forward.

Table 4: Bridge Vehicle Traffic Growth Projections

Description	Value
2019 AADT	9,466
2023 AADT	10,351
2047 AADT	14,796
Annual Growth Factor	1.50%

AADT – Average Annual Daily Traffic

In addition, bicycle and pedestrian traffic was counted and projected for the bridge. Bicycle and pedestrian traffic experiences a significant uptick on weekends due to recreational travel in the area, likely associated with the local beaches. This traffic is also expected to grow by 1.5 percent annually.

Table 5: Bridge Bicycle and Pedestrian Traffic Growth Projections

Description	Value			
	Bicycle		Pedestrian	
	Weekday	Weekend	Weekday	Weekend
2019 AADT	150	309	264	504
2023 AADT	159	159	280	535
2047 AADT	228	469	400	764
Annual Growth Factor	1.50%			

Maritime vessel traffic was provided by NHDOT and includes a mix of recreational and commercial activity. Like the projections for vehicles, bicycles and pedestrians, this traffic is assumed to grow by 1.5 percent annually in line with vehicle growth projections found in the TSL report. These projections and any benefits associated with maritime traffic are used for sensitivity analysis only.

Table 6: Bridge Maritime Vessel Growth Projections

Description	Value
2019 Annual Traffic	1,155
2023Annual Traffic	1,226
2047 Annual Traffic	1,753
Annual Growth Factor	1.50%

7. Estimation of Economic Benefits

7.1 Benefits Measurement, Data and Assumptions

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

LIST OF BENEFITS ANALYZED

The benefits assessed for the Hampton Harbor Bridge Replacement project are as follows:

- **Travel Time Savings:** Captures the reduced travel time for automobiles and trucks, bicycles and pedestrians under the build scenario as a result of bridge reconfiguration and replacement. Travel time savings will be realized by:
    - Passenger vehicles, bicycles, and pedestrians that will avoid delays associated with bridge lifts.
    - Truck drivers who will also avoid potential diversions associated with weight limits that could be placed on the existing bridge due to structural deficiencies. A 12-mile diversion would be expected if trucks could not use the bridge. It is estimated in the travel demand model that 7 percent of traffic in the study area would need to be diverted due to weight limitations.

Given the substantial traffic that travels over the bridge on a daily basis, travel delays due to bridge lifts to accommodate maritime traffic for both the no build and build scenarios were estimated. Travel delays were modeled in terms of average second delays per vehicle given the bridge lift schedule. The benefit-cost analysis utilized values for vehicle seconds converted into hours as produced by the travel model. It is expected that there will be travel time improvements throughout the day on both weekdays and weekends.

- **Accident Cost Savings:** The proposed improvements will improve bicycle and pedestrian facilities, which are expected to reduce the number of collisions between vehicles and bicycles that current travel in vehicle traffic lanes. This project will create an additional buffer of space between vehicles and pedestrians on the sidewalk.

- **Emission Cost Savings:** The proposed improvements will reduce emissions by allowing for more consistent free flow speeds and less time spend idling during bridge lifts. The project will also avert emissions associated with trucks that have to divert on longer route around the bridge. The diversion is approximately 12 miles compared the a 0.4-mile trip across the bridge. As a result of the proposed improvements, emissions will decrease for pollutants such as carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), fine particulate matter (PM2.5), sulfur dioxide (SO_2), and carbon dioxide (CO_2).

- **Journey Quality Benefits:** The improvements for bicycles and pedestrians include widening shoulders and sidewalks. These improvements will provide a separated bike lane for bicycles and improve pavement evenness and curb level for pedestrians, all of which will improve the quality of the trip.

- **Operations & Maintenance Cost Savings:** Bascule lift bridges require significantly more O&M costs on an annual basis than fixed bridges. Costs for lift bridges that are above and beyond those of fixed bridges include wear and tear on the mechanical and electric equipment used to lift and lower the bridge and labor costs that are required to have a technician manning of the bridge during hours of operation.

METHODOLOGY

The methodology used for estimating each of the benefits listed is presented below:

Accident Cost Savings – Bicycles and Pedestrians: The current road configuration only accommodates a 1-foot shoulder on either side of the road. This forces bikes to travel in the lanes of vehicular traffic and puts pedestrians in close contact with vehicles. Using injuries and fatality rates for bicycles and pedestrians per 100 million VMT, the baseline expected fatalities and injuries on the bridge were calculated. The incident per 100 million VMT are provided nationally by the FHWA. A CMF of 0.734 was obtained from CMF Clearinghouse. This CMF is specific to lane widening and its effect on bicycle and pedestrian safety. This CMF was applied to the baseline injuries and fatalities rate and monetized using USDOT guidance of $10,900,000 per fatality and $197,600 per injury. There are no significant improvements for vehicle safety.

