# CAPE FEAR MEMORIAL BRIDGE REPLACEMENT

## APPENDIX E: Benefit-Cost Analysis Technical Appendix

FY 2023 - FY 2026

NOVEMBER 27, 2023

**BRIDGE INVESTMENT PROGRAM** | **LARGE BRIDGE PROJECT GRANTS**

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## Executive Summary

The North Carolina Department of Transportation (NCDOT) is seeking funding through the Bridge Investment Program Discretionary Grant (BIP) program for a Large Bridge Project that rebuilds the Cape Fear Memorial Bridge (CFMB) in Wilmington, NC that runs over the Cape Fear River. Specifically, the replacement structure is anticipated to be a fixed-span structure with 135 feet of vertical clearance, just larger that of the existing structure in its raised position. The new structure will increase the total lanes from 4 to 6, while widening each lane, widening shoulders, and improving the retroreflectivity of traffic lines and markers. The ramp and flyover alignments connecting to the current structure will be improved by increasing the radii of the ramps. The bridge replacement will accommodate cyclists and pedestrians with a 15-foot multi-use path facility. The path will be separated from the general-purpose lanes over the bridge and will tie into other bike and pedestrian facilities on each side of the bridge.

A benefit-cost analysis (BCA) was completed in accordance with the USDOT's Benefit-Cost Analysis Guidance for Discretionary Grant Programs to communicate the societal benefits generated by this project. A custom Excel-based model was developed and used for this purpose, in lieu of the BIP BCA tool, to enable modeling multiple sources of traffic impacts and different combinations of safety improvements for different sections of the project area.

A 39-year analysis period was used to estimated project costs and benefits, from 2023 through 2061. Some preliminary engineering (PE) costs have already been spent (modeled in 2023), and the remaining PE and NEPA costs are assumed to be completed in 2024. Final design costs will be spent by 2027, and right-of-way costs by 2028. Construction will start in 2027 and be substantially complete in late 2031. The analysis assumes 30 years of operation starting in 2032, such that annual benefits are estimated through 2061. Table 1 and Table 2 summarize the outcomes of the benefit-cost analysis.

**Table 1: Key BCA Metrics for the Project Improvements**

| Project Evaluation Metric | Constant Dollars ($M) | Discounted ($M) |
|---|---|---|
| Total Net Benefits | $1,867.0 | $328.5 |
| Total Costs | $441.5 | $264.1 |
| Net Present Value | $1,425.5 | $64.4 |
| Benefit / Cost Ratio | N/A | 1.2 |
| Internal Rate of Return (%) | 8.5% | |
| Discounted Payback Period* | N/A | 30 Year(s) |

*The payback period is counted from the start of the analysis (2023).

Benefits from the project accrue to commercial vehicle and passenger vehicle drivers in the project area, as well as anticipated new active transportation mode users and residents of the surrounding area. A majority of the benefits are related to traffic impacts: the bridge replacement avoids delays and detours from required maintenance and bridge lifts and reduces peak congestion. Additionally, the new multi-use path is expected to create a shift in trips from vehicle to pedestrian and cycling modes and induce active transportation trips that would have otherwise not existed.

Considering all monetized benefits and costs with a 7 percent real discount rate (except for $CO_2$ emissions, which are discounted at a 3 percent real discount rate), the project investment of $264.1 million would result in $328.5 million in total benefits and a benefit-cost ratio (BCR) of approximately 1.2.

In addition to the monetized benefits, the project is expected to provide benefits that are described qualitatively. Though these are not monetized in the BCA, they are still important considerations in the evaluation of the project's societal benefits. A brief description of these benefits is provided below.

**Safety Benefits:**

- Pedestrian and cyclist facilities across the Cape Fear River will provide a safe and enjoyable path for active transportation users.
- The design safety improvements along the bridge and at the Front St ramps and approaches will reduce crashes and thus crash-related congestion. This will create more reliable travel times in and out of Wilmington.
- Wider shoulders and clear zones provide more space for emergency responders to react and handle incidents with reduced impact on traffic operations.

**Environmental Sustainability Benefits:**

- The project improves freight connectivity to marine and rail transport at the North Carolina State Port, located about 2.5 miles south of the project, which will contribute to a more resilient and reliable transportation network overall.
- Adding a lane to US 17 on the Cape Fear Memorial Bridge increases efficiency and provides redundancy should a lane need to be closed temporarily for an emergency or routine maintenance.

**Quality of Life Improvements:**

- The new Cape Fear Memorial Bridge will improve and revitalize the Wilmington cityscape, provide a new connection for tourism activities, and create a beautified pathway for all users.

**Mobility and Community Connectivity:**

- By reducing congestion and improving driving conditions on US 17 and providing active transportation facilities, the project enhances people movement and reduces barriers between communities.
- The project's pedestrian accommodations will connect tourism attractions, as well as future potential housing, commercial, and industrial developments on both sides of the river.

**Economic Competitiveness and Opportunity:**

- Reducing freight-related congestion on US 17 will lead to more efficient movement of goods from the port in and out of the city.

Table 2 summarizes the benefits of the project to all users and includes the value of the benefits monetized in the BCA.

**Table 2: Benefit Estimates for the Build Alternative, 2021 Dollars, Discounted**

| Current Status/Baseline and Problem to be Addressed | Change to Baseline | Impacts and Benefit Description | Benefit Category | Discounted Value ($M) |
|---|---|---|---|---|
| The bridge is functionally obsolete, the design is not up to standards, and existing traffic patterns lead to unsafe driving conditions that are not optimized for future traffic growth. | Improving the bridge and ramp designs lead to safer driving conditions. | Reducing the number of vehicle crashes each year after the project opens. | Crash Reduction Savings | $18.5 |
| Traffic and congestion caused by the existing roadway configuration. | Replacing the bridge and improving the ramps and approaches in the project area. | Reducing travel times and improving speeds within the project area. | Travel Time Savings | $92.2 |
| | | | Emissions Reduction Benefits | $4.0 |
| A complete lack of pedestrian and bicycle facilities leads to missing pedestrian and cycling connections and opportunities over the bridge. | Adding a dedicated multi-use path on the Cape Fear Memorial Bridge structure. | Improved facilities will enable some vehicle trips to shift to active transportation modes, leading to a reduction in mortality, emissions, and vehicle operating costs, and an increase in journey quality. | Cyclist Journey Quality Benefits | $0.3 |
| | | | Pedestrian Journey Quality Benefits | $0.3 |
| | | | Health Benefits | $3.1 |
| | | | Vehicle Operating Cost Savings | $1.0 |
| | | | Emissions Reduction Benefits | $0.1 |

| Current Status/Baseline and Problem to be Addressed | Change to Baseline | Impacts and Benefit Description | Benefit Category | Discounted Value ($M) |
|---|---|---|---|---|
| The existing vertical lift bridge causes consistent traffic delays to allow marine traffic to pass under the bridge. | Replacing the bridge with a new fixed span bridge. | The new bridge will eliminate traffic impacts related to marine traffic passage under the bridge. | Travel Time Savings | $5.1 |
| | | Eliminating vehicle idling time while waiting for the marine traffic reduces emissions from gasoline-based vehicles. | Emissions Reduction Benefits | $0.2 |
| The existing bridge asset requires extensive routine maintenance and several major rehabilitations over the coming years due to the age and complexity of the movable bridge components. Some of these maintenance activities will require partial or full closures of the bridge for short periods of time. | The newly constructed asset will require no closures to maintain the bridge for decades to come. | Avoiding delays and detours incurred from periodic bridge closures will save travel time, vehicle operating costs, accident costs, and emissions. | Travel Time Savings | $143.3 |
| | | | Crash Avoidance | $9.5 |
| | | | Vehicle Operating Cost Savings | $11.9 |
| | | | Emissions Reduction Benefits | $1.9 |
| The aging bridge structure is costly to maintain and is reaching the end of its expected service life. | The project will construct a new bridge, approaches, and ramp connections. | Several project components will have a useful life that extends beyond the end of this analysis. | Residual Value | $14.7 |
| | | The new bridge will need less work and cost to maintain a state of good repair. | Operation and Maintenance Savings | $22.6 |
| Longer delays and more congestion will lead to a less pleasant driving experience for residents and visitors. | Improving vehicle conditions and traffic flow via new structures and configurations. | Improvements to the quality of driving through the downtown Wilmington area. | Not Monetized | - |
| More traffic negatively affects the efficiency and throughput of freight vehicles. | | Increasing economic activity by improving local freight movement. | Not Monetized | - |

## Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the Cape Fear Memorial Bridge Replacement project:

- Section 1, Methodological Framework, introduces the conceptual framework used in the BCA.

- Section 2, Project Overview, provides an overview of the project, including a brief description of existing conditions, proposed alternatives, and a summary of cost estimates and schedule.
- Section 3, General Assumptions, discusses the general assumptions used in the estimation of project costs and benefits.
- Section 4, Demand Projections, presents estimates of future demand for active transportation movement along key overpasses and vehicle movement in the project area and along connected corridors.
- Section 5, Benefits Measurement, Data and Assumptions, presents specific data elements and assumptions pertaining to the long-term outcomes of the project, along with associated benefit estimates.
- Section 6, Summary of Findings and BCA Outcomes, introduces estimates of the project's net present value (NPV), its benefit/cost ratio (BCR), and other project evaluation metrics.
- Section 7, 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 in the review of this application.[1]
- Section 8, Annual BCA Results, presents discounted project costs, benefits, and net present value as annual time series.

# 1. Methodological Framework

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

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

While the BIP Notice of Funding Opportunity (NOFO) recommends that projects use the BIP BCA tool developed by FHWA to produce the BCA, this application is supported by a custom Excel-based spreadsheet model for the BCA (submitted with the application). The team determined that the CFMB Replacement Project involved enough complex and varied traffic impact modeling

[1] The BCA spreadsheet model is provided as part of the application.
[2] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023.
[3] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023.

(speed improvements from the new bridge asset, bridge lift and queueing delays, lane closure delays for maintenance and rehabilitation activities, and mode shifts) that a custom Excel-based model would be better suited for the purposes of this analysis. The BIP BCA tool was used to collect NBI data for the CFMB segment, which is discussed further in Section 4.

