ECONOMICS APPENDIX

NORTH LANDING BRIDGE REPLACEMENT FEASIBILITY STUDY:

ATLANTIC INTRACOASTAL WATERWAY

APPENDIX B: ECONOMICS

October 2019

U.S. Army Corps of Engineers
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1 INTRODUCTION

The study area includes the North Landing Bridge and vicinity. This bridge crosses the boundary line between the cities of Chesapeake and Virginia Beach, Virginia about 150 miles southeast of Washington D.C. The bridge is located at the eastern border of Chesapeake and the southwestern border of Virginia Beach in a relatively rural section of both cities. The bridge services vehicular traffic in the cities of Chesapeake and Virginia Beach and boat traffic, including both local and transient vessels traveling the Atlantic Intracoastal Waterway (AIWW).

The North Landing Bridge is a double-swing span two-lane bridge constructed in 1951. It has a length of 238 feet, a width of 28 feet, vertical clearance of 6.5 feet, and a horizontal channel clearance of 80 feet. It has a weight limit of 13 tons/26,000 pounds. The original design capacity had a limit of 8,000 vehicles per day. At the time of construction, it cost approximately $372,400. It currently operates in accordance with 33 CFR 117.1021, which requires openings on the hour and half hour from 0600 to 1900 and on demand from 1900 to 0600. The bridge also opens on demand at all times for commercial vessel traffic. When the bridge is open, there is an 80-foot horizontal channel clearance and an unlimited overhead clearance. When it is closed, there is a 6-foot vertical clearance. The roadway width from curb to curb is 24 feet and provides two 12-foot-wide traffic lanes, but no shoulder. It was built primarily to serve rural traffic and provided adequate service at that time.

2 WITHOUT PROJECT CONDITION (EXISTING)

The North Landing Bridge is owned and operated by the Norfolk District, U.S. Army Corps of Engineers (USACE) as a part of the AIWW project. The bridge spans the Albemarle and Chesapeake Canal (ACC) portion of the AIWW and connects the cities of Chesapeake and Virginia Beach, Virginia. Its current weight limit of 13 tons/26,000 pounds is below current Virginia Department of Transportation (VDOT) roadway standards, preventing certain emergency vehicles and trucks from crossing the bridge. The current daily traffic on the bridge is approximately 11,000 vehicles per day (2017)

and is well in excess of its original design capacity of 8,000 vehicles per day. Traffic loads are projected to steadily increase as Chesapeake and Virginia Beach continue to develop.

The bridge is in a growing suburban area and its 2-lane capacity is often the cause of traffic problems, primarily when the bridge is opened for navigational traffic. Due to its roadway width, design capacity, and the age of its equipment, it has become functionally obsolete. The bridge, when built, was quite adequate for serving a country road through a quiet rural area, but it has become overloaded (carrying almost 1.37 times its theoretical maximum) and projected traffic counts show this trend will continue in the future.

As reported in the 2012 Initial Appraisal (IA), the North Landing Bridge does not meet VDOT standards as it does not conform to either existing traffic level of service (LOS) standards or current design vehicle load limits for traffic volumes. The bridge has been determined to be structurally deficient and functionally obsolete based on this assessment. The table below compares the existing bridge design with VDOT standards.

Table 1. Bridge Criteria

Item	Recommended Criteria	Existing Bridge
Clear Roadway Width	40 feet (1)	24 feet
Design Load	HS2)-44 (2)	H15 (3)

1) Based on a rural collector road system VDOT manual of the structure and bridge division measured between curbs.
2) Design vehicle comparable to a semi-tractor trailer truck weighing 36 tons.
3) Design vehicle comparable to a 15-ton truck.

The bridge also has high operation and maintenance (O&M) costs at approximately $600,000 per year. The bridge closes frequently for repairs due to malfunction and/or allisions. These problems create the following risks and impacts:

1. Current and future increasing costs to navigation commerce due to vessel delays.
2. Current and future increasing costs to road commerce due to traffic delays and forced detours.
3. Future increasing risk to Navy readiness by delaying fuel deliveries to Naval Air Station Oceana, in the case of a bridge shutdown in the closed position.

During the past 10 years, the bridge has been closed to navigation traffic on eighteen separate occasions due to various problems. These problems include (but are not limited to) mechanical failure, storm damage, heat related failure, main circuit breaker failure, jammed wedges, gear box failure, and high water. Table 2 details the record of major facility downtime since 1999.

Table 2. Record of Major Facility Downtime

Date	Operation Out / In	Description of Breakdown
01/05/1999	1132/1330	North span stopped half open
07/05/1999	1430/1500	Both spans stuck in middle, shut both spans and opened Chesapeake span ok
08/17/1999	1400/1500	South span would not close
08/17/1999	0830/1245	Brake on V.B. span stuck
06/30/2000	0730/1125	Wedge bars broken
08/28/2000	1025/1116	South span would not open
10/08/2000	1301/1925	North span would not open
11/14/2000	1730/1912	About two days, north span only gear box
11/16/2000	1730/1500	Replaced gear box
12/31/2000	0800/0900	Limit switches frozen
05/03/2001	1100/1200	Bridge stuck due to heat
05/05/2001	1330/0630	Removing wrecked car and debris
06/11/2001	1430/1500	One span stuck due to heat
06/20/2001	1530/1705	Bridge stuck due to heat
05/13/2003	1230/1900	Span motor wiring & resistor bank
05/15/2003	0800/0845	Wedge motor jammed
06/10/2003	1411/1500	Bridge stuck due to heat

07/24/2003	0800/0900	Wedge motor brake not releasing
08/08/2003	1130/1235	Wedges on Virginia Beach span would not pull
09/10/2003	1330/1435	Wedges on Virginia Beach span would not pull
10/03/2003	1409/1455	N.E. traffic gate
06/18/2004	1400/1630	Bridge stuck due to heat
09/27/2004	1500/1600	Lost power to console
10/21/2004	2011/2207	Traffic gate
01/24/2005	0846/1045	South span power failure
04/30/2005	1330/1935	South span power failure
05/12/2005	1200/1235	Wedges on Virginia Beach span would not pull
11/14/2005	1400/1817	Replaced brake coils on wedge motor & faulty coupling
04/12/2006	1225/1450	Wedges on Virginia Beach span would not pull, coupling problem
06/27/2006 – 06/28/2006	2300/---/0800	High water in electrical boxes
08/31/2006	0907/0930	Limit switch on Virginia Beach span
09/01/2006-09/06/2006	1435/ --- / 1317	High water in electrical boxes
09/11/2006	1230 / 1310	Air buffer spring broke
09/18/2006	1500 / 1535	Amperage problem Virginia Beach span
02/04/2008	0900/0925	Bad three phase relay
04/13/2008	1330/1700	Wedge motor failure
06/07/2008	1410/1715	Bridge would not close due to excessive heat
06/11/2008	1200/1400	Broken pin on wedges
11/10/2008	0930/1116	Wedge motor failure
02/28/2009	1145/1201	Bridge would not close – unknown failure
04/18/2009	1400/1530	Wedge failure

06/13/2009	1330/1515	Storm damage – trees down across road
08/19/2009	1530/1645	Heat related failure. Reconfigured water cooling system
10/09/2010	1730/1750	Local power outage. Cutover to generator power
10/10/2010	0440/0500	Local power outage. Cutover to generator power
12/06/2010	0615/0900	Main circuit breaker failure
12/28/2010	0950/1200	South wedge failure
01/14/2011	0840/0855	Wedge motor failure
03/11/2012	1700 – 1800	Virginia Beach wedge failure
05/15/2012	0900-1700	Virginia Beach span gear box failure
05/31/2013	1000 – 1425	Virginia Beach wedge failure
07/03/2013	1234 – 1420	Chesapeake wedge failure
08/20/15	1000 - 1140	Virginia Beach wedge failure
09/29/2015	1240 – 1253	Gate failure, going up and down
07/24/2016	1635 – 1759	Virginia Beach wedge failure
05/18/2017	0830 – 1415	All wedges would not drive
06/12/2018	0900 – 1400	Virginia Beach wedge fell off

2.1 Navigation User Traffic

The AIWW bisects the study area, and the navigation use of this waterway is made by the way of two routes--the Dismal Swamp Canal (DSC) route and the ACC route. The ACC serves as a primary transportation link for the AIWW system, due in large part to its maintained depth. The DSC route is only maintained to six feet, ruling it out as a reasonable alternative route for most vessel traffic. Navigation traffic on the ACC is characterized by various amounts of commercial (including Naval fuel barges)

and recreational activity, although pleasure boats are by far the predominate user. The following table gives a monthly breakdown of the vessel traffic and commerce passing the North Landing Bridge during Fiscal Year 2018 heading both north and south. Typically, recreation vessels are the majority users of the canal. Vessel activity is slow during the period from November to March

Table 3. Vessel Activity

FISCAL YEAR GREAT BRIDGE GUARD LOCK (#11)

2018	Direction	Government Vessels	Passenger Boat or Ferry	Recreation Vessels	Towboats w/Barges	Towboats wo/Barges	Tonnage	Lockings
OCTOBER	**N**	6	0	118	56	20	1,627	148
	S	2	0	1,163	54	25	97,867	338
NOVEMBER	**N**	3	0	52	38	19	5,920	93
	S	3	1	879	43	27	81,550	297
DECEMBER	**N**	2	0	21	33	6	840	60
	S	3	1	241	33	8	67,368	185
1ST QUARTER TOTALS		19	2	2,474	257	105	255,172	1,121
JANUARY	**N**	4	0	11	26	6	40	40
	S	3	1	53	30	7	65,050	78
FEBRUARY	**N**	4	1	24	43	21	6,900	85
	S	4	1	38	47	22	91,244	96
MARCH	**N**	7	0	74	44	11	4,800	120
	S	9	1	54	44	16	82,800	104
2ND QUARTER TOTALS		31	4	254	234	83	250,834	523
APRIL	**N**	5	1	501	45	35	6,070	265
	S	4	0	92	42	30	88,195	130
MAY	**N**	8	3	1,004	48	9	7,110	394
	S	7	0	160	55	8	111,771	177
JUNE	**N**	10	0	717	47	11	8,470	350
	S	12	0	178	42	12	89,339	174
3RD Q TOTALS		46	4	2,652	279	105	310,955	1,490
JULY	**N**	11	1	354	37	12	6,111	259
	S	12	0	175	42	8	93,771	170
AUGUST	**N**	6	0	221	46	11	4,070	208
	S	6	0	194	47	13	114,175	198
SEPTEMBER	**N**	6	2	116	18	14	600	115
	S	5	0	210	24	11	53,278	166
4TH QUARTER TOTALS		46	3	1,270	214	69	272,005	1,116
GRAND TOTAL		**142**	**13**	**6,650**	**984**	**362**	**1,088,966**	**4,250**

Source: U.S. Army Corps of Engineers

Reported trips in the study area are reported to and published by the Institute for Water Resources (IWR), USACE. Table *4* details vessel activity from the last ten years. It is noted that a predominant number of bridge openings are for single vessel passage.