Travel Time Savings - Vehicles: Calculated based on average vehicle delays due to bridge lifts. Average delays due to lifts were entered for northbound and southbound traffic in the BCA model. Vehicles and bicycles and pedestrians are assumed to be idling during this time. Average vehicle occupancy and percent trucks data were also entered in the model. The model multiplies the number of hours saved by personal vehicle drivers and truck drivers by their corresponding vehicle occupancy rates and values of time. Travel time costs are compared between the no build and build and the difference is the travel time savings.

Travel Time Savings – Bicycles and Pedestrians: Pedestrians going north and south are expected to experience the same delays as their vehicular counterparts. The average time of delays modeled for vehicles is applied to bicycles and pedestrians who have their time valued at $33.00 per hour per USDOT guidance.

Travel Time Savings – Diverted Trucks: Due to the Hampton Harbor Bridge's inclusions on the New Hampshire "Red-List," it is expected that in the No-Build scenario the existing bridge will be weight restricted due to structural deficiencies. This bridge provides the quickest and most direct route for traffic in this area and a diversion would start just south of the bridge and end north of it over a 12-mile stretch. If these trucks were to drive the direct route over the bridge from the same point A to point B it would be a 0.4-mile trip. Annual truck traffic was multiplied by the 12-mile diversion and 0.4-mile direct route over the bridge to estimate the annual potential VMT of both. The difference between the two gave the net VMT, which was divided by an assumed 30 miles per hour travel speed to give the expected increase in VHT associated with the diversion. This VHT figure was then multiplied by the truck driver wage rate provided by the USDOT 2021 Discretionary Grant Guidance of $30.80. The resulting value equals the estimated value of travel time savings for the averted diversion for truck traffic.

Travel Time Savings – Maritime Vessels (Sensitivity Analysis only): This analysis uses the assumption from the TS&L Study report of an average of 2 lifts per hour lasting 400 seconds each. Assuming that lifts occur at 30-minute intervals and that the arrival of vessels is stochastic throughout each hour, this analysis assumes that the average wait time is 5 minutes on average. Worker and passenger occupancy was estimated for each boat by vessel type. Using the assumed wait time and occupancy, a VHT for waiting time was calculated and applied to hourly values of time of $33.00 for passengers and $30.80 for workers per USDOT guidance.

Travel Time Savings – Bridge Closure (Sensitivity Analysis only): The Hampton Harbor Bridge has been stuck in the up position due to electrical or mechanical failure several times since 2000. Disruptions associated with these failures can cause hours-long closures and require significant diversions for all types of traffic. The diversion used in this scenario is the same route weight-restricted trucks would be expected to take. The diversion routes cars 12 miles around the bridge to a point where the direct route would have only been 0.4 miles. The VHT for this diversion was determined using an average speed of 30 miles per hour, which is consistent with average speeds observed on the bridge.

Vehicle Operating Cost Savings – Truck Diversion: Calculated based on the additional VMT associated with diverting trucks 12 miles. The structurally deficient state of the bridge means that weight limits in the near term are highly probable. Seven percent of AADT over the bridge is attributed to trucks. In the No-Build scenario, these trucks would need to be rerouted. The monetary value of these savings was derived by calculating the net increase in VMT associated with the diversion and multiplying that by $0.93 per mile per USDOT guidance. This per-mile figure accounts for vehicle operating costs such as fuel consumption, maintenance and repair, insurance and depreciation.

Journey Quality Benefits: This roadway configuration of this bridge project widens the roadways' shoulders and sidewalks. This effectively provides separated bike lanes where there were previously none, which takes bicycles out of the vehicle lanes of traffic. This BCA leverages Cal-B/C AT methodology to quantitatively assess the value of improved journey quality for existing pedestrians and cyclists.

For pedestrians, journey quality benefits "are based on the results of stated preference surveys" and are monetized on a per-mile basis.[8] Cal-B/C AT parameters include per-mile pedestrian benefits for seven distinct types of pedestrian amenities: "Street Lighting," "Curb Level," "Crowding," "Pavement Evenness," "Information Panels," "Benches," and "Directional Signage." This BCA combines the per-mile benefits of Street Lighting, Curb Level, Crowding, and Pavement Evenness—consistent with the pedestrian infrastructure improvements provided by this project—and aggregates total benefit as the product of per-mile benefits and expected pedestrian walking mileage over the period of analysis. This aggregation conservatively only considers the mileage walked by pre-existing pedestrians, excluding the additional consumer surplus gained by new pedestrians who begin walking as a result of project improvements.