The methodology in the custom Excel-based BCA model for this application was developed using the BCA guidance published by USDOT and is consistent with Bridge Investment Program guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the Build and No-Build scenarios;
- Assessing benefits with respect to the selection 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, safety benefits, reductions in air emissions, and active transportation-based journey quality while also relying on other standard industry best practice where applicable;
- Discounting future benefits and costs with the real discount rate per the USDOT BCA Guidance (January 2023), which is 7 percent for all benefits except $CO_2$ emissions, which are discounted at 3 percent real discount rate; and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

This analysis also produces BCA results using a 3 percent discount rate for all benefits, as a sensitivity, to reflect the Office of Management and Budget Circular A-4 more closely, which was updated in November of 2023.[4]

USDOT recommends that the period of analysis covers the full development and construction of the project, plus at least 20 years of operation after construction is complete to account for the benefits and costs of highway transportation projects.[5] USDOT recommends an analysis period of 30 years for "projects involving the initial construction or full reconstruction of highways or other similar facilities" as well as "road and rail bridges, tunnels, or other major structures", and an operating period of 20 years for "projects aimed primarily at capacity expansion or to address other operating deficiencies."[6]

As the Cape Fear Memorial Bridge project will reconstruct a significant bridge asset carrying a highway, a 30-year period of operations is utilized. However, all traffic growth forecasts are capped at the horizon year of the travel demand forecast (2050, 20 years into the operation period), to

[4] Office of Management and Budget, Circular No. A-4, November 2023. OMB Circular A-4 (whitehouse.gov)
[5] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023.
[6] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023.

avoid overestimating demand or introducing high levels of uncertainty. Results of a sensitivity test with respect to the period of analysis are presented in Section 7.

# 2. Project Overview

The Cape Fear Memorial Bridge (CFMB) is an iconic landmark in Wilmington, NC. The 54-year-old structure with a 65-foot clearance is one of the only connections between two of the fastest growing communities in North Carolina. The bridge currently undergoes major rehabilitations every few years that are very costly and often require some lane closures across the bridge, further increasing congestion along US 17. The proposed project aims to replace the current vertical-lift structure with a 135-foot fixed-span structure with additional general purpose lanes, along with new pedestrian and cycling facilities across the length of the bridge.

The replacement bridge aims to improve safety, mitigate congestion on a key connection across the Cape Fear River, ensure a state of good repair for the bridge asset, and provide active transportation accommodations to enable walking and biking trips across the bridge. The fixed nature of the proposed replacement will allow for increased and continuous throughput along the length of the bridge, avoiding the need for traffic to pause every time the current bridge is lifted to allow for ship passage underneath, and avoiding lane closure impacts for regular maintenance.

The Project will:

- Replace the existing CFMB with a fixed-span structure that includes additional lanes, more reflective markings, and active transportation facilities;
- Reduce the operations and maintenance costs associated with maintaining the old vertical-lift structure;
- Increase the radii of ramps connecting to the CFMB; and
- Update the alignment of the flyover that connects to the bridge.

## 2.1 Base Case and Alternatives

A single No-Build (base case) and Build (alternative) scenario have been developed to assess the benefits and costs associated with this project.

The No-Build scenario assumes that the CFMB and its ramps will be maintained in their current state. This will lead to increased congestion in the future, continued safety issues for all users, and expensive maintenance costs to keep the bridge in working order. The bridge will continue to be an arduous connection over Cape Fear for the agency and roadway users, entirely lacking infrastructure for pedestrians and cyclists.

The Build scenario includes the completion of the project as outlined in the application, which replaces the CFMB, increases the lanes and lane widths from the original structure, improves the bridge ramp conditions, and adds pedestrian and cyclist accommodations over Cape Fear. Specifically, the CFMB Replacement Project includes the following changes to the bridge and surrounding area:

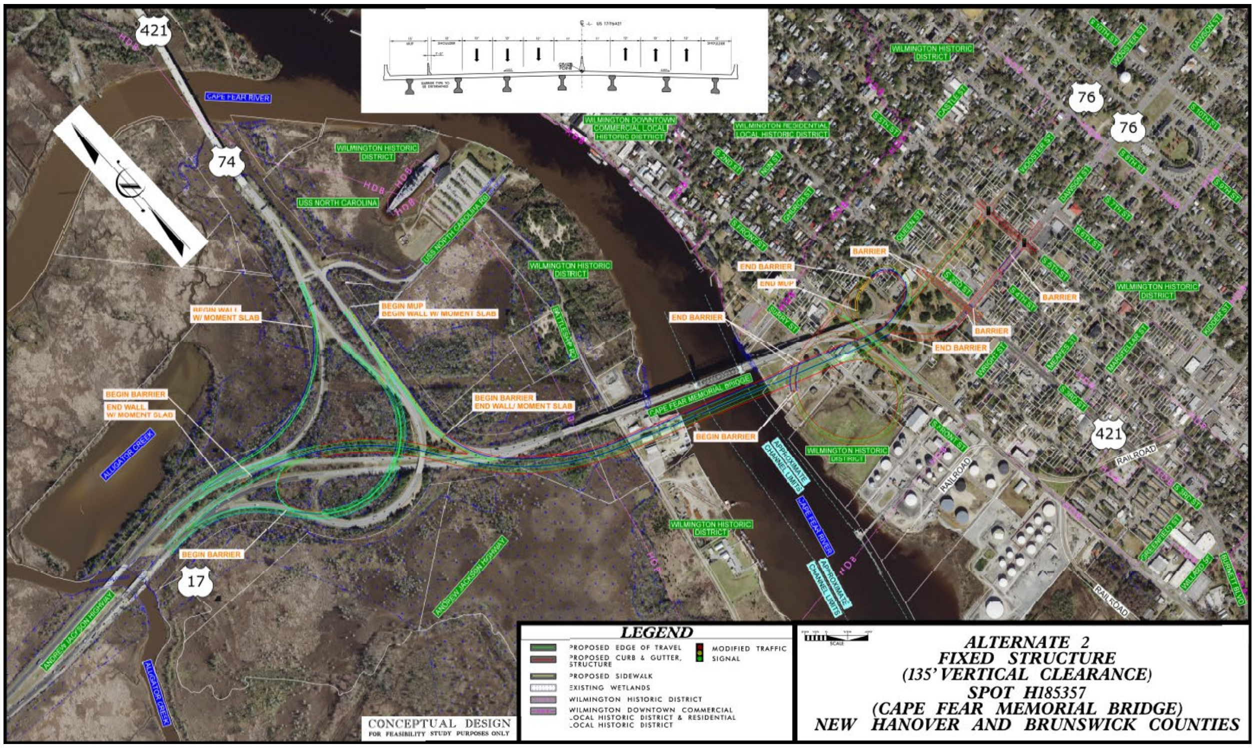
- Replacing the existing Cape Fear Memorial four-lane steel vertical-lift bridge with a six-lane fixed-span 135-foot structure (including travel lanes that align with current design standards);
- Reconstructing the bridge approaches and ramps to accommodate the new bridge height (which is anticipated to include the removal of 3rd Street connections to US 17, as the new alignment will overpass 3rd Street)
- Increasing the radii and improving sight-lines on the ramps connecting to the CFMB, particularly those on the east side;
- Increasing the visibility of pavement markers on new pavement for all reconstructed sections;
- Adding a 15-foot multi-use path separated from the general-purpose lanes over the bridge; and
- Implementing a roundabout at the intersection of Front Street and the US 17 on-ramp.

The figures below depict existing (No-Build) and planned (Build) conditions of the CFMB.

**Figure 1: Existing Conditions on the Cape Fear Memorial Bridge**

Source: NCDOT Project Team.

**Figure 2: Proposed Alignment and Cross-Section for the Cape Fear Memorial Bridge Replacement**




Source: Preliminary Roll Plot for the 135-ft fixed-span bridge replacement. NCDOT Project Team.

## 2.2 Project Cost and Schedule

The CFMB Replacement Project requires $400.6 million in construction costs in 2023 dollars. NCDOT also provided costs for the feasibility study (already spent), preliminary engineering (underway), and NEPA costs ($2.2 million in 2022 dollars), final design costs ($20.0 million in 2023 dollars), right-of-way costs ($60.0 million in 2023 dollars), and utility relocation costs ($3.7 million in 2023 dollars). The model deflates these costs correspondingly to 2021 dollars as inputs for the BCA, using the Bureau of Economic Analysis GDP Price Deflators.[7]

Therefore, the project requires $441.5 million in capital expenditures in 2021 dollars, including $362.1 million for construction, $18.1 million for final design, $56.1 million for right of way, $3.3 million for utility relocations, and $2.0 million for preliminary engineering and NEPA costs.

Preliminary engineering and NEPA costs started in June 2023 and are expected to finish in 32 months, in February 2026. Final design costs are expected to start alongside right of way and utility relocation in April 2026. Final design and utility relocation are expected to take 15 months, with expenditures finishing in July 2027. Right of way is expected to take two years, with expenditures finishing in April 2028. This leaves construction, which is anticipated to begin in July

[7] Bureau of Economic Analysis, National Income and Product Accounts, Table 1.1.9, "Implicit Price Deflators for Gross Domestic Product" (October 2022)

2027 and be completed in September 2031. Based on this schedule, there is sufficient buffer between then and the BIP obligation requirement date.

**Table 3: Project Cost Expenditures by Year**

| Year | Undiscounted Capital Expenditures (Millions of 2021 Dollars) | Capital Expenditures Discounted at 7% (Millions of 2021 Dollars) |
|---|---|---|
| 2023 | $0.4 | $0.3 |
| 2024 | $0.8 | $0.6 |
| 2025 | $0.8 | $0.6 |
| 2026 | $32.1 | $22.9 |
| 2027 | $77.1 | $51.4 |
| 2028 | $95.1 | $59.2 |
| 2029 | $86.9 | $50.6 |
| 2030 | $86.9 | $47.3 |
| 2031 | $61.5 | $31.3 |
| **TOTAL** | **$441.5 million** | **$264.1 million** |

### 2.3 Disruptions Due to Construction

The new alignment is anticipated to be parallel to and just south of the existing bridge (as shown in the roll-plot in Figure 2). NCDOT is dedicated to maintaining existing traffic conditions on CFMB throughout the construction period (though the existing traffic conditions are congested, the aim is to avoid making it worse). The maintenance of traffic plan is anticipated to mitigate impacts to traffic during construction by making connections to the adjacent existing roadways as efficiently as possible. As such, negligible and short-term delays to traffic are expected, so no construction delays are modeled in the analysis.

## 3. General Assumptions

The BCA measures benefits against costs throughout a period of analysis beginning at the start of project development and including 30 years of operations after the project opens.

The monetized benefits and costs are estimated in 2021 dollars, and dollars incurred in the future are discounted in compliance with USDOT BCA guidance using a 7 percent real rate (except for $CO_2$ emissions cost savings, which are discounted using a 3 percent real rate).

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

- Input prices are expressed in 2021 dollars;

- The period of analysis begins in 2023 and ends in 2061. It includes project development and construction years (2023 to 2031) and 20 years of operations (2032 to 2061);
- A constant 7 percent real discount rate is assumed throughout the period of analysis, except for $CO_2$ emissions which are discounted using a 3 percent real rate; and
- Project impacts in the Build scenario and location-specific demand data are used as a basis for estimation.