Table 4. Vessel Reports

Year	Gov't Vessels	Passenger Boat or Ferry	Recreation	Towboat w/Barge	Towboat w/o Barge	Tonnage
2009	113	44	7278.00	780	425	680,900
2010	135	31	7485.00	835	430	828,590
2011	191	19	6874.00	863	789	856,815
2012	130	27	6460.00	971	514	1,081,800
2013	120	20	6136.00	890	364	1,001,620
2014	120	18	5913.00	869	324	909,188
2015	105	10	6205.00	859	400	961,323
2016	109	12	6598.00	913	489	989,267
2017	130	22	7345.00	912	459	1,052,464
2018	142	13	6650.00	984	362	1,088,966
Average	129.5	21.6	6694.4	887.6	455.6	1,001,620

Source: U.S. Army Corps of Engineers

2.2 Commercial Navigation

A limited amount of commercial traffic transits the North Landing Bridge, principally serving northeastern North Carolina and the Hampton Roads, Virginia area. Principal commerce consists of sand, gravel, and wood products, as well as fuel delivered to a nearby storage facility serving Naval Air Station Oceana. The Waterborne Commerce of the United States Report (fiscal year 2018) indicates that approximately 1,088,966 short tons of commerce traveled the ACC Route in 2018. Additional tonnage data from the last ten years can be seen in Table *4* above.

2.3 Recreational Navigation

Recreational activity has grown significantly over recent years as a direct result of the growth in population and the increase in leisure time devoted to water-based bi-directional activities. The North Landing Bridge services both locally based recreation traffic and intracoastal traffic enroute to destinations along the Atlantic and Gulf

coastlines. Over the most recent 10-year period of record, recreational vessels made 82 percent of all vessel trips, according to recent USACE data.

2.4 Highway User Traffic

Virginia Route 165, which is named Mt. Pleasant Route in Chesapeake and North Landing Road in Virginia Beach, provides a connection from Chesapeake's Civic Center in Great Bridge, where it intersects with Virginia Route 168 (Battlefield Boulevard), to the Municipal Center in Virginia Beach, which is located at the intersection of Princess Anne Road and North Landing Road. Route 165 runs in an east-west direction and crosses the AIWW at the North Landing Bridge. Figure 1 shows a detailed aerial view of the study area. The starred pins mark the nearest intersection on either side of the bridge. Virginia Beach is located north of the river, while Chesapeake is south of the river.

Figure 1. Satellite View of Study Area

According to the 2005 Functional Virginia Highway Classification map for the city of Chesapeake, VDOT has classified Route 165 as Urban Minor Arterial. Table *5* details the historical average daily vehicle counts for the North Landing Bridge.

Table 5. Average Daily Vehicle Counts

Year	Location A(1)	Location B(2)
2017	11,000	12,000
2016	11,000	11,000
2015	11,000	11,000
2014	11,000	10,000
2013	7,800	11,000
2012	7,700	11,000
2011	7,900	12,000
2010	11,000	12,000
2009	10,000	12,000
2008	9,900	12,000

Source: Virginia Department of Transportation

(1) Location A: Between Fentress Airfield Road and Chesapeake City Limit

(2) Location B: Between North Landing Road and Indian River Road

A detailed traffic study was completed by an independent contractor, WSP USA, Inc. (WSP). WSP is a transportation consulting company familiar with VDOT data. Their report can be viewed in Appendix XXX. The study was conducted using the preexisting Hampton Roads Traffic Demand Model. The traffic study estimated existing demand and forecasted future demand, as well as vehicle miles traveled (VMT) and vehicles hours traveled (VHT), for the FWP and FWOP conditions in the study area. These estimates were used to calculate benefits for vehicle traffic with a bridge replacement.

3 WITHOUT PROJECT CONDITION (FUTURE)

The FWOP condition is defined as a continuation of maintenance and repair of the existing structure in its present alignment until such time as the existing bridge undergoes a major rehabilitation in 2028. Subsequent to the rehabilitation, O&M costs will continue to occur.

In the event of bridge failure, which would halt or delay vessels along the waterway, a joint effort (the Corps of Engineers, the City of Chesapeake, and the U.S. Coast Guard) would be made to minimize impacts to navigation and highway traffic. The extent of the problem would determine the extent of down time involved and the remedial action taken to rectify the situation. Table *6* details the timeline and expected O&M costs under the FWOP conditions.

Table 6. Timeline of Operations and Maintenance

Year		Action and Cost
2026-Forward		Maintain existing bridge @ $608,000/yr
2028		Major rehabilitation @ $8,608,000/yr
2038-Forward		Painting, localized steel repair @ $1,000,000/10 yr
2058		Deck Replacement @ $3,000,000

Source: USACE

Since the bridge is owned and maintained by the Corps, these costs would be totally borne by the Federal Government, as would all succeeding life cycle replacements. A true replacement bridge in-kind was not considered because such a bridge would not meet current standards and regulations as defined by the American Association of State Highway and Transportation Officials (AASHTO) and the United States and Virginia Departments of Transportation. A bridge replacement that adheres to current guidelines would differ so significantly in design and structure that it could not be reasonably defined as “in kind.” Instead, an alternative was developed that most closely resembles the existing bridge, but adheres to all current VDOT and AASHTO regulations.

3.1 Navigation User Traffic

Based on a trend line analysis utilizing historical data provided by the Norfolk District Operations Branch, it is projected that the number of bridge openings will not increase or decrease to a significant degree. This is based on a linear trend analysis using 20 years of historical data. Based on this data and the expertise of the NAO Operations Branch, it was assumed that bridge openings would remain steady over the period of the project. The average delay time per cycle has been estimated at 4.5

minutes based on an analysis of current bridge opening/operating conditions. Table 7 details the projected annual bridge openings.

Table 7. Projected Bridge Openings

Fiscal Year	Number of Openings	Vessel Traffic	Yearly Change in Openings
1998	5562	7,030	N/A
1999	5293	7,031	-269
2000	4862	7,032	-431
2001	5537	7,032	675
2002	4366	7,033	-1171
2003	5096	7,039	730
2004	5448	7,035	352
2005	5335	7,040	-113
2006	5230	7,053	-105
2007	5175	7,066	-55
2008	4718	7,042	-457
2009	4063	7,115	-655
2010	4512	7,132	449
2011	4315	7,131	-197
2012	4704	7,158	389
2013	4180	7,530	-524
2014	4482	7,244	302
2015	4637	7579	155
2016	4328	8121	-309
2017	4835	8868	507
2018	5326	8151	491
2019	5138	7571	-188
2020	5017	8055	-121
2021	4990	8240	-27
2022	4833	8050	-157
2023	4915	7324	83
2024	4851	7948	-64
2025	4720	8150	-131
2026	4614	7999	-106
2027	4529	7749	-85
2028	4454	7654	-75
2029	4467	8098	13
2030	4606	8020	139

2031	4650	7826	43
	4730	7765	80
2033	4731	7882	1
	4836	8055	106
2035	4881	7884	44
	4895	7801	14
2037	4973	7863	78
	4952	7956	-22
2039	4836	7956	-116
	4762	7832	-74
2041	4714	7851	-48
	4673	7921	-42
2043	4662	7938	-11
	4634	7889	-29
2045	4617	7846	-17
	4624	7897	8
2047	4651	7926	27
	4693	7902	42
2049	4748	7871	55
	4798	7878	51
2051	4821	7914	23
	4836	7908	15
2053	4836	7884	0
	4837	7880	1
2055	4819	7898	-18
	4793	7909	-26
2057	4766	7893	-27
	4724	7883	-42
2059	4687	7892	-37
	4673	7902	-14
2061	4672	7898	0
	4681	7887	8
2063	4696	7890	15
	4712	7898	16
2065	4733	7899	21
	4756	7892	24
2067	4778	7889	22
	4794	7895	16
2069	4803	7898	8
	4801	7894	-2

2071	4790	7891	-11
2072	4775	7893	-15
2073	4759	7896	-17
2074	4743	7895	-16
2075	4727	7893	-16
2076	4714	7893	-12

3.2 Highway User Traffic

The without project highway user traffic estimates were provided by the contractor, WSP, and results can be seen in Appendix A. The delays to vehicular traffic desiring to cross the bridge have traditionally been a function of the number of bridge openings and the amount of time that the bridge stays open during each opening cycle. Projections of future highway user traffic were made consistent with Virginia State Data Center projections for growth in population and employment in the study area. Consistent with historical methods of operation, it is assumed that navigation traffic will continue to be given priority over highway traffic relative to the timing of bridge openings. Table *8* details the projected average daily vehicular traffic over the 50-year planning period. As stated earlier, the original design capacity for the bridge was 8,000 vehicles per day. It was later increased to 13,000 vehicles per day, which will be surpassed by projected volume before 2027.