Journey quality benefits for cyclists "are driven primarily by revealed preference research on cyclist route [choice]," leveraging "values [that] capture the preference for a designated bike route in comparison with a basic roadway."[9] Cal-BC A/T parameters include cycling "Facility Preference Factors as function of distance by facility class." For example, the Facility Preference Factor for Class I trails—consistent with the separated multi-use paths included in the project improvements—is 0.57, indicating that one mile travelled on a Class I trail is equivalent to 0.57 miles traveled on a standard roadway without bicycle facilities. Expressed another way, one mile of cyclist travel on a Class I trail is equivalent to a cyclist averting 0.43 miles of travel on a standard roadway. The mile-equivalent savings of improved cycling facilities is monetized according to average cyclist speed, per Cal-B/C AT parameters, and the per-hour valuation of cyclist time, per USDOT BCA Guidance. As is the case for pedestrian journey quality, cyclist journey quality in this BCA is only monetized for distance travelled by pre-existing cyclists, conservatively excluding additional consumer surplus gained by individuals that begin cycling as a result of project improvements.

Emission Cost Savings: There are five types of emissions measured in the analysis: carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NO_x), fine particulate matter (PM 2.5), sulfur dioxide (SO_2), and carbon dioxide (CO_2). Emissions per mile travelled for these pollutants were estimated using EPA's Motor Vehicles Emissions Simulator (MOVES) model run for Rockingham County, NH, for the years of 2016 to 2045.

Emissions in the No-Build Scenario are estimated using idling time for vehicles due to bridge lifts, additional VMT from diverted trucks due to weight restrictions, and for all traffic during bridge closure events due to mechanical or electrical failure.

O&M Cost Savings: As per USDOT's BCA guidance (February 2021) net O&M costs are included in the numerator along with other project benefits when calculating a benefit-cost ratio for a project proposed under the discretionary grant programs. O&M cost savings are reported from 2028 to 2047.

Bridge Electrical/Mechanical Failure (Sensitivity Analysis only): The Hampton Harbor Bridge has closed several times since 2000 and is expected to have unexpected closures due to electrical or mechanical issues going forward. For the sensitivity analysis, it is assumed that electrical closures occur once every 5 years and mechanical failures cause closures once every 20 years. As the bridge continues to age, the probability of closures due to issues with the lift mechanism is expected to increase in probability by 0.5 percent annually.

Residual Value: The Hampton Harbor Bridge Replacement project will include physical components with useful service lives that extend beyond the 20-year period of operations analysis. The substructure has an estimated useful service life of 100 years and the superstructure has an estimated useful service life of 60 years. The construction costs for these two components are straight-line depreciated from 2028 to 2047 and their residual value is captured in 2047.

ASSUMPTIONS

The assumptions used in the estimation of economic benefits for the project are summarized in the table below.

Table 7: Assumptions Used in the Estimation of Benefits, 2019 Dollars

Benefit Categories	Variable Name	Unit	Value	Source / Notes
Travel Time Savings	Average Vehicle Occupancy (Automobiles)	Persons per vehicle	1.67	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs. February 2021*.
	Average Vehicle Occupancy (Trucks)	Persons per vehicle	1.00	
	Share of Trucks	Percentage	7%	NHDOT ATR Data
	Travel Time Cost (Automobiles) – All Purposes Local	Dollars per hour	$16.50	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs. February 2021*.
	Travel Time Cost (Trucks)	Dollars per hour	$30.80	
	Travel Time Cost (Bicycles & Pedestrians)	Dollars per hour	$33.00	
Closure-Related Travel Time Savings	Annual Likelihood of Electrical Failure	Probability of Closure	20%	NHDOT Bridge Failure Records & HDR Assumption
	Repair Cost Per Electrical Failure	Dollars	$1,000	
	Average Hours to Divert Traffic During Electrical Repairs	Hours per closure	5	
	Annual Likelihood of Mechanical Failure	Closures per year	5%	
	Repair Cost Per Mechanical Failure	Dollars	$759,000	
	Average Hours to Divert Traffic During Mechanical Repairs	Hours per Closure	48	
	Annual Increase in Likelihood of Failure	Increased Probability	0.5%	
Vehicle Operating Costs	Vehicle Operating Costs – Passenger Vehicles	Dollars per mile	$0.43	USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 2021
	Vehicle Operating Costs – Commercial Vehicles	Dollars per mile	$0.93	

Benefit Categories	Variable Name	Unit	Value	Source / Notes
Journey Quality Benefits	Class II Bikeway Facility Preference Factor	Facility Preference Factor	0.49	California Department of Transportation: California Active Transportation Benefit/Cost Analysis Model Version 7.2; February 2020
	Average Bicycle Speed	Miles per hour	11.8	
	Walking Journey Quality by Amenity – Curb Level	Dollars per mile	$0.078	
	Walking Journey Quality by Amenity – Pavement Evenness	Dollars per mile	$0.026	
Accident Cost Savings	Fatality Crash	Dollars per fatality	$10,900,000	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* June 2018. CMFs are presented in the Methodology section above. Please see **Error! Reference source not found.** for crash data summary.
	Injury Crash	Dollars per injury	$197,600	
	Bike and Pedestrian Fatality Rate per 100 million VMT	Fatalities per 100 million VMT	0.22	FHWA
	Bike and Pedestrian Injury Rate per 100 million VMT	Injuries per 100 million VMT	4.32	
	CMF for Shoulder Widening	Crash Modification Factor	0.734	CMF Clearing House