# 4. Demand Projections

There are three sources of vehicle traffic impacts from the CFMB Replacement Project, and the potential for new active transportation trips that would occur after the project is implemented. This section describes the approach, data sources, and methods to estimate these vehicle and active transportation impacts due to the project.

## 4.1 Traffic Impact from Bridge and Roadway Improvements

The first source for user impacts is the Cape Fear Memorial Bridge Improvement Study (2023)[8] which provided travel demand model (TDM) results for vehicle hours traveled (VHT) and vehicle miles traveled (VMT) in an AM peak hour and a PM peak hour, for 2023 and 2050 in the No-Build scenario, and 2050 in the Build scenario. The 2023 No-Build scenario reflects the base year traffic volumes and roadway network configuration within the study area and will serve as a "baseline" to compare with the future-year scenarios.

The model covered the area around the CFMB from the US 17/74 trumpet-style interchange with US 17/76/421 to the 5th Avenue intersections, including the Front Street interchange ramps and the 3rd Street intersections. The 2050 No-Build scenario reflects the same roadway network configuration as in the 2023 No-Build Scenario with the inclusion of the improvements made to Front Street as part of the U-5734 project, which is assumed to be completed by 2050. Both the 2023 and 2050 No-Build volumes are based on the traffic forecast provided by NCDOT.

The 2050 Build (Alternative B 135-ft span) scenario includes widening CFMB to 6 lanes and removing US 17 access to 3rd Street and 4th Street. The removal of access to 3rd Street and 4th Street is due to limitations in the roadway geometry as the bridge is anticipated to be constructed with a clearance of 135 feet (versus the existing 65-foot clearance and the replace-in-kind design considered in Alternative A). The new CFMB is anticipated to be constructed to the south of its current location. Due to the reduced access, turn lane improvements were proposed along S 5th Avenue to accommodate future traffic volumes. As part of this alternative, the Front Street ramp intersections were reconfigured to allow the on and off ramps via one roundabout intersection to be located at the existing Front Street and US 17/76 On-Ramp. Future year Alternative B traffic

[8] Cape Fear Memorial Bridge Improvements Study, NCDOT Project HB-0039, Capacity Analysis Report. Prepared for NCDOT, prepared by HDR Inc. DRAFT November 2023.

volumes are based the forecast provided by NCDOT, which was developed assuming reduced connectivity to 3rd Street and 4th Street. The modeled area, shown in Figure 3, does not include alternate routes across Cape Fear (these detour routes and impacts are discussed in following sections). The raw TDM results provided for the analysis are presented in Table 4.

**Figure 3: TDM Model Area**

Source: NCDOT Project Team, TDM Selected Links, Received November 2023.

**Table 4: Cape Fear Memorial Bridge Improvement Study, Raw TDM Data**

| Model Output | Time | No-Build | No-Build | Build |
|---|---|---|---|---|
| | | 2023 | 2050 | 2050 |
| AM Peak Hour VMT | 8:00-9:00 | 19,219 | 23,860 | 26,877 |
| PM Peak Hour VMT | 17:00-18:00 | 20,383 | 25,323 | 27,941 |
| AM Peak Hour VHT | 8:00-9:00 | 502 | 1,067 | 783 |
| PM Peak Hour VHT | 17:00-18:00 | 556 | 1,376 | 977 |

Source: NCDOT Travel Demand Model Output, Received November 2023.

The following adjustments were made to the TDM results to forecast vehicle demand for the purposes of the benefit-cost analysis, and the result of the adjustments is shown in Table 5:

1. The 2050 Build VMT was set to be the same as the 2050 No-Build VMT, as the Project is only expected to improve throughput, not induce (or reduce) VMT;

2. Using the original calculated 2050 Build speed based on the TDM outputs, 2050 Build VHT is adjusted to reflect the adjusted 2050 Build VMT;
3. The representative 2023 Build VMT is interpolated using the growth between the 2023 and 2050 No-Build VMT and applying it to the adjusted 2050 Build VMT; and,
4. The 2023 Build VHT is interpolated in the same manner as 2023 Build VMT.

After the adjusted 2023 and 2050 Build VMT and VHT are calculated, the daily peak total is calculated using a weighted average daily factor of 2 hours per peak period (a weighted average of 2.5 hours per peak period on weekdays, and 0.75 hours per peak period on weekends).[9] The analysis conservatively does not consider speed improvements for the off-peak hours that may be generated by the project.

**Table 5: Adjusted and Interpolated TDM Data**

| Model Output | Time | No-Build | | Build | |
|---|---|---|---|---|---|
| | | 2023 | 2050 | 2023 | 2050 |
| AM Peak Hour VMT | 8:00-9:00 | 19,219 | 23,860 | 19,219 | 23,860 |
| PM Peak Hour VMT | 17:00-18:00 | 20,383 | 25,323 | 20,383 | 25,323 |
| AM Peak Hour VHT | 8:00-9:00 | 502 | 1,067 | 327 | 695 |
| PM Peak Hour VHT | 17:00-18:00 | 556 | 1,376 | 358 | 885 |
| **Daily Average VMT** | | **79,203** | **98,366** | **79,203** | **98,366** |
| **Daily Average VHT** | | **2,115** | **4,885** | **1,369** | **3,161** |

Source: Calculated from NCDOT Travel Demand Model Output for the BCA.

Daily (peak period) VMT and VHT are then annualized and interpolated between 2023 and 2050[10] using the compound annual growth rate (CAGR) between the adjusted 2023 and 2050 TDM results. The 2050 value is used to represent demand for years beyond 2050. Passenger vehicle and truck VMT and VHT are separated using the truck traffic percentage from the National Bridge Inventory traffic data for the CFMB.[11] These assumptions are summarized in Table 6.

**Table 6: Roadway Improvement Travel Demand Assumptions**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Hours per AM/PM Peak on Weekday | hours per peak period | 2.50 | NCDOT Project Team (traffic related to commuting patterns in Wilmington) |

[9] Peak hours per peak period are provided by the NCDOT Project Team. Weekday peak hours are derived from traffic related to commuter patterns, weekend peak hours are derived from traffic related to tourism.

[10] VMT and VHT forecasts in the Build and No-Build are capped at the 2050 levels for years after 2050, as this is the horizon year of the TDM results.

[11] FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Calculated from Table 3. Average Annual Daily Traffic (AADT).
An alternate truck traffic percentage from a Traffic Forecast Report for the project is considered in the sensitivity analysis (Traffic Forecast - Cape Fear Memorial Bridge Replacement (NCDOT Project HB-0039) Report. Prepared for NCDOT Transportation Planning Division, prepared by Clearbox Forecast Group. September 2023. Table E.2, pg. 36.)

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Hours per AM/PM Peak on Weekend | hours per peak period | 0.75 | NCDOT Project Team (traffic related to tourism in and through Wilmington) |
| Peak Hours Per Day | hours per day | 2.0 | HDR Calculation from hours per AM/PM peak on weekdays/ weekends |
| Truck Percentage | percent | 13.6% | FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Calculated from Table 3. Average Annual Daily Traffic (AADT) |
| Annualization | days per year | 365 | Peak period travel demand modeled data represents average daily peak demand across the entire year. |

### 4.2 Traffic Impact Estimation for Bridge Lift Delays

The vertical lift bridge raises, closing to vehicle traffic, to allow boat traffic to pass. On average, the bridge opens 236 times per year, or 4.5 times per week, and lasts 9 minutes per lift.[12] These relatively short bridge closures add trip time and create queues on the surface street network. When a bridge lift occurs, vehicles wait for the bridge to reopen, and a queue forms. At certain hours of the day, this queue extends to the adjacent surface street intersections and at times begins to affect traffic movements for vehicles that are not even crossing the bridge.

#### DELAY AND QUEUEING METHODOLOGY

The bridge lift data implies that lifts do not occur evenly across the day, and traffic is certainly not evenly distributed across a day, so the analysis is performed by the hour to capture the interplay of bridge lift delays and traffic demand. These impacts are estimated through hourly demand, queues, and clearing time to determine how many vehicles are affected by the bridge lifts and for how long.

The total delay due to a bridge lift is estimated as the sum of the vehicle-delay during the bridge lift, the vehicle-delay during the bridge's queue clearing time, and the vehicle-delay for through-movement queues caused at adjacent intersections. The analysis steps are as follows:

1. Annual average daily traffic (AADT) for the CFMB[13] and hourly vehicle count data from 2020, 2021, and 2023 in the project area[14] is used to estimate an average hourly distribution of traffic across the day, by hour (no 2022 data was available at the relevant count locations).

[12] Calculated from bridge lift log data, provided by Division Bridge Maintenance Engineer, North Carolina Department of Transportation. Received October 26, 2023.
[13] FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Table 3. Average Annual Daily Traffic (AADT).
[14] Analysis of historical traffic counts from 2020, 2021, and 2023 at count locations on the CFMB and east of the CFMB (location IDs 650000535, 650000526, 650000030, 650000103, 650000525 ,650000524; https://ncdot.public.ms2soft.com/tcds/tsearch.asp?loc=ncdot ). Data retrieved October 27, 2023.

2. The number of vehicles affected by a bridge lift in any given hour is estimated from the percent of time in an hour that a bridge lift would cover (9 minutes, or 15% of an hour) multiplied by the hourly share of average daily volume (and assuming an even volume rate across the hour).
3. The **vehicle-hours of delay during the bridge lift** is estimated as the average delay time (half the average bridge lift duration of 9 minutes per vehicle) multiplied by the vehicles affected by a bridge lift, by hour.
4. Then, vehicles affected by a lift headed westbound across the bridge are estimated (approximately 50% of all traffic, with slightly less in the AM peak and slightly more in the PM peak), by hour, to represent the queue that affects the Wilmington surface streets.
5. This volume is translated to passenger-car-equivalents (PCEs), using the percentage for truck traffic and PCE factor for trucks. For some hours of the day, the corresponding queue length extends down the bridge approach and onto the surface streets, including the Front Street loop, 3rd Street (southbound right-turning and northbound left-turning directions), and westbound on US 17 (Wooster St). The number of PCE vehicles queued on the bridge is estimated from the bridge approach length, and the remaining affected vehicles are distributed to queues on the surface streets proportionally from the AADT estimates[15] for vehicle movements heading toward the bridge. Queued vehicles by segment are estimated for each hour of an average day.
6. The number of queued PCE vehicles is compared to the clearing rate for the queue for each segment to estimate the total time required to clear the queue, by hour.
7. **Vehicle-minutes of delay during the queue clearing time** is the product of the queued vehicles and the average time each vehicle takes to clear their queue (half the total clear time, for all the segments each set must travel to cross the bridge). This is translated from PCE vehicle-minutes to straight vehicle-hours, for each hour.
8. Finally, the number of vehicles affected heading southbound and northbound on 3rd Street (through movements) by hour is estimated, similar to above, from AADT and the hourly distribution of traffic.
9. Vehicles that queue during the bridge queue dissipation time are estimated from the queue rate and the dissipation time, by hour.
10. The total time to clear these through-movement queues is estimated from the clearing rate and the queued vehicles.
11. **Vehicle-minutes of delay for through-movements** is estimated from the queued vehicles and the average time each vehicle takes to clear the through-movement queue (half the total clear time). This is again translated from PCE vehicle-minutes to straight vehicle-hours, for each hour.