Table 8. Projected Vehicle Traffic Crossings (Vehicles Per Day)

Year	Volume
2009	10108
2027	13993
2040	16798
2076	16798

The information presented in Table *8* is indicative of a condition whereby traffic demand can no longer be accommodated. It is expected that the level of service will continue to deteriorate causing motorists to continue to seek alternate routes at the expense of an increase in time and cost to them.

4 ECONOMIC EVALUATION OF COSTS AND BENEFITS

4.1 Technical Economic Criteria

The economic criteria that were applied in the formulation of the alternative plans are as follows.

a. In accordance with the overall objectives of the study, the plan should:

1. Minimize the total cost including investment, operations, maintenance, and replacement;

2. Minimize highway and navigation user costs; and

3. Minimize the overall economic impact on the surrounding area.

b. Alternative plans will be compared on the basis of a least cost and a benefit-cost analysis. Cost to be considered in the analysis should include, but not be limited to, the following:

1. Construction cost;

2. Lands and damages, easements, and rights-of-way;

3. Relocations;

4. Environmental and mitigation costs;

5. Interest during construction;

6. Average cost of O&M, repairs, rehabilitation, major replacement costs; and

7. Highway and navigation user costs.

c. To be consistent with planning horizons on Federal navigation projects, alternatives will be compared using an economic life approaching 50 years.

d. Assessment of detailed plans were compared using October 2019 (FY20) price levels and a discount rate of 2 $^{3/4}$ percent.

e. Appropriate risk and uncertainty analyses will be required to determine the economic sensitivity of the various economic variables. These could include such items as increases in cost of construction material required; increases in cost of fuel associated with highway and navigation user costs; and interest during installation period.

f. The plan or system should be consistent with present and future local, regional, state, and national needs for commercial and industrial growth.

g. The plan should recommend an appropriate cost-sharing proposal acceptable to both Federal and local interests.

h. The plan should be responsive to the city of Chesapeake's financial and economic perspective.

4.2 Average Annual Benefits (Reduced User Costs)

The quantification of user costs will serve as the basis for which to compare the FWOP conditions with the alternative plans of improvement under consideration. These user costs will be borne by highway and waterway traffic. The following paragraphs detail the user costs to the various forms of traffic affected by the North Landing Bridge. While highway traffic demand analysis was provided by WSP, a multi-disciplined team from the Corps of Engineers, WSP, the City of Chesapeake, and the City of Virginia Beach worked together to determine the highway transportation needs of the study area.

4.3 Navigation User Costs

As indicated previously, bridge openings are impacted by collisions, allisions, component failure, and other circumstances. Vessels traversing the waterway bear the cost of these bridge closures. Because there are no future plans for bridge replacement in the 50 year study period, it is expected that frequency and duration of these closures

will increase. This increase was determined via engineering reliability functions. These reliability functions use a Weibull distribution which is a continuous probability distribution to determine over the study period how reliable each bridge component is and the probability of failure (hazard function) in any given year. (Cape Cod Canal Bridges Major Rehabilitation Evaluation Report, 2018) For this reason, significant negative impacts (costs) to navigation are forecast. These costs were calculated using the Waterways Limited Cost Estimator for Navigation (WLCEN) model, in coordination with the Inland Navigation Planning Center of Expertise (PCX). Model documentation has been submitted for certification. Basic assumptions made when using the WLCEN model are shown in Table *9*.

Table 9. WLCEN Model Assumptions

WLCEN Model Assumptions
• Vessel traffic to remain steady across period of analysis
• There will be a delay time reduction in the future due to a wider channel. (Vessels will not have to slow down as much.)
• Water level threshold at which damage occurs is 4 feet.
• Missing "water level" daily data replaced with median data values for that year.
• Commercial Barge Operating Cost: $300/hr
• Recreational Vessel Operating Cost: $150/hr
• Percent Commercial: 10%

The general theory underlying the model is that, due to the nature of service disruptions and the lack of available alternate overland modes, the vast majority of existing condition traffic delay or disruption impacts, and thus the degree to which an alternative can reduce these, impacts (benefits) can be closely approximated by computing the total cost of vessel delays in the existing and alternative conditions and taking the difference. The benefits of a given alternative can be defined as the reduction in total vessel delay in hours multiplied by the hourly operating cost. The model is designed to estimate this total vessel delay.

The primary model inputs are those parameters which define the nodes (projects and river linkages) which comprise the system, and the flotillas. These inputs can be

sub-divided into two categories; constants and distributional parameters. Table *10* below identifies these input parameters. Table *11* details the FWOP cost for vessel traffic delays ($596,283).

Table 10. Input Parameters

Parameter	Fit Distribution
Chamber Length	Constant
Chamber Width	Constant
Number of Mooring Cells	Constant
Risk Aversion/Operator Policy	Constant
Velocity Threshold for Restriction	Constant
Velocity Threshold for Day Hours Only	Constant
Velocity Threshold for Closure	Constant
Head Diff Threshold for Restriction	Constant
Head Diff Threshold for Closure	Constant
River Condition Update Interval	Constant
Arrival Interval	Exponential
Barges per Tow	Discrete
Processing Time	Exponential
Tow Break Time	Triangular
Tow Reassemble Time	Triangular
Travel Time Between Projects	Gamma
Accident Probability	Triangular
Accident Repair Duration	Weibull
River Velocity	Markov Chain
Head Differential	Markov Chain

Table 11. Without Project Vessel Traffic Costs

	Mean	Median	Min	Max	Std Dev	5th PCT	95th PCT	25th PCT	75th PCT
Total Time	$596,823	$590,420	$561,105	$1,012,633	$36,905	$573,936	$630,674	$582,340	$599,676
Total Processing Time	$198,370	$198,297	$188,273	$205,387	$2,821	$193,757	$202,714	$196,488	$200,585
Total Queuing Time	$13,211	$12,419	$9,397	$78,262	$5,120	$10,527	$17,875	$11,597	$13,225
Total OpClose Time	$376,604	$376,753	$354,305	$414,235	$7,938	$364,414	$388,281	$370,667	$382,033
Total Closure Time	$8,638	$1,757	$0	$335,915	$28,061	$0	$32,857	$399	$5,275

4.4 Highway User Costs

The combination of a projected increase in highway traffic and an expected increase in delays due to bridge inoperability will produce an increase in the user costs under the without project condition. As indicated in the traffic study performed by WSP, highway demand under the FWOP condition is expected to grow from 10,108 vehicles per day in 2009 to 13,993 vehicles per day in the base year 2027, and to 16,798 vehicles per day in 2076. The highway user costs can be expected to grow as a result of two factors: (1) vehicle operating costs, and (2) opportunity cost of time for motorists. Both of these factors will be discussed later in this report.

Certain data was required to establish standard costs. Engineering costs, including costs for repair, rehabilitation, and maintenance of the bridge and surrounding roadway, were determined using historical data and/or sourced from a traffic study performed by WSP. Vehicle queue length and clearing time was based on Waterborne Data Statistics (to estimate vessel count) and historical vessel count from NAO District Operations Branch. The average number of passengers per vehicle was sourced from the US Department of Transportation. Vehicle operating costs were sourced from the AASHTO 2010 manual. Both will be discussed later in the report.

Certain assumptions were made to facilitate the calculation of outputs. They are listed in Table *12*.

Table 12. List of Assumptions

- There is no distinction from persons living in the surrounding study area versus visitors or travelers passing thru the bridge.
- Because the final year of forecast provided by the Hampton Roads Transportation Planning Organization (HRTPO) was 2040, it was decided that traffic volumes would be held constant from that point.
- WSP created forecast trends using historical population, industrial, and employment data provided by the HRTPO data set.
- The cities of Chesapeake and Virginia Beach developed future master plans that do not explicitly display plans for a 4 lane road or have funding allocated to such a project. Therefore, only two-lane road scenarios were considered.
- Estimated traffic volumes used were based on WSP outputs from the HRTPO Regional Travel Demand Model.

In accordance with procedure, a base condition was developed. In this scenario the bridge is maintained by regularly scheduled maintenance. Possible component failures include: bridge deck, superstructure, and substructure. When a failure occurs, emergency funds will be required to repair these failures. During repairs there will be lane and bridge closures which impose a value of time cost on travelers over the bridges as traffic becomes congested.

One of the key inputs for the vehicle model is the total cost of traffic delay for closure by project (emergency repair or major rehabilitation). The spreadsheet follows Guidance in ER 1105-2-100 to determine the value of time for drivers that will be delayed in traffic due bridge opening or traffic rerouting. Traffic data was modeled by WSP utilizing the HRTPO Regional Travel Demand Model.

4.5 Vehicle User Costs

User costs include operating and opportunity costs. Vehicle operating costs are the costs of owning and operating a vehicle that are borne by individual users. As prescribed by Corps of Engineers policy, vehicle operating costs are to be based on a model developed by AASHTO entitled, “User and Non-User Benefit Analysis for Highways, 2010. Costs from the AASHTO manual were updated to FY20 price levels using a composite index consisting of the Consumer Price Index (CPI) for motor fuel, automobile maintenance, and automobile tires. Table *11* details the vehicle operating costs as defined by AASHTO and after the CPI

conversion. Vehicle opportunity cost is the value attributed to a vehicle user's time. This value is different for different types of users and/or trip purposes. It is conventionally expressed as dollars per hour.