Table 8: Assumptions Used in Value of Emission per metric ton by Type, 2019 Dollars

Emission Type	NOx	SO2	PM2.5	CO2
2020	$15,700	$40,400	$729,300	$50
2021	$15,900	$41,300	$742,300	$52
2022	$16,100	$42,100	$755,500	$53
2023	$16,400	$43,000	$769,000	$54
2024	$16,600	$43,900	$782,700	$55
2025	$16,800	$44,900	$796,600	$56
2026	$17,000	$45,500	$807,500	$57
2027	$17,300	$46,200	$818,600	$58
2028	$17,500	$46,900	$829,800	$59
2029	$17,700	$47,600	$841,200	$60
2030	$18,000	$48,200	$852,700	$61
2031	$18,000	$48,200	$852,700	$62
2032	$18,000	$48,200	$852,700	$63
2033	$18,000	$48,200	$852,700	$64
2034	$18,000	$48,200	$852,700	$66
2035	$18,000	$48,200	$852,700	$67
2036	$18,000	$48,200	$852,700	$68
2037	$18,000	$48,200	$852,700	$69
2038	$18,000	$48,200	$852,700	$70
2039	$18,000	$48,200	$852,700	$71
2040	$18,000	$48,200	$852,700	$72
2041	$18,000	$48,200	$852,700	$73
2042	$18,000	$48,200	$852,700	$75
2043	$18,000	$48,200	$852,700	$76
2044	$18,000	$48,200	$852,700	$77
2045	$18,000	$48,200	$852,700	$78
2046	$18,000	$48,200	$852,700	$79
2047	$18,000	$48,200	$852,700	$80
2048	$18,000	$48,200	$852,700	$81
2049	$18,000	$48,200	$852,700	$83
2050	$18,000	$48,200	$852,700	$84

AGGREGATION OF BENEFIT ESTIMATES

Table 8 presents the benefit estimates by benefit categories over the project's lifecycle. Travel time savings (including closure-related) represent the large majority of the total benefits ($31.1 million) followed by vehicle operating cost savings ($20.6 million). Emissions benefits are expected to also be significant due to averted delays due to bridge lifts and diverted traffic ($6.0 million) and the bridge is expected to still hold significant residual value at the end of the analysis period due to durable components such as the substructure and superstructure ($3.6 million). Bicycle and pedestrian traffic is not a significant portion of traffic over this bridge so safety and journey quality benefits associated with the new roadway configuration are limited ($0.3 million and $0.4 million respectively). Benefits discounted by 3 percent are provided as a comparison.

Table 9: Estimates of Economic Benefits, Millions of 2019 Dollars

Benefit Category	Over the Project Lifecycle	
	Discounted at 7%	Discounted at 3%
Travel Time Savings	$31.1	$60.5
Accident Cost Savings	$0.3	$0.5
Vehicle Operating Cost Savings	$20.6	$35.5
Emissions Cost Savings	$6.0	$7.2
Journey Quality Benefits	$0.4	$0.7
O&M Cost Savings	$0.8	$1.4
Residual Value	$3.6	$10.5
Total Benefits	$62.8	$116.4
Benefit Cost Ratio	1.61	2.41

*Total may not sum up due to rounding

7.2 Comparison of Benefits and Costs

The project's benefits exceed the costs over the life-cycle of this project. The inclusion of non-monetized benefits (e.g., travel time reliability) would increase the overall benefit-cost ratio.

8. Summary of Findings and BCA Outcomes

With a 7 percent real discount rate, the $39.0 million investment would result in $62.8 million in total benefits and a benefit-cost ratio of approximately 1.61.

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 outcomes of the quantitative sensitivity analysis for the project using a 7 percent discount rate are summarized below.

- The inclusion of vehicle operating costs savings, travel time benefits and repair costs associated with bridge closures due to electrical and mechanical failures increase the BCR by 0.8 percent to 1.62.
- Inclusion of maritime vessel travel delays due to waiting for bridge lifts is expected to increase the BCR by 1.5 percent to 1.63.
- A 25 percent increase in the capital cost of the project decreases the BCR by 20 percent to 1.29.
- A 25 percent increase in the O&M costs has a negligible effect and the BCR goes down by less than 0.1% and is unchanged at 1.61.
- A 3 percent real discount rate generates a net present value of $116.4 million, for a benefit-cost ratio of 2.41.

To summarize, none of the sensitivity scenarios tested above drives the BCR below 1.00.