[15] Traffic Forecast - Cape Fear Memorial Bridge Replacement (NCDOT Project HB-0039) Report. Prepared for NCDOT Transportation Planning Division, prepared by Clearbox Forecast Group. September 2023. Page 3.

Again, the sum of these three sources of vehicle delays approximates the total bridge lift impact. The total hours of vehicle delay from a bridge lift, per hour per day, are multiplied by the average annual bridge lift occurrences, per hour per day, and summed across hours. This results in an estimated 25 vehicle-hours of delay per day, on average, from bridge lifts in 2023, and an average of 56 vehicle-hours of delay per day saved after the project's completion. (See the "BridgeLift_Delay" sheet in the BCA model for more detail and calculations.)

The frequency of CFMB lifts is based on three years of data on bridge lift occurrences (from June 2020 to June 2023). This estimate does not cover Coast Guard operations or freight business operations in the area. However, the project team expects that either the Coast Guard or a commercial freight property will begin operations upriver of the CFMB in the next ten years (prior to the new project's opening year), which would significantly increase the number of bridge lifts required. Thus, annualized vehicle-delay is increased by 50 percent to account for this impact. This results in a base estimate of 38 vehicle-hours of delay per day for 2023-equivalent traffic levels, and an average of 84 vehicle-hours of delay per day saved after the project's completion.

This estimate was separated for passenger vehicles and trucks using a constant percentage for truck traffic and forecasted through the period of analysis with a CAGR for bridge traffic. The analysis uses the traffic data (AADT, truck percentage, and CAGR) from the National Bridge Inventory dataset. [16] An alternate traffic data source and corresponding results are considered in the sensitivity analysis.

#### ASSUMPTIONS AND DATA

Table 7 lists the assumptions related to bridge demand that are constant across a day and not specific to street segments for the queueing analysis.

**Table 7: CFMB Demand Data and Assumptions for Bridge Lift Delay**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| CFMB AADT | 2021 vehicles per day | 69,000 | FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Calculated from Table 3. Average Annual Daily Traffic (AADT) |
| CFMB Lift Duration | minutes per lift | 9 | Calculated from bridge lift log data, provided by Division Bridge Maintenance Engineer, North Carolina Department of Transportation. Received October 26, 2023. |
| Truck Percentage | % | 13.6% | FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Calculated from Table 3. Average Annual Daily Traffic (AADT) |
| Annual Growth | % per year | 3.72% | FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Table 4. NBI's Calculated Average Annual Daily Traffic (AADT) Growth Rate |

[16] FHWA, National Bridge Inventory dataset. Accessed using the BIP BCA Tool v1.0.0, September 26, 2023. Table 3. Average Annual Daily Traffic (AADT).

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Passenger Car Equivalent (PCE) Factor | factor | 1.5 | Project Team Traffic Modeler |
| Length of PCE Vehicle | ft | 25 | "NCDOT Capacity Analysis Guidelines, Best Practices." March 2021. NCDOT Congestion Management Section. Page 33. Best Practices - Capacity Analysis Guidelines.pdf (ncdot.gov) |
| WB Bridge Approach Length | ft | 1,500 | Google Earth measurement, from bridge lift stop line to 3rd Street intersection. |

Table 8 lists the assumptions for capacity and queue calculations by street segment, and Table 9 lists the assumptions that are variable by hour.

**Table 8: Capacity and Flow Assumptions**

| Variable Name | WB Bridge Approach | Front St Loop, WB | 3rd Street, SB, Right-Turning | 3rd Street NB, Left-Turning | US 17 WB, Through |
|---|---|---|---|---|---|
| Number of Lanes | 2 | 1 | 1 | 1 | 2 |
| Green Time (% of cycle) | 100% | 100% | 25% | 28% | 47% |
| Saturation Flow (vphpl) | 1,900 | 1,200 | 1,900 | 1,900 | 1,900 |
| Friction Factor | 0.9 | 1.0 | 0.9 | 1.0 | 0.9 |
| Capacity (vph) | 3,420 | 1,200 | 400 | 511 | 1,606 |

Note: Capacity is calculated as the product of the number of lanes, green time, saturation flow, and friction factor. Acronyms: SB – southbound, NB – northbound, WB – westbound. Data and methods sourced from the Project Team Traffic Modeler.

**Table 9: Hourly Traffic and Bridge Lift Frequency Data**

| Hour of the day | Daily Traffic (%)* | Westbound Traffic (%)** | Avg Annual Bridge Lifts per hour per day*** |
|---|---|---|---|
| 00:00 - 01:00 | 0.4% | 50% | 0.05 |
| 01:00 - 02:00 | 0.3% | 50% | 0.07 |
| 02:00 - 03:00 | 0.3% | 50% | 0.06 |
| 03:00 - 04:00 | 0.3% | 50% | 0.05 |
| 04:00 - 05:00 | 0.7% | 50% | 0.03 |
| 05:00 - 06:00 | 1.8% | 40% | 0.00 |
| 06:00 - 07:00 | 5.4% | 40% | 0.02 |
| 07:00 - 08:00 | 8.4% | 40% | 0.01 |
| 08:00 - 09:00 | 7.3% | 40% | 0.01 |
| 09:00 - 10:00 | 6.2% | 40% | 0.02 |

| Hour of the day | Daily Traffic (%)* | Westbound Traffic (%)** | Avg Annual Bridge Lifts per hour per day*** |
|---|---|---|---|
| 10:00 - 11:00 | 6.3% | 50% | 0.04 |
| 11:00 - 12:00 | 6.2% | 50% | 0.03 |
| 12:00 - 13:00 | 6.5% | 50% | 0.02 |
| 13:00 - 14:00 | 6.5% | 50% | 0.03 |
| 14:00 - 15:00 | 6.6% | 55% | 0.04 |
| 15:00 - 16:00 | 7.0% | 55% | 0.02 |
| 16:00 - 17:00 | 7.5% | 55% | 0.02 |
| 17:00 - 18:00 | 7.5% | 55% | 0.01 |
| 18:00 - 19:00 | 4.8% | 55% | 0.02 |
| 19:00 - 20:00 | 3.7% | 50% | 0.02 |
| 20:00 - 21:00 | 2.6% | 50% | 0.00 |
| 21:00 - 22:00 | 1.8% | 50% | 0.00 |
| 22:00 - 23:00 | 1.2% | 50% | 0.04 |
| 23:00 - 24:00 | 0.8% | 50% | 0.04 |

Sources: * Analysis of historical traffic counts from 2020, 2021, and 2023 at count locations on the CFMB and east of the CFMB (location IDs 650000535, 650000526, 650000030, 650000103, 650000525 ,650000524; https://ncdot.public.ms2soft.com/tcds/tsearch.asp?loc=ncdot ). Data retrieved October 27, 2023. Due to rounding, the sum of the reported data may not equal 100 percent.
** Project Team Traffic Modeler.
***Calculated from bridge lift log data, provided by Division Bridge Maintenance Engineer, North Carolina Department of Transportation. Received October 26, 2023.

#### ESTIMATED IMPACTS FROM BRIDGE LIFTS

Table 10 summarizes the estimates for vehicle-hours of delay (additional VHT) due to bridge lifts.

**Table 10: Average Vehicle-Hours of Delay Saved from Bridge Lifts Over 30 Years of Project Operations**

| | Daily VHT | Annual VHT |
|---|---|---|
| Passenger Vehicles | 72.9 | 26,626.3 |
| Truck | 11.5 | 4,204.2 |
| **Total** | **84.5** | **30,830.4** |

### 4.3 Traffic Impact Estimation for Bridge Maintenance and Rehabilitation

The existing movable bridge requires regular maintenance, and will require major rehabilitations throughout its remaining life. These activities have and will continue to require periodic lane closures that affect traffic across the bridge. The analysis estimates these impacts using the methodology within the Work Zone User Costs (Chapter 3) in the Life-Cycle Cost Analysis in

Pavement Design – Interim Technical Bulletin (FHWA, 1998).[17] The travel demand modeling does not incorporate traffic impacts from periodic lane closures, so the vehicle hours and miles estimated for queue delays and detours (which are avoided with the proposed project) are in addition to the speed improvement impacts expected from the new bridge asset and the avoided vehicle-hours related to bridge lifts.

#### WORK ZONE IMPACT METHODOLOGY

The benefit-cost analysis uses the portion of the Work Zone User Cost methodology that estimates an increase in VMT and VHT (referred to as the Work Zone User Impact analysis). There are four main steps, described here, and assumptions and data used in the analysis are presented in the next subsections.

1. **Traffic Analysis of the Work Zone:** This step estimates the overall demand on the roadway, translates to PCE vehicles, and compares to the available capacity assuming changes in travel conditions in the work zone across the day (i.e. lane closures and speed changes). Based on this comparison, the analysis estimates vehicles that detour, vehicles that travel the work zone length, and vehicles that queue.
2. **Work Zone Delay:** This step estimates the impacts for vehicles that travel the work zone length, assuming that vehicles experience a slower speed through the work zone due to a speed limit restriction or congestion. This results in additional VHT.
3. **Queue Delay:** This step estimates impacts for vehicles that are queued (prior to entering the work zone) due to congestion through the work zone under a reduced capacity. Queued vehicles experience slower speeds as they work through the queue and wait for it to clear, and this results in additional VHT.
4. **Detour Delay:** This final step estimates impacts for vehicles that decide to detour around the work zone rather than enter the queue. The analysis compares travel times and distances without and with the detour to determine the additional VMT and VHT.

These steps are calculated for each hour in a day, using average traffic and capacity estimates. The analysis then aggregates the VMT and VHT across the sources and hours, and translates from PCE to straight vehicles, to generate an average daily impact.

#### TYPES OF CLOSURES

After several conversations with the NCDOT Bridge Maintenance Division and Project Team staff, there are four types of possible closure outcomes for future CFMB maintenance and major rehabilitations in the No-Build scenario, described below:

- **Option 1 – Nighttime lane closures:** Commonly used for isolated deck repair needs, and specifically avoids traffic impacts, occurring between 9pm and 5am. The analysis assumes

[17] "Life-Cycle Cost Analysis in Pavement Design: Pavement Division Interim Technical Bulletin September 1998." 1998. Publication No. FHWA-SA-98-079. USDOT, Federal Highway Administration. Page 33 to 80. https://www.fhwa.dot.gov/pavement/lcca/013017.pdf.

this closure type maintains one lane of traffic in each direction (bidirectional half capacity). The Work Zone User Impact analysis estimates no traffic impacts associated with this closure type (which tracks with the intent).