Table 13. Vehicle Operating Costs

Operating Costs (cents/mile)	**Small Car**	**Midsize Car**	**Large Car**	**SUV**	**Van**
Fuel and Oil	7.30	9.50	10.20	13.0	10.90
Maintenance	3.30	3.50	4.00	4.0	3.90
Tires	0.60	0.70	0.70	0.8	0.60
Total Operating Costs (cents/mile)	11.20	13.70	14.90	17.8	15.40
In dollars	0.11	0.14	0.15	0.2	0.15
CPI Conversion					
Operating Costs (cents per mile)					
Fuel and Oil	14.32	18.63	20.00	25.5	21.38
Maintenance	5.37	5.69	6.51	6.5	6.35
Tires	0.75	0.88	0.88	1.0	0.75
Total Operating Costs (cents per mile)	20.44	25.20	27.39	33.0	28.47
In dollars	$0.20	$0.25	$0.27	$0.3	$0.29
Average Car Operating Costs Comp		$0.24			
Average Truck Operating Costs Comp		$0.31			

Source: AASHTO 2010, Page 5-10

In this study, vehicle user costs are broken down into four categories: operating and opportunity cost of bridge delay, opportunity costs due to a reduction in VHT, operating costs due to a reduction in VMT, and advance bridge replacement.

4.6 Operating and Opportunity Cost (Bridge Delay)

The traffic study supplied by WSP does not incorporate a delay cost associated with the constant opening and closing of the bridge to allow vessel passage. This event causes vehicular traffic to stop for an estimated timeframe of 8 minutes. The delay cost can be computed by estimating average time the bridge is open, of around 5 minutes, and the average time it takes for the vehicle queue to clear, currently estimated at 3 minutes. In addition, the queue size or length was determined by manual computation of average daily traffic for base and future years divided by the number of minutes per day to derive cars per minute estimate. It was assumed that not every vehicle will be subject to an 8 minute delay and an average delay per car was estimated to be 4.5 minutes. The wait time is then multiplied by an appropriate queue length of around 80-100 vehicles for years 2027 and 2076, and the associated operating and opportunity cost functions to compute the cost of delay.

4.7 Opportunity Cost (Vehicle Hours Traveled)

VHT for North Landing Bridge was computed using the HRTPO Regional Travel Demand Model. The reductions in VHT were multiplied by the opportunity cost function, as described in the AASHTO guidebook. The result produces a value related to the cost of spending additional time operating a vehicle while traveling addition miles on either per person or per vehicle basis depending on the trip purpose. For work related trip purposes, the cost of time was computed on a per person basis (1.3 people per vehicle), and for recreational related trips, the cost was estimated on a per vehicle basis.

4.8 Operating Cost (Vehicle Miles Traveled)

VMT for North Landing Bridge was also computed using the HRTPO Regional Travel Demand Model. The reductions in VMT were multiplied by the operating cost function results to estimate the cost of vehicle rerouting. As an aggregate value based on all fleet components and adjusted price levels using the CPI, the cost of operating a vehicle one additional mile was assumed to be $0.57, based on operating cost function guidance from AASHTO.

4.9 Advance Bridge Replacement

The current expected future Operations and Maintenance (O&M) liabilities can be estimated based on an early replacement of the bridge. This liability becomes the advance bridge replacement benefit.

These benefits are compared with the direct project construction costs supplied by the USACE Norfolk District Cost Engineering section, resulting in a final benefit to cost ratio. A more detailed breakdown can be visually observed in figure 2 below.

Figure 2. Benefit Categories

Existing conditions of the North Landing Bridge were simulated in the WLCEN model. Historical and future year numbers are generated for the bridge from year 1998 thru 2076. The number of historical bridge opening and vessel traffic values were determined based on data provided from the Norfolk District Operations Branch. For North Landing Bridge, only 5 years of historical data was available from year 2013 thru year 2017. Historical and future values were determined based on a trend analysis function in Excel. For NLB, there isn't an anticipation of increased vessel traffic in the future and the trend analysis seems to be the best fitted approach. The 2027 and 2076 bridge opening values were used to estimate bridge delay costs. Table 7 shows bridge openings and vessel traffic.

4.10 Consumer Price Index and Operating Cost Functions

Operating costs were provided by the AASHTO manual and were updated to current price levels. Data was sourced from the Bureau of Labor and Statistics (BLS).

4.11 Vehicle Fleet Composition

Vehicle classes were broken down and separated out to better estimate operating cost per mile. The source for the data comes from US Department of Transportation. Because the

greatest contributor to the overall operating cost is the price and consumption of gasoline per mile, vehicle class proportions are critical. A breakdown of fleet composition over the past 10 years available can be seen in Table *14*.

Table 14. Vehicle Fleet Composition

Year	Registered Passenger Cars	Registered Light Trucks	Total Registered Vehicles	Percent Passenger	Percent Light Truck
2007	137,929,951	100,817,496	238,747,447	57.77%	42.23%
2008	139,028,041	100,862,944	239,890,985	57.95%	42.05%
2009	137,203,972	102,008,600	239,212,572	57.36%	42.64%
2010	135,310,480	102,376,147	237,686,627	56.93%	43.07%
2011	126,966,714	118,702,389	245,669,103	51.68%	48.32%
2012	127,077,676	118,690,690	245,768,366	51.71%	48.29%
2013	128,936,225	120,491,485	249,427,710	51.69%	48.31%
2014	131,138,925	123,470,278	254,609,203	51.51%	48.49%
2015	133,218,366	127,401,053	260,619,419	51.12%	48.88%
2016	134,879,198	132,000,600	266,879,798	50.54%	49.46%
10 YR Average	133,207,580	114,682,168	247,889,748	53.74%	46.26%

Source: US Department of Transportation

4.12 Operating Cost Functions

The operating cost functions are sourced from the AASHTO manual. There are three different categories of costs: gasoline or fuel related, maintenance, and tires. The greatest contributor to the overall operating cost is the price and consumption of gasoline per mile. The cost function is associated with the price of gasoline, time delay for with- and without project scenarios. The output varies based on expected queue clearing time developed using historical bridge opening frequency data. Historical changes to the price of gasoline were sourced from the Energy Information Administration at the Department of Energy

4.13 Opportunity Cost Functions

These functions are based on guidance provided in ER 1105-2-100 and the AASHTO manual. A 100% hourly cost for work related trips was applied, while 50% of the hourly opportunity cost was applied to trips related to recreational purposes. Opportunity cost values and time saved adjustment percentages were found in ER 1105-2-100. The average hourly wage was used in calculating opportunity benefits related to bridge delay reduction and vehicle hours traveled. Work related trips estimated the opportunity cost at 100% of the hourly wages, whereas recreational trips had a reduced cost estimate of 50% hourly wage. After careful consideration, national data statistics supplied by the Bureau of Labor and Statistics (BLS) were utilized.

4.14 Time and Cost Savings

To estimate value of time saved per hour, cost saved per rerouting, and bridge delay cost savings categories, tables provided in the ASHTO 2010 manual were used. Values were calculated for both bridge delay (BD) and re-routing (RR).

Table 15. Opportunity Costs of Bridge Delay (Work)

Description	2027	2076
Percentage of hourly wage	100%	100%
Average hourly wage	$27.48	$27.48
Average vehicle occupancy	1.3	1.3
Delay without improvement (min.)	4.5	4.5
Delay with improvement (min.)	0	0
Value of time per hour	$35.72	$35.72
(wage X percentage X occupancy)		
For delay change:		
Travel time saved per vehicle (min.):	4.500	4.500
(delay without - delay with)		
Value of time saved per vehicle	$2.6793	$2.6793
(VOT per hour * time saved / 60)		
Value of time saved per VMT	$2.6793	$2.6793
(VOT per vehicle / length)		

Table 16. Opportunity Costs of Bridge Delay (Social)

Description	2027	2076
Percentage of hourly wage	50%	50%
Average hourly wage	$27.48	$27.48
Average vehicle occupancy	1	1
Delay without improvement (min.)	4.5	4.5
Delay with improvement (min.)	0	0
Value of time per hour	$13.74	$13.74
(wage X percentage X occupancy)		
For delay change:		
Travel time saved per vehicle (min.):	4.500	4.500
(delay without - delay with)		
Value of time saved per vehicle	$1.0305	$1.0305
(VOT per hour * time saved / 60)		
Value of time saved per VMT	$1.0305	$1.0305
(VOT per vehicle / length)		

Table 17. Opportunity Costs of Re-routings (Work)

Description	2027	2076
Percentage of hourly wage	100%	100%
Average hourly wage	$27.48	$27.48
Average vehicle occupancy	1.3	1.3
Delay without improvement (min.)	4.5	4.5
Delay with improvement (min.)	0	0
Value of time per hour	$35.72	$35.72
(wage X percentage X occupancy)		
For delay change:		
Travel time saved per vehicle (min.):	4.500	4.500
(delay without - delay with)		
Value of time saved per vehicle	$2.6793	$2.6793
(VOT per hour * time saved / 60)		
Value of time saved per VMT	$2.6793	$2.6793
(VOT per vehicle / length)		

Table 18. Opportunity Costs of Re-routings (Social)

Description	2027	2076
Percentage of hourly wage	50%	50%
Average hourly wage	$27.48	$27.48
Average vehicle occupancy	1	1
Delay without improvement (min.)	4.5	4.5
Delay with improvement (min.)	0	0
Value of time per hour	$13.74	$13.74
(wage X percentage X occupancy)		
For delay change:		
Travel time saved per vehicle (min.):	4.500	4.500
(delay without - delay with)		
Value of time saved per vehicle	$1.0305	$1.0305
(VOT per hour * time saved / 60)		
Value of time saved per VMT	$1.0305	$1.0305
(VOT per vehicle / length)		

4.15 Traffic Demand and Data Extrapolation

The following tables provide a summary of traffic volume, vehicle miles traveled, and vehicle hours traveled. For North Landing Bridge, the period of analysis for the WSP traffic study spans from 2009-2040, but the study is designed for a 50 year period of analysis spanning from 2027 to 2076. Given the discrepancy and an inability to adjust the time period for the traffic study, an assumption was made to cap the increases in the spread between the VMT, VHT and ADT for base and future years. They were capped at 2040 levels received from the HRTPO Regional Travel Demand Model. This decision was made after careful consideration and consultation with the vertical team. All extrapolations use a straight line growth rate formula to compute 2027 and 2076 values.