- **Option 2 – Partial lane closures:** Most frequently utilized approach when daytime work or inspections are required. The analysis assumes this closure type maintains one lane of traffic in each direction (bidirectional half capacity), and assumes that when faced with a potential queue, a portion of vehicles will detour rather than wait through the queue.
- **Option 3 – Directional lane closures:** The major rehabilitation work NCDOT has planned for 2024 on the CFMB will utilize this approach, which will close one direction of traffic at a time, forcing half the vehicles to detour (unidirectional half capacity). The Work Zone User Impact analysis estimates no delays for the open direction of traffic, and estimates the added time and distance from the required detour route for the closed direction of traffic.
- **Option 4 – Full closures:** In the unlikely event that a bridge inspection reveals a crack in the truss, or a gear is sheared during a bridge lift operation, the entire bridge will be closed for emergency repair (zero capacity). In this case, all vehicles are required to detour.

### WORK ZONE IMPACT ASSUMPTIONS AND DATA

The Work Zone User Impact analysis is based on the same traffic data used in the estimation for bridge lift delays (the AADT, truck percentage, and traffic growth presented in Table 7, and the hourly distribution of traffic presented in Table 9). The Work Zone User Impact analysis also uses the assumptions in Table 11 and Table 12 to estimate vehicle impacts for each closure type.

**Table 11: Work Zone Impact Analysis (Lane Closures) Data and Assumptions**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Queue dissipation per lane per hour | vehicles per lane per hour (vplph) | 1,818 | "Life-Cycle Cost Analysis in Pavement Design: Pavement Division Interim Technical Bulletin September 1998." 1998. Publication No. FHWA-SA-98-079. USDOT, Federal Highway Administration. Page 48. https://www.fhwa.dot.gov/pavement/lcca/013017.pdf. |
| Free-flow Speed | mph | 45 | CFMB speed limit (assumed for unrestricted and work zone conditions without congestion). |
| Normal Congested Speed | mph | 37 | NCDOT Travel Demand Model Output, Received November 2023. Average speed across peak periods calculated from the No-Build scenario data (assumed for unrestricted peak periods). |
| Work Zone Congested Speed | mph | 16 | NCDOT Travel Demand Model Output, Received November 2023, assuming half normal capacity across the bridge.[18] Average speed across peak periods calculated from the No-Build scenario data (assumed for congested work zone conditions). |

[18] The maintenance of traffic 2023 scenario reflects the predicted roadway conditions within the model area during the reconditioning/rehabilitation of the existing moveable bridge. During the reconditioning process, it is anticipated that the bridge would be reduced to one lane in each direction over the Cape Fear River to allow for the required work to be completed. This scenario utilized the same volumes as the 2023 Base Year No-Build Scenario with no changes to the proposed traffic routing.

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Capacity | vplph | 1,900 | Project team Traffic Modeler |
| Work Zone Length | miles | 0.19 | Google Earth, approximate bridge length across the water. |

**Table 12: Lane Closure and Traffic Detouring Assumptions by Closure Type**

| Variable Name | Option 1 Nighttime only | Option 2 Partial | Option 3 Directional | Option 4 Full |
|---|---|---|---|---|
| Work Zone Number of Lanes | 2 (9pm-5am) | 2 (all day) | 2 (all day) | 0 (all day) |
| Traffic Forced to Detour | 0% | 0% | 50% of traffic | 100% of traffic |
| Traffic Choosing to Detour | 0% | 75% of queue demand | 0% | 0% |

Source: NCDOT Bridge Maintenance Division and Project Team, approximations of future lane closure conditions.

The work zone congested speed is used to represent conditions in any hour that is either a peak traffic hour (total of four hours per day) or when the work zone queue is nonzero; otherwise, the free-flow speed is used. The analysis considers the detour for vehicles for peak and off-peak hours in the Work Zone User Impact analysis (performed on an hourly basis), though the difference is relatively small. The detour assumptions in Table 13 represent the daily average miles and minutes on the base and detour routes by vehicle type.

**Table 13: Detour Assumptions, Averaged Across Peak and Off-Peak Periods**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| CFMB Route for Passenger Vehicles | miles per trip | 1.6 | Google maps, Route from US 17 east of CFMB to US 17 west of CFMB, across the CFMB. |
| | minutes per trip | 3.0 | |
| Detour Route for Passenger Vehicles | miles per trip | 4.5 | Google maps, Route from US 17 east of CFMB to US 17 west of CFMB, using 3rd Street and the Isabel Holmes Bridge to cross the river (north of CFMB). |
| | minutes per trip | 9.3 | |
| CFMB Route for Trucks | miles per trip | 4.2 | Google maps, Route from the port to US 17 west of CFMB, across the Cape Fear Memorial Bridge. |
| | minutes per trip | 8.0 | |
| Detour Route for Trucks | miles per trip | 14.9 | Google maps, Route from the port to US 17 west of CFMB, using US 117 to US 74 and the Isabel Holmes Bridge to cross the river. Detour route for trucks avoids downtown Wilmington, per project team. |
| | minutes per trip | 25.8 | |

The Work Zone User Impact analysis results in the following estimated impact on vehicles for one average day of closure, by type of closure. Details of the analysis can be found in the "LaneClosure-Delay" spreadsheet of the model.

**Table 14: Average Increase in VMT and VHT from Lane Closures by Type in 2023**

| Per Day of Closures | VMT | VHT |
|---|---|---|
| Option 1 – Nighttime | 0 | 0 |
| Option 2 – Partial | 46,934 | 24,835 |
| Option 3 – Directional | 152,645 | 5,517 |
| Option 4 – Full | 305,291 | 11,035 |

### ROUTINE MAINTENANCE & REHABILITATIONS ASSUMPTIONS, DATA, AND METHODS

The analysis annualizes the traffic impact of routine maintenance and major rehabilitations using the average frequency per year and average duration of related lane closures. Traffic impacts are approximated from the closure options described above, and how often they would be employed during a maintenance or rehabilitation activity. These assumptions are listed in Table 15.

Routine maintenance is intended to cover regular maintenance and inspection activities. The cost is included in the annual maintenance item (discussed further in the Operation and Maintenance Savings section). Frequency and types of closures expected are based on email correspondence and phone conversations with the NCDOT Project Team and the NCDOT Bridge Maintenance Division.

Major rehabilitations cover large multi-million dollar expenditures that are intended to extend the useful life of bridge components as they are rehabilitated (each major rehabilitation activity touches on a different component of the bridge). Frequency (and average cost) is based on 16 years of data on contracts for significant works on the CFMB and the planned work in 2024. Types of closures expected in the future are based on email correspondence and phone conversations with the NCDOT Project Team and the NCDOT Bridge Maintenance Division.

**Table 15: Lane Closure Assumptions for Routine Maintenance and Major Rehabilitations**

| | Unit | Value | Source |
|---|---|---|---|
| **Routine Maintenance** | | | |
| Frequency | events per year | 18 | HDR Calculation from closures in the past year, plus 8 to 12 daytime inspection-type activities per year. Division Bridge Maintenance Engineer, North Carolina Department of Transportation. Email correspondence, October 26, 2023. |
| Duration | days per event | 1 | |
| **Future Closures Expected** | | | |
| Option 1 – Nighttime | % | 50% | Assumes half the closures are nighttime (no traffic impacts) and half are partial closures (one lane in each direction), per NCDOT Project Team. |
| Option 2 – Partial | % | 50% | |
| Option 3 – Directional | % | 0% | |
| Option 4 – Full | % | 0% | |

| | Unit | Value | Source |
|---|---|---|---|
| **Major Rehabilitations** | | | |
| Frequency | events per year | 0.38 | HDR Calculation from 16 years of data on major rehabilitation contracts.<br>NCDOT Bridge Maintenance Division, email correspondence received November 7, 2023. |
| Duration | days per event | 39 | NCDOT Bridge Maintenance Division: best case, closures last 1 week (5 days), worst case is 3 months (90 days). Duration is an average across the range, assuming that 1 month is most likely (50% weight) |
| **Future Closures Expected** | | | |
| Option 1 – Nighttime | % | 25% | NCDOT Project Team. Partial closures are most often, directional closures are expected to become more frequent as the bridge ages for maintenance work. Full/emergency closure is least likely. |
| Option 2 – Partial | % | 35% | |
| Option 3 – Directional | % | 30% | |
| Option 4 – Full | % | 10% | |

The average traffic impact from an event (routine maintenance or major rehabilitation) is estimated as the average traffic impact (daily VMT & VHT) across the possible closure types, weighted by the distribution of types of closures expected. So, for example, the average daily impact of routine maintenance-related lane closures on traffic is represented as 50% nighttime impacts and 50% partial closure impacts.

The calculated daily impacts are multiplied by the expected days per event and the events per year to generate an annualized average for traffic impacts from closures. Since major rehabilitations occur less than once per year (the average is 2.6 years per major rehabilitation activity), the "events per year" assumption is less than one and can also be interpreted as a 38% chance of needing a major rehabilitation in any given year.

#### ESTIMATED IMPACTS FROM CLOSURES

Again, the analysis uses the same AADT, truck percentage, and traffic growth percentage as utilized in the bridge lift delay estimates (Table 7). Table 16 below presents the resulting annualized VMT and VHT impacts, for passenger vehicles and trucks in 2023, related to routine maintenance and major rehabilitations for the existing bridge. Alternate assumptions for the distribution of types of closures are considered in the sensitivity analysis.

**Table 16: Average Annual Traffic Impacts from Lane Closures Avoided Over 30 Years of Project Operations**

| | VMT | VHT |
|---|---|---|
| **Routine Maintenance** | **940,988** | **497,920** |
| Passenger Vehicles | 812,672 | 430,022 |

| | VMT | VHT |
|---|---|---|
| Truck | 128,317 | 67,898 |
| **Major Rehabilitations** | **3,042,427** | **375,622** |
| Passenger Vehicles | 2,627,550 | 324,400 |
| Truck | 414,876 | 51,221 |

### 4.4 Active Transportation Traffic Demand Estimation

There is currently no pedestrian or cyclist demand along the existing CFMB as there are no facilities that would allow for such a crossing. By introducing pedestrian and cycling facilities over Cape Fear it is expected that there will be a portion of vehicle trips across the existing structure that will choose to shift to an active mode. The new facilities are expected to induce a portion of new trips across the replacement structure in addition to the mode shifted trips.