Table 19. Traffic Volume

Year	Without Project (vehicles/day)
2009	10,108
2027	13,993
2040	16,798
2076	16,798

Table 20. Vehicle Miles Traveled

Year	Without Project
2009	38,222,336
2027	45,654,700
2040	51,022,518
2076	51,022,518

Table 21. Vehicle Hours Traveled

Year	Without Project
2009	977,183
2027	1,223,712
2040	1,401,760
2076	1,401,760

4.16 Benefit (or Cost) Computations

Opportunity and operating values were calculated for the bridge delay cost due to bridge openings. The bridge delay benefit is the delay associated with vehicles having to stop and wait while the bridge is open for vessel traffic. In a more simple form, a reduction in miles traveled produces a reduction in hours traveled, but the reduction in hours traveled does not account for wait times associated with bridge opening. Therefore that cost is computed in 4 separate "bridge delay" scenarios. The tables below detail these costs.

- Without Project Opportunity Costs Associated with Bridge Delays: This models Without or FWOP project opportunity delay cost incurred for passengers in vehicles that must wait in queue as the bridge opens to allow for vessel traffic to traverse. Table *22* details the expected average annual opportunity cost of time under the FWOP condition for bridge delays.

Table 22. Without Project Opportunity Costs (Bridge Delays)

USER COST COMPONENTS:	**BASE YEAR**		**YEAR**
	2027		**2076**
WORK TRIPS			
Bridge Openings Per Year	4,529		4,714
Number of Cars Per Opening	20		24
Cost Per Car Per Opening	2.68		2.68
USER COST	242,690		303,134
SOCIAL/RECREATIONAL TRIPS			
Bridge Openings Per Year	4,529		4,714
Number of Cars Per Opening	19		23
Cost Per Car Per Opening	1.03		1.03
USER COST	89,608		111,926
OTHER TRIPS			
Bridge Openings Per Year	4,529		4,714
Number of Cars Per Opening	41		49
Cost Per Car Per Opening	1.03		1.03
USER COST	190,418		237,843
TOTAL USER COSTS (Undiscounted)	522,716		652,903
AVERAGE ANNUAL USER COST			
(Discounted)		$574,834	
(ROUNDED)		**$575,000**	

Note: Trip purpose weights were sourced from Federal Highway Administration

- Without Project Operating Costs Associated with Bridge Delays: This models operating delay cost incurred for vehicles that must wait in queue as the bridge opens to allow for vessel traffic to traverse. Cost per car per opening is estimated. Table *23* details the expected average annual vehicle operating costs for bridge delays ($129,000).

Table 23. Without Project Vehicle Operating Costs (Bridge Delays)

	BASE YEAR		YEAR
	2027		**2076**
Operating Costs			
Bridge Openings Per Year	4,529		4,714
Number of Cars Per Opening	80		96
Cost Per Car Per Opening	0.32		0.32
USER COST	117,438		146,687
AVERAGE ANNUAL USER COST		$129,147	
(Discounted)			
(ROUNDED)		**$129,000**	

4.17 Benefits: Operating and Opportunity

Values were calculated for opportunity and operating costs based on VMT and VHT reductions provided by the WSP traffic study. For calculations concerning opportunity cost, there are 3 types of user cost components; work, recreational, and other trips. Future With-Project (FWP) and Future Without-Project (FWOP) conditions were modeled based on changes in VMT provided by the HRTPO Regional Travel Demand Model. All user costs are discounted using the discount factor and converted to the average annual benefits/cost (AAC). These costs are summarized in Table *24* and Table *25*.

Table 24. Without Project Vehicle Operating Costs (Reroutings)

USER COST COMPONENTS:	BASE YEAR		YEAR
	2027		2076
Without Project Vehicle Miles Traveled	45,654,700		51,022,518
With Project Vehicle Miles Traveled	45,639,118		50,995,682
Difference	-15,582		-26,836
Miles Difference	15,582		26,836
Number of Days Per Year	365		365
Cost Per Mile	0.57		0.57
USER COST	$3,255,542		$5,606,766
Average Annual Benefits		$4,196,808	
(Discounted)		**$4,197,000**	

Table 25. Without Project Vehicle Opportunity Costs (Reroutings)

	2027		2076
Without Project Vehicle Hours Traveled	1,223,712	daily	1,401,760
With Project Vehicle Hours Traveled	1,222,969	daily	1,400,481
Difference	743		1,279
Trip Purpose as percent			
Work (25 Percent)	186	daily	320
Social Recreation (24 Percent)	178	daily	307
Other (51 Percent)	379	daily	652
USER COST COMPONENTS:	BASE YEAR		YEAR
Work Trips	2027		2076
25%			
Travel Time (Hours)	186		320
Cost Per Hour of Travel	35.72		35.72
Number of Days Per Year	250		250
USER COST	1,658,141	annual	2,855,687
AVERAGE ANNUAL USER COST			
(Discounted)		$2,011,152	
Social/Recreation	2027		2076
24%			

	2027		2076
Travel Time (Minutes)	178		307
Cost Per Rerouted Trip	13.74		13.74
Number of Days Per Year	365		365
USER COST	893,866	annual	1,539,435
AVERAGE ANNUAL USER COST			
(Discounted)		$1,084,166	
Other	2027		2076
51%			
Travel Time (Minutes)	379		652
Cost Per Rerouted Trip	13.74		13.74
Number of Days Per Year	365		365
USER COST	1,899,464	annual	3,271,300
AVERAGE ANNUAL USER COST			
(Discounted)		$2,308,478	
TOTAL AVERAGE ANNUAL USER COST (Discounted)		$5,410,012	
ROUNDED		**$5,410,000**	

4.18 Without Project Condition Associated with Bridge Replacement

The project costs for the major rehabilitation and the replacement bridges, including the scheduled major repairs in later years, were discounted using the PV factor. The costs were then summed over the 50 years and added with the interest during construction (IDC). Costs were provided in FY 2020 dollars by the cost engineer.

4.19 Average Annual Operations and Maintenance Costs

The average annual cost was determined using existing bridge operations and maintenance (O&M) costs, along with future routine repairs that have to be undertaken in order to keep the bridge from failing. The current O&M cost for North Landing Bridge is $608,000 per year, of which 75% is operations related and the rest is basic maintenance and supplies. Additional costs include painting, localized steel repair, and eventually a major rehab of the bridge. Given that these costs will not actualize if a new bridge is constructed, they can be claimed as a saving or benefit.

5 WITH PROJECT CONDITION

The FWP condition consists of 4 alternatives that examine combinations of crossing bridge types and alignments (East or West of the existing bridge.) While construction costs for each alternative differ significantly according to the bridge type (fixed v. moveable), the difference according to alignment is relatively small. Analysis was performed with respect to the two bridge types and two possible alignments. However, because the traffic demand analysis and vessel traffic analysis did not show any difference in benefit associated with bridge alignment, most calculations were done considering just a high (fixed) or low (moveable) bridge. Additionally, given the lack of confidence in US-165 expansion, the current 2 lane existing road remains the base and future scenario. This significant assumption limits the scope of the study to four 2-lane alternatives.

5.1 Navigation User Traffic

The FWP conditions are expected to increase the width of the opening from 80 feet to 100 feet. This change would result in a more navigable and less obstructed channel. A minimum of 65 foot vertical clearance is expected for the fixed span bridge and is in compliance with the Coast Guard regulations. The 65 foot clearance is acceptable due to an upstream bypass bridge along the channel (US Route 168, Great Bridge Bypass) that also has a 65 foot clearance. A construction of a taller bridge would yield no additional benefits due to the constraint. High water conditions could potentially have an impact, but the constraint would be felt at the other upstream bridge.

As indicated earlier, the WLCEN model was used to estimate the benefits associated with decreased delays and collisions with a bridge replacement. Variables such as fuel cost, wages, and other costs associated with vessel O&M were considered in these calculations.

Table *26* and Table *27* detail the FWP condition costs for a fixed bridge ($182,043) and a moveable bridge ($545,403).

Table 26. With Project Condition (Fixed Bridge)

	Mean	Median	Min	Max	Std Dev	5th PCT	95th PCT	25th PCT	75th PCT
Total Time	$182,043	$182,067	$174,598	$190,999	$2,701	$177,447	$186,571	$180,219	$183,761
Total Processing Time	$182,043	$182,067	$174,598	$190,999	$2,701	$177,447	$186,571	$180,219	$183,761
Total Queuing Time	$14,711	$14,688	$12,581	$17,430	$870	$13,329	$16,165	$14,143	$15,268
Total OpClose Time	$11,213	$11,220	$10,747	$11,666	$157	$10,956	$11,487	$11,113	$11,316
Total Closure Time	$0	$0	$0	$0	$0	$0	$0	$0	$0

Table 27. With Project Condition (Moveable)

	Mean	**Median**	**Min**	**Max**	**Std Dev**	**5th PCT**	**95th PCT**	**25th PCT**	**75th PCT**
Total Time	$545,403	$545,342	$541,657	$548,548	$1,293	$543,307	$547,487	$544,588	$546,321
Total Processing Time	$200,434	$200,412	$199,334	$201,586	$429	$199,796	$201,105	$200,142	$200,739
Total Queuing Time	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total OpClose Time	$344,968	$344,966	$340,090	$349,214	$1,697	$342,334	$347,661	$343,849	$346,143
Total Closure Time	$0	$0	$0	$0	$0	$0	$0	$0	$0

Table 28. FWOP Costs vs. FWP Costs shows a comparison of FWOP conditions and FWP conditions. As expected, FWP conditions for a moveable bridge are similar to those of the FWOP conditions. Whether a moveable bridge is constructed or the current moveable bridge is left in place, user costs remain high.