The 2009 National Household Travel Survey[19] data is used as the basis for estimating modal shift. Walking, biking, transit, and passenger vehicle trips are summarized by ranged trip distance category and aggregated to active transportation trips (walking and biking) and vehicle trips (not including transit trips). The share of active transportation and vehicle trips is then for each ranged distance category. The analysis assumes that the project will create enough mode shifts from vehicles to walk/bike trips to achieve half of the national average share of walk/bike trips. So, the national average percent of walk/bike trips (versus vehicle trips) are halved to inform how much vehicle traffic will shift to active transportation modes after the project is implemented, presented in Table 17.

**Table 17: Mode Shift from Vehicles to Walk/Bike Trips due to New AT Facilities by Ranged Distance Category**

| | 0-1 mi | 1-2 mi | 2-3 mi | 3-5 mi | 5-10 mi | 10+ mi |
|---|---|---|---|---|---|---|
| Percent of existing vehicle trips that will shift modes | 28.2% | 5.8% | 1.2% | 0.6% | 0.3% | 0.1% |

Source: HDR Calculation on NHTS 2009 Survey data.

To calculate the number of vehicle trips that will be mode shifted by ranged distance category, Fall 2022 and Spring 2023 Replica network linkage data was used. Vehicle trips across the CFMB (eastbound and westbound) were aggregated and averaged to a representative daily count that applies to the whole year, then summarized in the same manner as the NHTS data by ranged trip distance category. By applying the mode shift percentages (shown above) to the vehicle trips in each distance category, a count of daily mode-shifted trips is calculated, which is then annualized to obtain an estimate of yearly passenger vehicle trips that are mode shifted in 2023.

[19] 2009 NHTS Survey Data, NHTS Datasets (ornl.gov).

These mode shifted trips are used to estimate the potential for new active transportation trips and a reduction in passenger VMT. Mode-shifted vehicle trips are translated to active transportation person-trips using the average vehicle occupancy assumed for the analysis. Fall 2022 and Spring 2023 Replica network linkage data along Front Street (between Church St and Mears St) was exported and summarized to represent the proportion of mode-shifted active transportation trips that will be walking vs. biking. Front Street was chosen as the proxy for trips across the new structure in the Build scenario for its proximity to the CFMB and its heavy cycling and pedestrian use (relative to other Wilmington links).

The CAGR for VMT calculated from the TDM results is applied to the 2023 walking and biking trips to project active transportation trips through the analysis period. Trip growth is capped at 2050 levels as the TDM result horizon is 2050. In addition to the mode shifted trips, it is expected that the new active transportation facilities will induce additional pedestrian and cycling trips beyond the mode shifted trips. A 10% increase in new walking and new biking trips is applied to the estimated mode-shifted trip counts to approximate these trips.

VMT reduction is calculated by multiplying the annual mode-shifted vehicle trips by the average distance in their corresponding ranged distance category, and summed to estimate the 2023 reduction in VMT. The TDM-based CAGR for VMT was then applied to the 2023 VMT reduction to project VMT reduction through the analysis period with reduction capped at 2050 levels (due to the TDM result horizon). The assumptions used in pedestrian and cycling demand estimation are found in Table 18.

**Table 18: Pedestrian Demand Estimation Assumptions**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Annualization Factor (Active Transportation Trips) | days per year | 365 | HDR Assumption, Use of Fall and Spring Replica Data for Annual Averages |
| Growth in VMT and Pedestrian and Cycling Trips (CAGR) | % | 0.81% | Cape Fear Memorial Bridge Improvements Study, NCDOT Project HB-0039, Capacity Improvement Report. Prepared by HDR for NCDOT. DRAFT November 2023 |
| Average Vehicle Occupancy | persons per vehicle | 1.48 | Analysis of Replica Network Links: Cape Fear Memorial Bridge (East and West) for Fall 2022 & Spring 2023 Thursday & Saturday Vehicle Trips |
| Walking Percent of Active Transportation Trips | % | 53% | Replica Network Linkage Data, Fall 2022 & Spring 2023, Thursday & Saturday along Front St between Church St and Mears St, Wilmington, NC |
| Biking Percent of Active Transportation Trips | % | 47% | |
| Expected Increase in Pedestrian and Cyclist Trips after Project | % | 10% | HDR Assumption, expected conservative for the project. |

The results of the mode shift analysis are summarized in Table 19.

**Table 19: Annual Average Trips Expected to Shifted Modes and VMT Reduced, Over 30 Years of Project Operations**

| | Vehicle Trips Expected to Shift to AT Modes | AT Person-Trips from Mode-Shifted Vehicle Trips | Annual VMT Reduced |
|---|---|---|---|
| Pedestrian Trips | 28,798 | 42,621 | |
| Cyclist Trips | 25,103 | 37,153 | |
| **Total** | **53,902** | **79,774** | **363,362** |

Source: HDR Calculations based on Replica Fall 2022 and Spring 2023 Exports and NHTS 2009 data.

# 5. Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each benefit and provides an overview of the associated methodology, assumptions, and estimates.

## 5.1 Travel Time Savings

The CFMB Replacement Project aims to improve traffic conditions on and around the CFMB. There are three identified sources of travel time savings for passenger vehicles and trucks. The first is roadway improvements from additional lanes and improved ramps, the second a reduction in delays due to the new structure not having the bridge lift component that the current bridge has, and the last elimination of the need for the detour route for when the current structure undergoes major rehabilitations to maintain a state of good repair. All sources of travel time savings will affect trucks and passenger vehicle trips; passenger trips include long-distance intercity trips, personal trips, and business trips.

### BRIDGE AND ROADWAY IMPROVEMENTS METODOLOGY

Vehicle hours traveled between the Build and No-Build scenarios, sourced from the Travel Demand Model, is used as the basis for estimating bridge and roadway improvement travel time savings. The process for estimating VHT linked to the bridge and roadway improvement is described above in the Demand Estimation for Bridge and Roadway Improvements section. Travel time savings are calculated as the difference in VHT from the No-Build scenario to the Build scenario. The results are presented in the “Travel Time Savings” tab under the “Roadway Improvement” header in the BCA model and summarized in Table 20.

**Table 20: Average Annual Vehicle and Passenger Delay Reduction from Roadway Improvements**

| | Vehicle-Hours | Person-Hours |
|---|---|---|
| Passenger Vehicles | 489,511 | 724,476 |
| Trucks | 79,824 | 79,824 |

### BRIDGE LIFT DELAY METHODOLOGY

Additional VHT that accrues from the CFMB lift opening, causing traffic delays, is the basis for estimating bridge lift travel time savings. The process for estimating the additional VHT linked to bridge lift openings is described above in the Traffic Impact Estimation for Bridge Lift Delays section. Travel time savings are calculated as the total additional VHT in the No-Build scenario, as the Build scenario will eliminate the need for a bridge lift, thus eliminating bridge lift delays. The results are presented in the "Travel Time Savings" tab under the "Bridge Lift" header in the BCA model and summarized in Table 21.

**Table 21: Average Annual Vehicle and Passenger Delay Reduction from Bridge Lift Delays**

| | Vehicle-Hours | Person-Hours |
|---|---|---|
| Passenger Vehicles | 26,626 | 39,407 |
| Trucks | 4,204 | 4,204 |

### CLOSURE DELAY AND DETOUR METHODOLOGY

Additional VHT that accrues from the CFMB needing to undergo routine maintenance and major rehabilitations, including lane closures, is the basis for estimating bridge lift travel time savings. The process for estimating VHT linked to lane closures is described above in the Traffic Impact Estimation for Bridge Maintenance and Rehabilitation section. Travel time savings are calculated as the difference between the No-Build VHT, which includes frequent lane closures over the course of analysis, and the Build VHT which eliminates the need for periodic and long-term lane closures within the period of analysis. The results are presented in the "Travel Time Savings" tab under the "Closure Delay & Detour (Periodic and Long-term)" header in the BCA model and summarized in Table 22.

**Table 22: Average Annual Vehicle and Passenger Delay Reduction from Lane Closure Delay and Detours**

| | Vehicle-Hours | Person-Hours |
|---|---|---|
| Passenger Vehicles | 754,422 | 1,116,545 |
| Trucks | 119,119 | 119,119 |

### ASSUMPTIONS

The assumptions used in the estimation of travel time savings from all sources are summarized in Table 23. The weighted average passenger auto value of time used to monetize passenger vehicle travel time savings is comprised of three monetization factors: personal auto trips, business auto trips, and long-distance intercity auto trips. Using Replica data[20] for trips across the CFMB, a

[20] Replica Export, Fall 2022 and Spring 2023 Thursday & Saturday on selected links across the Cape Fear Memorial Bridge, Exported November 3, 2023

percentage of trips that are long-distance intercity are identified. The USDOT recommends a typical distribution of local travel by surface modes of 88.2% for personal trips and 11.8% for business trips. These trip characteristics are combined with the relevant values of time recommended by the USDOT for personal, business, and long-distance intercity trips to calculate a weighted average passenger auto value of time. This weighted average is used in the monetization of all passenger auto travel time savings.

**Table 23: Assumptions used in Travel Time Savings Benefits**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Average Vehicle Occupancy | persons per vehicle | 1.48 | Analysis of Replica Network Links: Cape Fear Memorial Bridge (East and West) for Fall 2022 & Spring 2023 Thursday & Saturday Vehicle Trips |
| Truck Occupancy | persons per vehicle | 1.00 | Assumption for commercial trucks |
| Percent of all passenger auto trips – Personal | percentage | 88.2% | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. January 2023. |
| Percent of all passenger auto trips – Business | percentage | 12.8% | |
| Percent of all auto trips – Long-Distance Intercity Travel | percentage | 20% | Replica Network Linkage Data, Fall 2022, Spring 2023, Cape Fear Memorial Bridge, Wilmington, NC |
| Value of Time for Passenger Vehicle Driver and Passenger, Personal | $ per hour | $17.00 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. January 2023. |
| Value of Time for Passenger Vehicle Driver and Passenger, Business | $ per hour | $31.90 | |
| Value of Time for Passenger Vehicle Driver and Passenger, Long-Distance Intercity Travel | $ per hour | $22.70 | |
| Weighted Average Value of Time for Driver and Passenger, Used in Calculations | $ per hour | $19.55 | HDR Calculation based on Values of Time for Personal, Business, and Long-Distance trips combined with distribution of Personal, Business, and Long-Distance trips. |
| Value of Time for Truck Driver | $ per hour | $32.40 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. January 2023. |

### BENEFIT ESTIMATES

Total travel time savings benefits for the CFMB Replacement Project are valued at $502.4 million for roadway improvements, $27.2 million for lift delay, and $770.5 million for lane closure delays and detours before discounting over the course of the analysis period, or $92.2 million, $5.1 million, and $143.3 million (respectively) when discounted at 7 percent.

**Table 24: Estimates of Travel Time Savings Benefits**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| **Total Roadway Improvement Savings** | **$502,420,088** | **$92,206,520** |
| Passenger Vehicles | $424,830,989 | $78,192,878 |
| Trucks | $77,589,100 | $14,013,642 |
| **Total Lift Delay Savings** | **$27,194,552** | **$5,057,712** |
| Passenger Vehicles | $23,108,118 | $4,297,707 |
| Trucks | $4,086,434 | $760,005 |
| **Total Lane Closure Delay and Detour Savings** | **$770,523,436** | **$143,303,925** |
| Passenger Vehicles | $654,739,463 | $121,770,125 |
| Trucks | $115,783,972 | $21,533,800 |

### 5.2 Safety

The proposed project will provide accident cost savings by implementing safety design features, such as increasing the number of lanes and bringing the highway up to design standards across the CFMB, ramps, and the associated interchange. The safer roadway conditions will result in fewer accidents in the Build scenario. Additionally, by avoiding the need for detours from bridge lane closures, there will be a statistically expected decrease in accidents due to the reduction in VMT.

#### BRIDGE AND ROADWAY IMPROVEMENT ACCIDENT REDUCTION METHODOLOGY

Crash rates are calculated over four project areas: the CFMB, the Front Street on-ramp, the four intersections between Wooster/Dawson and 3$^{rd}$/5$^{th}$ Streets, and the US 17 Mainline west of the CFMB. The analysis also separately considers pedestrian-involved crashes in the project area. The NCDOT Traffic Engineering Accident Analysis System Strip Analysis provides data along the first three areas over a five-year period, from September 2018 through August 2023. Total crashes on each of the areas were used to calculate the per-year crash rates and crash distributions for fatal, Class A, Class B, Class C, and property damage only (PDO) crashes. The number of injuries per crash type (and vehicles involved for all crash types) are averaged over all three areas.

An NCDOT map of fatal and series injury crash locations[21] identifies one fatal vehicle crash (with one fatality) on the US 17 Mainline west of the bridge in 2022, and two pedestrian incidents resulting in severe injuries in the project area in 2022. The first was used as to calculate an annual

[21] Fatal and Serious Injury Crash Locations. New Hanover County, State of North Carolina DOT. https://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=9a25021dbe91427a92f2eca57bd71ee2. Accessed November 13, 2023.

fatal crash rate (assuming one fatality per fatal crash) to include in the analysis. The pedestrian-related crashes were used to create an average pedestrian-involved crash rate with one serious injury per pedestrian-involved crash.

To estimate a reduction in crashes once the replacement bridge structure comes online, crash modification factors (CMFs) are used, largely sourced from the FHWA CMF Clearinghouse. Each of the four areas have different combinations of safety design improvements, thus different CMFs are applied to each area. Table 25 shows the CMFs that are applicable to the project and to which of the four described segments they apply. For the pedestrian-involved crashes, there was not an applicable CMF from the FHWA Clearinghouse for an existing bridge asset with no pedestrian accommodations, so instead the analysis assumes that adding pedestrian facilities that are physically separated from vehicle traffic were none exist currently will reduce the chance of a pedestrian-vehicle collision by 95 percent.

**Table 25: CMFs Applied to Each Project Segment**

| CMF (FHWA CMF Clearinghouse ID) | CMF | CMFs Applicable to Each Project Segment | | | | |
|---|---|---|---|---|---|---|
| | | US 17 from County line to overpass (CFMB) | US 17 on-ramp & Front St | Wooster\| Dawson & 3rd\|5th St Intersections | US 17 Mainline, west of CFMB | Pedestrian Crashes |
| Increase Lane Width (8340) | 0.95 | ✓ | ✓ | | | |
| Increase Inside Shoulder Width (4238) | 0.776 | ✓ | | | ✓ | |
| Increase Outside Shoulder Width (4251) | 0.793 | ✓ | | | | |
| Increase Highway from 4 to 6 Lanes (7924) | 0.85 | ✓ | ✓ | | ✓ | |
| Resurface Pavement (2976) | 0.95 | ✓ | ✓ | ✓ | ✓ | |
| Upgrade to Wet-Reflective Pavement Markings (8101) | 0.887 | ✓ | ✓ | ✓ | ✓ | |
| Convert an Intersection to a Roundabout (10094) | 0.439 | | ✓ | | | |
| Add a Multi-Use Path and Separate Modes of Traffic** | 0.05 | | | | | ✓ |

**Multi-use path that separates pedestrians from traffic is assumed to reduce the risk of pedestrian-related crashes on US 17 over the CFMB by 95 percent.

CMFs for each segment are multiplied together to generate a combined CMFs that is representative of all safety countermeasures for each project area. These are applied to the crash rates in the associated segments (with pedestrian-related crashes in their own category) to calculate the annual crash rates by project area in the Build scenario.

The calculated crash rates for each crash type (which are calculated as an annual average from 2018 to 2023 historical data) are assumed to be representative of 2023 crashes to remain conservative. The estimated annual crash rates across all specified project areas are shown below in Table 26 for the Build and No-Build scenarios.

**Table 26: Crash Rates and Crash Modification Factors (2023), by Project Segment**

| Segment/Project Area | No-Build Crash Rate (crashes per year) | Combined CMF | Build Crash Rate (crashes per year) |
|---|---|---|---|
| US 17 from County line to overpass (CFMB)* | 28.00 | 0.42 | 11.72 |
| US 17 on-ramp & Front St* | 1.20 | 0.30 | 0.36 |
| Wooster/Dawson & 3rd/5th St Intersections* | 69.00 | 0.84 | 58.14 |
| US 17 Mainline, west of CFMB** | 0.20 | 0.56 | 0.11 |
| Pedestrian Crashes** | 0.40 | 0.05 | 0.02 |

* NCDOT, Traffic Engineering Accident Analysis System, Strip Analysis Reports for multiple project segments. Rates and statistics are calculated from report data.
** Fatal and Serious Injury Crash Locations. New Hanover County, State of North Carolina DOT. https://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=9a25021dbe91427a92f2eca57bd71ee2. Accessed November 13, 2023. Visual inspection shows one fatal crash and two pedestrian crashes on US 17 west of the CFMB.

To forecast crashes in each area in the Build and No-Build scenarios, the VMT CAGRs from the Build and No-Build TDM data are used. Crash rate growth is capped at 2050 levels for years after 2050, as this is the horizon of the TDM results, from which the CAGR is based upon. The estimated yearly avoided crashes for each crash type are calculated by taking the difference between the No-Build and Build yearly crashes by crash type.

Based on the estimated avoided yearly crash rates and the fatalities and injuries per fatal and injury crash rates, the number of fatalities and injuries avoided is calculated. The rate of average vehicles involved across all crashes us used to estimate avoided vehicle damages. Fatalities, injuries, and property damage avoided due to the project are monetized in the "Safety" tab under the "Accident Reduction from Road & Bridge Improvements" heading in the BCA model, using the monetization factors defined in the USDOT BCA Guidance, shown in Table 28.

#### DETOUR REDUCTION ACCIDENT REDUCTION METHODOLOGY

Per the Traffic Impact Estimation for Bridge Maintenance and Rehabilitation section, completion of the project is associated with a reduction in VMT along the detour routes taken when bridge lanes are closed. To estimate crash rates along the detour route, the countywide crash rate per 100 million vehicle-miles traveled (MVMT), based on NCDOT 2022 countywide crash facts,[22] is combined with the annual detour VMT. The analysis assumes the countywide crash statistics are

[22] North Carolina 2022 Traffic Crash Facts, North Carolina DMV, 2023. Page 103. https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2022.pdf

representative on average of crashes along the detour route, as reliable detour-specific VMT-based crash data is unavailable. Crash rates are disaggregated by type into fatal, non-fatal injury, and PDO crashes. NCDOT crash facts include fatalities per fatal crash and injuries per non-fatal injury crash in their reported statistics. There are also statistics for the average number of vehicles involved in fatal, non-fatal injury, and PDO crashes. These statistics are presented in Table 27.

**Table 27: Detour Route Crash Statistics**

| Accident Type | Crashes per 100 MVMT | Events per Crash Type | Vehicles Involved per Crash Type |
|---|---|---|---|
| Fatal Crashes | 1.24 | 1.08 fatalities | 1.77 |
| Non-Fatal Injury Crashes | 75.06 | 1.46 injuries | 1.88 |
| PDO Crashes | 333.68 | N/A | 1.75 |

The detour route crash rates are combined with the avoided detour VMT in the No-Build scenario to estimate the number of crash events, persons killed/injured, and vehicles involved due to bridge lane closures. The Build scenario assumes the additional VMT will be eliminated, thus the crashes associated with the detour VMT represent accident reduction in the Build scenario. Detour accident cost savings are calculated under the "Accident Reduction from Detour Reduction (avoiding closures)" heading in the "Safety" tab in the BCA model using reduction the monetized factors defined in the USDOT BCA Guidance-provided monetization factors, shown in Table 28.

### ASSUMPTIONS

The assumptions used in the estimation of safety benefits are summarized in Table 28.

**Table 28: Assumptions Used in the Estimation of Safety Benefits**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Vehicle-Miles Traveled, Compound Annual Growth Rate from 2023 to 2050 | percent | 0.81% | Cape Fear Memorial Bridge Improvements Study, NCDOT Project HB-0039, Capacity Improvement Report. Prepared by NCDOT, prepared by HDR. DRAFT November 2023. |
| Value of Avoided Possible Injury (C) | $ per injury | $78,500 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* January 2023. |
| Value of Avoided Non-Incapacitating (B) | $ per injury | $153,700 | |
| Value of Avoided Incapacitating Injury (A) | $ per injury | $564,300 | |
| Value of Avoided Fatality (K) | $ per fatality | $11,800,000 | |
| Value of Avoided Vehicle Damages | $ per vehicle | $4,800 | |

#### BENEFIT ESTIMATES

Total crash cost savings for the project is valued at $127.3 million before discounting, or $41.0 million when discounting at 7 percent over the analysis period.

**Table 29: Estimates of Safety Benefits**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Accident Cost Savings from Bridge & Roadway Improvements | $90,337,069 | $18,479,249 |
| Accident Cost Savings from Lane Closure Detour Reduction | $50,980,334 | $9,481,453 |

### 5.3 Environmental Sustainability

The CFMB Replacement Project is expected to enable more efficient travel on and around Cape Fear, induce a portion of passenger vehicle trips to mode shift to active transportation trips, eliminate bridge lift delays, and reduce the need for bridge maintenance- and rehabilitation-based lane closures and detours. These factors will reduce vehicle emissions from passenger vehicles and trucks by reducing the miles driven and idling hours after the project opens.