Table 28. FWOP Costs vs. FWP Costs

	FWOP	FWP Fixed Bridge	FWP Moveable Bridge
Mean	$596,823	$182,043	$545,403
Median	$590,420	$182,067	$545,342
Min	$561,105	$174,598	$541,657
Max	$1,012,633	$190,999	$548,548
Std Dev	$36,905	$2,701	$1,293
5th PCT	$573,936	$177,447	$543,307
95th PCT	$630,674	$186,571	$547,487
25th PCT	$582,340	$180,219	$544,588
75th PCT	$599,676	$183,761	$546,321

The table below shows the average annual benefits for both FWP conditions when compared to FWOP conditions.

Table 29. Average Annual Benefits—Vessel Traffic

	Fixed Bridge	Moveable Bridge
Mean	$414,780	$51,420
Median	$408,353	$45,079
Min	$386,507	$19,448
Max	$821,634	$464,085
Std Dev	$34,204	$35,612
5th PCT	$396,489	$30,629
95th PCT	$444,103	$83,188
25th PCT	$402,121	$37,752
75th PCT	$415,915	$53,356

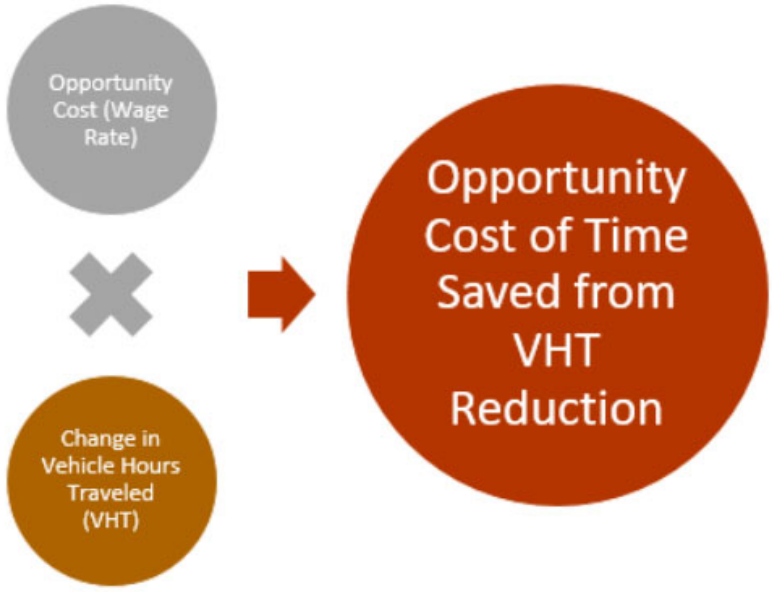
5.2 Highway User Costs

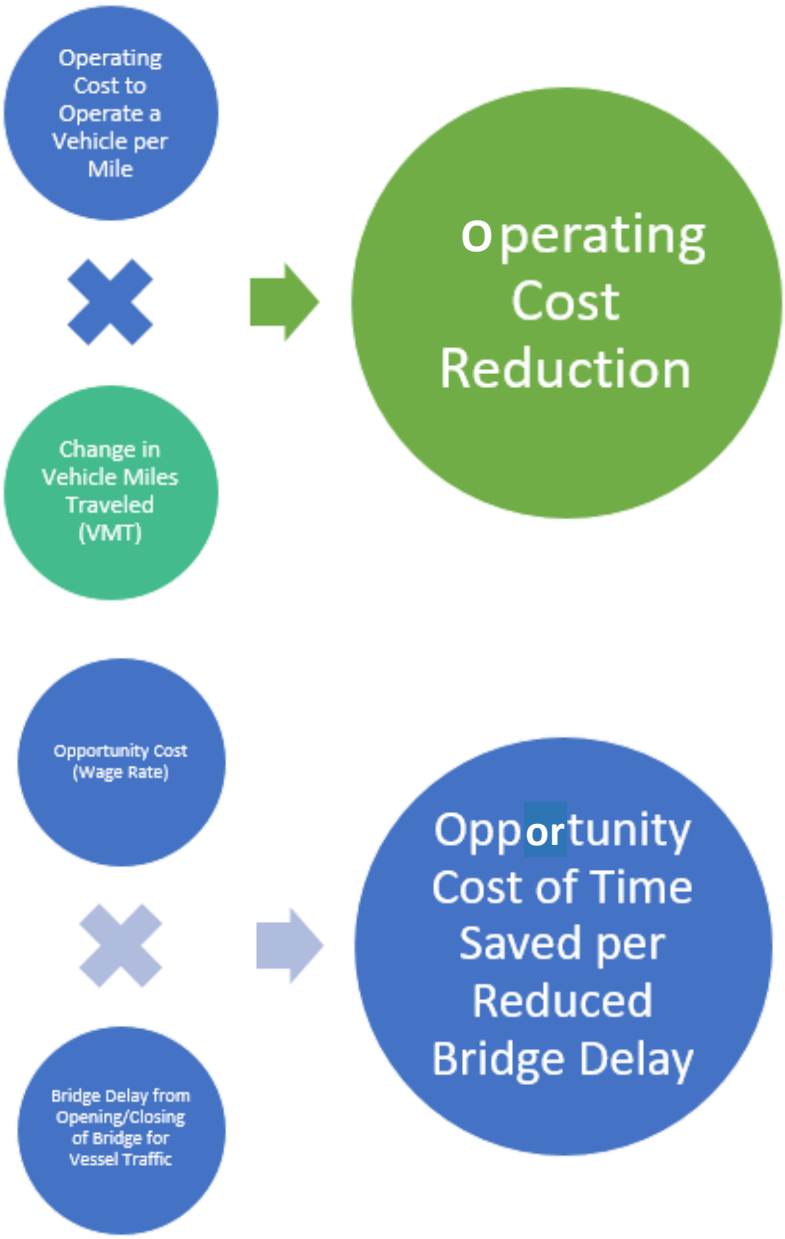
To determine costs associated with highway use, an existing economic model was modified. The model allows for an economic cost to benefit comparison between performing varying types of bridge replacements. It estimates construction project costs, periodic maintenance costs, and travel costs and savings attributed to replacement of the bridge. Model

results will be used to determine the economic benefits for the 50 year period of analysis following Operations guidance EP 1130-2-500 Appendix B - Rehabilitation Evaluation Report, and Appendix E – Benefits Evaluation Procedures. The Value of Time (VOT) calculation follows the Planning Guidance Notebook ER 1105-2-100 Appendix D (30 June 2004) pages D-19 and D-20 table D-4. The model also follows guidance to estimate benefits within Section D-4 Planning Special Topics and Cautions.

The vehicle traffic model was created following operations guidance EP 1130-2-500 Appendix B - Rehabilitation Evaluation Report, and Appendix E – Benefits Evaluation Procedures. The Value of Time (VOT) calculation follows the Planning Guidance Notebook ER 1105-2-100 Appendix D (30 June 2004) pages D-19 and D-20 table D-4. The model also follows guidance to estimate benefits within: Section D-4 Planning Special Topics and Cautions.
The model is an Excel spreadsheet that uses data supplied by HRTPO and the vehicular traffic study conducted by WSP. A comparison of the FWOP and the FWP condition is used to estimate the difference between the two scenarios that will yield benefits related to the project. The base condition, also referred to as FWOP, is the scenario in which the bridges are regularly maintained with no scheduled major construction projects and emergency funds are used to repair instances of component failures. The replacement alternatives are the scenarios in which a replacement bridge is constructed, adjacent to the existing bridges over four years consecutively. The economic approach utilized in this model can be seen in Figure 3.

Figure 3. Economic Approach





*VMT and VHT values are provided by the HRTPO Regional Travel Demand Model.

Using the costs described above, outputs were generated to determine the expected costs and benefits for the major rehabilitation and replacement scenarios. These outputs were then used to compare Benefit Cost Ratios (BCRs). Alternative plans include either a fixed or moveable bridge option. The NED benefits are generated by addressing inefficiencies in the existing transportation system to lower transportation costs. Net benefits are calculated by subtracting the total cost to construct and maintain the improvements over a 50-year study

period from the total transportation cost savings that would be generated by the proposed improvements over that period.

Table 30. Traffic Volume—High Bridge

Year	With Project (vehicles/day)	Without Project (vehicles/day)
2009	10,108	10,108
2027	14,290	13,993
2040	17,310	16,798
2076	17,310	16,798

Table 31. Traffic Volume—Low Bridge

Year	With Project (vehicles/day)	Without Project (vehicles/day)
2009	10,108	10,108
2027	13,993	13,993
2040	16,798	16,798
2076	16,798	16,798

Table 32. Vehicle Miles Traveled—High Bridge

Year	With Project	Without Project
2009	38,222,336	38,222,336
2027	45,639,118	45,654,700
2040	50,995,682	51,022,518
2076	50,995,682	51,022,518

Table 33. Vehicle Miles Traveled—Low Bridge

Year	With Project	Without Project
2009	38,222,336	38,222,336
2027	45,654,700	45,654,700
2040	51,022,518	51,022,518
2076	51,022,518	51,022,518

Table 34. Vehicle Hours Traveled—High Bridge

Year	With Project	Without Project
2009	977,183	977,183
2027	1,222,969	1,223,712
2040	1,400,481	1,401,760
2076	1,400,481	1,401,760

Table 35. Vehicle Hours Traveled—Low Bridge

Year	With Project	Without Project
2009	977,183	977,183
2027	1,223,712	1,223,712
2040	1,401,760	1,401,760
2076	1,401,760	1,401,760

- With Project Opportunity Costs Associated with Bridge Delays This models With project or FWP opportunity delay cost incurred for passengers in vehicles that must wait in queue as the bridge opens to allow for vessel traffic to traverse.

Table 36. With Project Opportunity Costs (Bridge Delays)—High Bridge

	2027	2076
WORK TRIPS		
Bridge Openings Per Year	0	0
Number of Cars Per Opening	20	24
Cost Per Car Per Opening	$2.68	$2.68
USER COST	0	0
SOCIAL/RECREATIONAL TRIPS		
Bridge Openings Per Year	0	0
Number of Cars Per Opening	19	23
Cost Per Car Per Opening	$1.03	$1.03
USER COST	0	0
OTHER TRIPS		
Bridge Openings Per Year	0	0
Number of Cars Per Opening	41	49
Cost Per Car Per Opening	$1.03	$1.03
USER COST	0	0
TOTAL USER COSTS (Undiscounted)	0	0
AVERAGE ANNUAL USER COST (Discounted)	$0.00	
ROUNDED	$0.00	

Note: A high bridge will not have bridge openings. Therefore, there will be no delay.

Table 37. With Project Opportunity Costs (Bridge Delays)—Low Bridge

	2027	2076
WORK TRIPS		
Bridge Openings Per Year	4,529	4,714
Number of Cars Per Opening	20	24
Cost Per Car Per Opening	2.68	2.68
USER COST	242,690	303,134
SOCIAL/RECREATIONAL TRIPS		
Bridge Openings Per Year	4,529	4,714
Number of Cars Per Opening	19	23
Cost Per Car Per Opening	1.03	1.03
USER COST	89,608	111,926
OTHER TRIPS		
Bridge Openings Per Year	4,529	4,714
Number of Cars Per Opening	41	49
Cost Per Car Per Opening	1.03	1.03
USER COST	190,418	237,843
TOTAL USER COSTS (Undiscounted)	522,716	652,903
AVERAGE ANNUAL USER COST (Discounted)	$574,233	
ROUNDED	$574,000	

- With Project Operating Costs Associated with Bridge Delays: This models With project or FWP operating cost incurred for vehicles that must wait in que as the bridge opens to allow for vessel traffic to traverse.

Table 38. With Project Operating Costs (Bridge Delays)—High Bridge

	2027	2076
STOP AND START CYCLE COSTS		
Bridge Openings Per Year	0	0
Number of Cars Per Opening	80	96
Cost Per Car Per Opening	$0.32	$0.32
USER COST	0	0
AVERAGE ANNUAL USER COST (Discounted)	$0	
(ROUNDED)	$0	

Table 39. With Project Operating Costs (Bridge Delays)—Low Bridge

	2027	2076
STOP AND START CYCLE COSTS		
Bridge Openings Per Year	4,529	4,714
Number of Cars Per Opening	80	96
Cost Per Car Per Opening	$0.32	$0.32
USER COST	117,438	146,687
AVERAGE ANNUAL USER COST (Discounted)	$129,012	
ROUNDED	$129,012	

Table 40. Vehicle Operating Costs (Reroutings)—High Bridge

USER COST COMPONENTS:	2027	2076
Without Project Vehicle Miles Traveled	45,654,700	51,022,518
With Project Vehicle Miles Traveled	45,639,118	50,995,682
Difference	-15,582	-26,836
Miles Difference	15,582	26,836
Number of Days Per Year	365	365
Cost Per Mile	$0.57	$0.57
USER COST	$ 3,255,542	$ 5,606,766
Average Annual Benefits		$4,185,965
(Rounded)		$4,186,000

Table 41. Vehicle Operating Costs (Reroutings)—Low Bridge

USER COST COMPONENTS:	2027	2076
Without Project Vehicle Miles Traveled	45,654,700	51,022,518
With Project Vehicle Miles Traveled	45,654,700	51,022,518
Difference	0	0
Miles Difference	0	0
Number of Days Per Year	365	365
Cost Per Mile	$0.57	$0.57
USER COST	$0	$0

Table 42. Vehicle Opportunity Costs (Reroutings)—High Bridge

	2027		2076
Without Project Vehicle Hours Traveled	1,223,712	daily	1,401,760
With Project Vehicle Hours Traveled	1,222,969	daily	1,400,481
Difference	743		1,279
Trip Purpose as percent			
Work (25 Percent)	186	daily	320

	2027		2076
Social Recreation (24 Percent)	178	daily	307
Other (51 Percent)	379	daily	652
USER COST COMPONENTS:	BASE YEAR		YEAR
Work Trips	2027		2076
25%			
Travel Time (Hours)	186		320
Cost Per Hour of Travel	$35.72		$35.72
Number of Days Per Year	250		250
USER COST	1,658,141	annual	2,855,687
AVERAGE ANNUAL USER COST			
(Discounted)		$2,015,191	
Social/Recreation	2027		2076
24%			
Travel Time (Minutes)	178		307
Cost Per Rerouted Trip	13.74		13.74
Number of Days Per Year	365		365
USER COST	893,866	annual	1,539,435
AVERAGE ANNUAL USER COST			
(Discounted)		$1,084,166	
Other	2027		2076
51%			
Travel Time (Minutes)	379		652
Cost Per Rerouted Trip	$13.74		$13.74
Number of Days Per Year	365		365
USER COST	1,899,464	annual	3,271,300
AVERAGE ANNUAL USER COST (Discounted)		$2,308,478	
TOTAL AVERAGE ANNUAL USER COST (Discounted)		$5,410,012	
ROUNDED		$5,410,000	

Table 43. Vehicle Opportunity Costs (Reroutings)—Low Bridge

	2027		2076
Without Project Vehicle Hours Traveled	1,223,712	daily	1,401,760
With Project Vehicle Hours Traveled	1,223,712	daily	1,401,760
Difference	0		0
Trip Purpose as percent			
Work (25 Percent)	0	daily	0
Social Recreation (24 Percent)	0	daily	0
Other (51 Percent)	0	daily	0
USER COST COMPONENTS:	BASE YEAR		YEAR
Work Trips	2027		2076
25%			
Travel Time (Hours)	0		0
Cost Per Hour of Travel	$35.72		$35.72
Number of Days Per Year	365		365
USER COST	0	annual	0
AVERAGE ANNUAL USER COST			
(Discounted)		$0	
Social/Recreation	2027		2076
24%			
Travel Time (Minutes)	0		0
Cost Per Rerouted Trip	$13.74		$13.74
Number of Days Per Year	365		365
USER COST	0	annual	0
AVERAGE ANNUAL USER COST			
(Discounted)		$0	
Other	2027		2076
51%			
Travel Time (Minutes)	0		0
Cost Per Rerouted Trip	$13.74		$13.74

	2027		2076
Number of Days Per Year	365		365
USER COST	0	annual	0
AVERAGE ANNUAL USER COST			
(Discounted)		$0	
TOTAL AVERAGE ANNUAL USER COST (Discounted)		$0	
ROUNDED		$0	

Table 44. FWOP Average Annual Highway User Costs

	Operating Costs	Opportunity Costs	Total
Bridge Delays	$129,000.00	$575,000.00	$704,000.00
Reroutings	$4,197,000.00	$5,410,000.00	$9,607,000.00
Total	$4,326,000.00	$5,985,000.00	$10,311,000.00

5.3 Average Annual Cost Summary

Table 45. Average Annual Benefits Summary

	FWP Fixed	FWP Moveable
Navigation	$414,780	$51,420
Vehicle		
Operating Delay	$129,000	0
Opportunity Delay	$575,000	0
Operating Rerouting	$4,197,000	0
Opportunity Rerouting	$5,410,000	0
Vehicle Subtotal	$10,311,000	0
Advanced Bridge Replacement	$1,009,863	$1,015,023
Total	**$11,735,643**	**$1,066,443**

Average annual economic costs for replacement of the existing North Landing Bridge are summarized in the table below. It can be noted that the initial screening identified the 2-lane high/fixed bridge aligned East of the existing bridge as the most economical replacement structure for North Landing. Costs for traffic signals were not included in the total project first cost, but are captured in the contingency. IDC was calculated using guidance provided in IWR

Report, 88-R-2 "NED Procedures Manual", page XI-35, Table XI-1. Length of design and construction used in the analysis was 60 months.

Table 46. Average Annual Cost Summary and Benefit Cost Ratio

Cost Item[1]	West Alignment		East Alignment	
	Fixed	Moveable	Fixed	Moveable
Civil Works Breakdown Structure[2]				
Roads and Bridges	$80,983,475	$61,885,304	$68,163,661	$72,938,684
Relocations	$386,446	$1,265,839	$1,583,522	$2,274,638
Cultural Resource Preservation	$772,978	$808,879	$519,262	$1,221,398
Lands and Damages	$1,854,937	$937,288	$2,722,941	$908,075
Planning, Engineering, and Design	$14,708,962	$10,944,715	$10,455,647	$12,992,837
Construction Management	$5,767,630	$4,291,606	$5,579,156	$5,094,709
Subtotal First Cost	$104,474,428	$80,133,631	$89,024,189	$95,430,341
Subtotal First Cost (Rounded)	$104,474,000	$80,134,000	$89,024,000	$95,430,000
Interest During Construction (Total Amount)	$3,502,126	$2,686,212	$3,533,960	$3,788,257
Annualized Investment Cost	$4,218,309	$3,192,437	$3,614,853	$3,823,638
Annualized O&M Cost	$271,848	$822,057	$271,848	$822,057
Total Average Annualized Cost	$4,490,156	$4,014,493	$3,886,700	$4,645,695
Total Average Annualized Cost (Rounded)	$4,490,000	$4,014,000	$3,887,000	$4,646,000
Average Annual Benefits (Vehicle Traffic)	$11,320,863	$1,009,863	$11,320,863	$1,009,863
Average Annual Benefits (Mariner Traffic)	$414,780	$51,420	$414,780	$51,420
Total Average Annual Benefits	$11,735,643	$1,061,283	$11,735,643	$1,061,283
Total Average Annual Benefits (Rounded)	$11,736,000	$1,061,000	$11,736,000	$1,061,000
Benefit Cost Ratio	**2.61**	**0.26**	**3.02**	**0.23**
Net Remaining Benefits	**$7,246,000**	**-$2,953,000**	**$7,849,000**	**-$3,585,000**

(1) Includes Contingency
(2) Interest Rate = 2.75%
Note: Prices are in FY20 Price Levels and AAB for Vehicle Traffic includes Advance Bridge Replacement.

6 PLAN SELECTION

The NED Plan is the alternative that reasonably maximizes net NED benefits while remaining consistent with the Federal objective of protecting the nation's environment. Where two cost-effective plans produce similar net benefits, the less costly plan is identified as the NED plan, even though the level of outputs may be less. Bridge replacement scenarios include:

- 2-lane low, movable or draw bridge type , with 2 minutes/mile bridge penalty for the HRTPO Regional Travel Demand Model run (No Build) on either East or West side of the existing bridge.
- 2-lane high bridge with no bridge penalty for the HRTPO Regional Travel Demand Model run (TLHB) on either East or West side of the existing bridge.

The benefit to cost ratio and net remaining benefits identify the East alignment, fixed span bridge as the NED Plan.

7 SENSITIVITY ANALYSIS

The sensitivity analysis relies on data provided by Hampton Roads Transportation Planning Organization (HRTPO) traffic demand model that was modeled by Architect Engineer (AE) firm specifically for North Landing Bridge. In Table 3, located in Section 3 of Memo 2, the traffic model calculated the Root Mean Square Error (RMSE) for the entire modeled area as 39.80% that represents square roots of squared differences between the traffic volume and count. Given that RMSE is represented as a percentage away from the mean, and not as a difference between the predicted and observed data, the RMSE and standard deviation would be equal. Given a known standard deviation, it allows for a more powerful test of local sensitivity by examining the change in output as each parameter is individuality increased by a factor of its standard deviation. In statistics, the empirical rule states that given a normal distribution, which is an assumption previously made, 68% and 95% percent of values will lie within a band around the mean at a distance of 1 and 2 standard deviations in both directions, respectively. Given the above rule, if an addition and subtraction of 1 standard deviation from the mean occurs, it will provide a 68% confidence interval, or an overall probability of a future expected value of the parameter lies within it. The same holds true for 95% confidence interval which is plus/minus 2 standard deviations. The result of the sensitivity analysis allows to set a probability associated with a certain range of future predicted values. The figure below shows the results.

Figure 4. Sensitivity Analysis for Fixed Span Bridge

Confidence Interval			Confidence Interval	
-2 Standard Dev	*-1 Standard Dev*	***Mean VHT***	*+1 Standard Dev*	*+2 Standard Dev*
95%	68%	$5,399,000	68%	95%
$1,101,396	$3,250,198	$5,399,000	$7,547,802	$9,696,604

Confidence Interval			Confidence Interval	
-2 Standard Dev	*-1 Standard Dev*	***Mean VMT***	*+1 Standard Dev*	*+2 Standard Dev*
95%	68%	$4,186,000	68%	95%
$853,944	$2,519,972	$4,186,000	$5,852,028	$7,518,056

Confidence Interval			Confidence Interval	
-2 Standard Dev	*-1 Standard Dev*	***Mean Bridge Delay***	*+1 Standard Dev*	*+2 Standard Dev*
95%	68%	$703,000	68%	95%
$143,412	$423,206	$703,000	$982,794	$1,262,588

(1) Sensitivity Analysis was performed using FY19 figures. The decreased federal discount rate is not expected to have a significant impact on this analysis.

Based on the results of the sensitivity analysis, there is a 68% probability that the future expected benefit value will lie between +$6,193,376 and +$14,382,624. In addition, at the 95% confidence interval or probability, the future expected benefit value will lie between an aggregate total of $2,098,752 and $17,214,660.

8 REGIONAL ECONOMIC DEVELOPMENT

Note: The analysis below was performed using costs from an FY19 Total Project Cost Summary. While the cost has fluctuated over time, this analysis still captures the essence and

purpose of this modeling tool. In addition, the internet based program used to create this analysis is not working properly.

USACE IWR, Louis Berger, and Michigan State University have developed a regional economic impact modeling tool, RECONS (Regional ECONomic System), that provides estimates of jobs and other economic measures such as labor income, value added, and sales that are supported by USACE programs, projects, and activities. This modeling tool automates calculations and generates estimates of jobs, labor income, value added, and sales through the use of IMPLAN®'s multipliers and ratios, customized impact areas for USACE project locations, and customized spending profiles for USACE projects, business lines, and work activities. RECONS allows the USACE to evaluate the regional economic impact and contribution associated with USACE expenditures, activities, and infrastructure.

The expenditures associated with All Work Activities, with Ability to Customize Impact Area and Work Activity at Virginia Beach-Norfolk-Newport News, VA-NC are estimated to be $84,381,067. Of this total expenditure, $81,265,000 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $84,381,067 support a total of 747.1 full-time equivalent jobs, $43,409,000 in labor income, $64,510,000 in the gross regional product, and $129,715,000 in economic output in the local impact area. More broadly, these expenditures support 1,191.0 full-time equivalent jobs, $78,672,000 in labor income, $119,906,000 in the gross regional product, and $235,771,000 in economic output in the nation.

Table 47. Project Information

Project Name	**Virginia Beach-Norfolk-Newport News, VA-NC**
Project ID	56069002
Type of Analysis	All Work Activities, with Ability to Customize Impact Area and Work Activity
Year of Expenditure	2023

Table 48. Economic Impact Area

Local Impact Area	Currituck (NC), Gates (NC), Gloucester (VA), Isle of Wight (VA), James City (VA), Mathews (VA), York (VA), Chesapeake city (VA), Hampton city (VA), Newport News city (VA), Norfolk city (VA), Poquoson city (VA), Portsmouth city (VA), Suffolk city (VA), Virginia Beach city (VA), Williamsburg city (VA)
Counties included	Currituck (NC), Gates (NC), Gloucester (VA), Isle of Wight (VA), James City (VA), Mathews (VA), York (VA), Chesapeake city (VA), Hampton city (VA), Newport News city (VA), Norfolk city (VA), Poquoson city (VA), Portsmouth city (VA), Suffolk city (VA), Virginia Beach city (VA), Williamsburg city (VA)
State Impact Area	North Carolina, Virginia
State(s) included	North Carolina, Virginia

Table 49. Project Expenditure

Business Line	All
Work Activity	Construction or Major Rehabilitation of Highway, Streets, and Bridges
Work Activity	2023
Current Expenditure ($)	$84,381,067

Table 50. Spending Profile

Spending Category	Percentage (%)
Construction of new highway, streets, and bridges	86%
Environmental Planning and Compliance	1%
USACE Labor -- Construction Management, Project Management, and Planning	9%
USACE Overhead	4%

Table 51. Local Purchase Coefficients

No	Industry	Expenditure	Local Purchase Coefficients		
		($000)	Local	State	US
56	Construction of new highways and streets	$72,567,718	100%	100%	100%
455	Environmental and other technical consulting services	$843,811	56%	82%	100%
462	Office administrative services	$3,375,243	75%	100%	100%
535	Employment and payroll of federal govt, non-military	$7,594,296	75%	100%	100%
	Total	$84,381,067			

Table 52. Overall RECONS Summary

Area	Local Capture ($000)	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
Local					
Direct Impact	$81,625	$81,625	453.7	$28,101	$37,183
Secondary Impact		$48,450	293.4	$15,308	$27,326
Total Impact		$129,715	747.1	$43,409	$64,510
State					
Direct Impact	$84,228	$84,228	489.3	$30,756	$40,060
Secondary Impact		$72,539	395.7	$22,699	$40,146
Total Impact		$156,767	885.0	$53,455	$80,206
US					
Direct Impact	$84,381	$84,381	491.1	$33,127	$41,351
Secondary Impact		$151,390	699.9	$45,545	$78,555
Total Impact		$235,771	1191.0	$78,672	$119,906

* Jobs are presented in full-time equivalence (FTE)

Table 53. Local Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
56	Construction of new highways and streets	$72,568	380.4	$21,343	$29,276
455	Environmental and other technical consulting services	$470	5.4	$318	$266
462	Office administrative services	$2,531	30.9	$1,862	$1,945
535	Employment and payroll of federal govt, non-military	$5,696	37.0	$4,577	$5,696
	Direct Impact	**$81,265**	**453.7**	**$28,101**	**$37,183**
	Secondary Impact	**$48,450**	**293.4**	**$15,308**	**$27,326**
	Total Impact	**$129,715**	**747.1**	**$43,409**	**$64,510**

* Jobs are presented in full-time equivalence (FTE)
* All costs are in 2019 price levels.