#### CHANGES IN SPEED EMISSIONS SAVINGS METHODOLOGY

The first source of emissions reduction is improvements in average travel speeds through the project area, represented by the TDM data. Passenger vehicle and truck emission rates (in grams-per-mile) are sourced from the EPA MOVES database for 2020, 2030, and 2040, by speed bin, for New Hanover County, North Carolina. Emission rates are interpolated for years between the data years from MOVES, and rates are capped at 2040 levels for years beyond 2040. Emissions in the No-Build and Build scenarios are calculated by combining the emission rates each year with that year’s average speed (VMT divided by VHT) and the yearly vehicle-miles traveled each year in both scenarios. The reductions are the difference in No-Build and Build emissions (shown in Table 30) and are monetized by pollutant according to the USDOT BCA Guidance. The calculations for this benefit are presented in the “Emissions Reduction” tab under the “Emissions Cost Savings from Changes in Speed” heading in the BCA model. Monetized results are shown in Table 34.

**Table 30: Emissions Reduction from Changes in Speed Over 30 Years of Project Operations**

| Emissions | Unit | Passenger Vehicle Emissions Reduced | Truck Emissions Reduced | Total Emissions Reduced (Passenger Vehicles + Trucks) |
|---|---|---|---|---|
| CO2 | metric tons | 66,211.19 | 29,039.39 | 95,250.58 |
| NOX | metric tons | 0.48 | 80.73 | 81.20 |
| PM2.5 | metric tons | 0.26 | 0.38 | 0.64 |
| SO2 | metric tons | 0.34 | 0.10 | 0.44 |

### REDUCED IDLING EMISSIONS SAVINGS METHODOLOGY

The gram-per-mile emission rates from the EPA MOVES database (described above) are also utilized for the second source of emissions reduction: reduced idling time from avoiding bridge lifts. Since the reduction in emissions calculated will be from a reduction in passenger auto and truck idling, the analysis assumes an average idling-equivalent speed of 2.5mph. Using the average idling speed, the yearly vehicle-hours spent idling in the No-Build scenario during bridge lifts, and the gram-per-mile emission rates for 2.5mph, the yearly idling emissions avoided is calculated. Avoided idling emissions (shown in Table 31) are monetized according to the USDOT BCA Guidance. The calculations for this benefit are presented in the "Emissions Reduction" tab under the "Emissions Cost Savings from Bridge Lift Reduced Idling" heading in the BCA model. Monetized results are shown in Table 34.

**Table 31: Emissions Reduction from Reduced Idling Over 30 Years of Project Operations**

| Emissions | Unit | Passenger Vehicle Emissions Reduced | Truck Emissions Reduced | Total Idling Emissions Reduced (Passenger Vehicles + Trucks) |
|---|---|---|---|---|
| CO2 | metric tons | 2,892.42 | 1,277.53 | 4,169.95 |
| NOX | metric tons | 0.03 | 2.60 | 2.63 |
| PM2.5 | metric tons | 0.01 | 0.01 | 0.02 |
| SO2 | metric tons | 0.01 | 0.00 | 0.02 |

### AVOIDED LANE CLOSURES EMISSIONS SAVINGS METHODOLOGY

The third source of emissions reduction is avoided detour VMT related to bridge lane closures in the No-Build scenario. The gram-per-mile emission rates from the EPA MOVES database (described above) are again utilized. Since the reduction in emissions is related to the detour route, the analysis assumes the average detour speed according to the detour mile and hour assumptions for the passenger car detour and the truck detour (shown in Table 13). Using the average speed by vehicle type, the yearly detour VMT in the No-Build scenario, and the corresponding gram-per-mile emission rates, the yearly emissions avoided from detours is calculated. Avoided detour emissions (shown in Table 32) are monetized according to the USDOT BCA Guidance. The calculations for this benefit are presented in the "Emissions Reduction" tab under the "Emissions Cost Savings, Detours from Lane Closures" heading in the BCA model. Monetized results are presented in Table 34.

**Table 32: Emissions Reduction from Avoided Lane Closures Over 30 Years of Project Operations**

| Emissions | Unit | Passenger Vehicle Emissions Reduced | Truck Emissions Reduced | Total Detour Emissions Reduced (Passenger Vehicles + Trucks) |
|---|---|---|---|---|
| CO2 | metric tons | 29,752.01 | 18,687.13 | 48,439.13 |

| Emissions | Unit | Passenger Vehicle Emissions Reduced | Truck Emissions Reduced | Total Detour Emissions Reduced (Passenger Vehicles + Trucks) |
|---|---|---|---|---|
| NOX | metric tons | 1.01 | 18.64 | 19.65 |
| PM2.5 | metric tons | 0.13 | 0.12 | 0.25 |
| SO2 | metric tons | 0.15 | 0.06 | 0.22 |

#### MODE SHIFT EMISSIONS SAVINGS METHODOLOGY

The fourth and final source of emissions reduction are mode shifts from passenger vehicle trips to walking and biking trips. The reduction of vehicle-miles is described in the Demand Estimation Active Transportation Traffic section. The applicable average speed by year is the same as the calculated speeds in the Build scenario TDM results, used above in calculating emissions reduction from speed improvements. The vehicle-miles reduced in the Build scenario is used with the yearly speed and the corresponding gram-per-mile emission rates to calculate the emissions avoided, presented in Table 33. Emission rates are monetized according to the USDOT BCA Guidance, calculations are presented in the "Emissions Reduction" tab under the "Emissions Cost Savings from Mode Shift" heading. Monetized results are presented in Table 34.

**Table 33: Emissions Reduction from Mode Shift Over 30 Years of Project Operations**

| Emissions | Unit | Passenger Vehicle Emissions Reduced |
|---|---|---|
| CO2 | metric tons | 2,872.71 |
| NOX | metric tons | 0.11 |
| PM2.5 | metric tons | 0.01 |
| SO2 | metric tons | 0.01 |

#### ASSUMPTIONS

Assumptions used in the estimation of environmental sustainability benefits are found in the "Emissions" tab in the BCA model. Note that both vehicle emission rates and monetization factors change over time, and that vehicle emission rates also vary by vehicle speed. Emission rates utilized correspond with the average speed per year calculated from the No-Build and Build scenario VMT and VHT, aside from idling which assumes an average speed of 2.5mph.

#### BENEFIT ESTIMATES

The total societal benefit of emissions reduction is $15.3 million, or $6.2 million when discounted (3 percent for $CO_2$, 7 percent for $NO_X$, $PM_{2.5}$, and $SO_2$) over the analysis period.

**Table 34: Estimates of Environmental Sustainability Benefits by Improvement**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted Value |
|---|---|---|
| $CO_2$ | $12,509,343 | $5,610,919 |
| $NO_X$ | $1,958,061 | $420,100 |
| PM2.5 | $842,426 | $186,849 |
| $SO_2$ | $35,386 | $6,445 |
| **Total Benefits** | **$15,345,215** | **$6,224,313** |

## 5.4 Vehicle Operating Cost Savings

Vehicle operating cost savings capture fuel cost savings and non-fuel cost savings (tire wear and tear, maintenance costs, depreciation, etc.) for passenger and commercial vehicles. Based on avoided detour-related VMT from periodic lane-closures in the No-Build scenario and passenger vehicle mode-shifted VMT in the Build, vehicle-mile-based benefits can be monetized for the project.

#### LANE CLOSURE DETOUR VOC SAVINGS METHODOLOGY

A reduction in VMT is calculated from avoided detours due to periodic lane closures (see the Traffic Impact Estimation for Bridge Maintenance and Rehabilitation section). The detour vehicle-miles in the No-Build scenario are assumed to be eliminated in the Build scenario. The detour-based VMT is monetized using the 2021 dollar-per-mile cost for vehicle operating costs, following the USDOT BCA Guidance for passenger vehicles and trucks. The sum of these values for passenger and commercial vehicles represents the vehicle operating cost savings from avoiding lane closure detours.

#### MODE SHIFT VOC SAVINGS METHODOLOGY

A reduction in VMT is calculated from passenger vehicle trips mode shifting to active transportation trips as a result of improved pedestrian facilities (see the Demand Estimation Active Transportation Traffic section). The mode shifted vehicle-miles in the Build scenario are monetized using the 2021 dollar-per-mile cost for vehicle operating costs, following the USDOT BCA Guidance for passenger vehicle miles. The sum of these values represents the vehicle operating cost savings from passenger vehicle trips shifting to active transportation trips.

#### ASSUMPTIONS

The assumptions used to estimate vehicle operating costs are summarized in Table 35.

**Table 35: Assumptions Used in the Estimation of Vehicle Operating Cost Savings**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Vehicle Operating Costs: Light Duty Vehicles | $ per vehicle mile | $0.46 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* January 2023. |
| Vehicle Operating Costs: Commercial Trucks | $ per vehicle mile | $1.01 | |

#### BENEFIT ESTIMATES

The vehicle operating cost savings resulting from the project is monetized to $63.9 million in 2021 constant dollars for avoided detours resulting from lane closures and $5.0 million for reduced vehicle trips due to mode-shift. Discounting at 7 percent over the analysis period gives savings of $11.9 million for lane closure related benefits, and $1.0 million for modal shift benefits.

**Table 36: Estimates of Vehicle Operating Cost Savings Benefits**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Lane Closure Vehicle Operating Cost Savings | $63,933,808 | $11,890,574 |
| Mode Shift Vehicle Operating Cost Savings | $5,014,398 | $1,025,740 |

### 5.5 Journey Quality Benefits

The proposed CFMB Replacement Project will add a pedestrian and cycling connection across the CFMB where none existed before. This will allow for new walking and biking trips across Cape Fear between the Wilmington downtown and the west side of Cape Fear. Pedestrian and cycling trips over the new active transportation facilities, estimated in Section 4.4, are used to quantify and monetize journey quality benefits.

#### METHODOLOGY

Journey quality benefits for pedestrians from the new multi-use path across the proposed bridge structure is estimated using the USDOT-provided monetization factors for additional feet of sidewalk width on a per-person-mile basis. The project proposes a 15-foot-wide multi-use path for pedestrians, and the entire width is used as additional feet of sidewalk because there is no sidewalk on the current structure. Additionally, cyclists can also use the multi-use path, so their journey quality benefits are estimated using the USDOT-provided monetization factor for a dedicated cycling lane on a per-cycling-mile basis.

All pedestrian and cycling trips are assumed to be "new" trips due to the lack of active transportation facilities along the current bridge structure (they are either completely new trips that wouldn't occur otherwise, or trips that have shifted modes from passenger vehicle trips). Thus, each active transportation trip benefit, both walking and biking, are monetized according to the "Rule of Half" per the USDOT BCA Guidance for induced trips. Benefits begin to accrue in 2032 upon completion of project construction.

#### ASSUMPTIONS

The assumptions used in the estimation of journey quality benefits are summarized in Table 37.

**Table 37: Assumptions Used in the Estimation of Journey Quality Benefits**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| New Pedestrian Sidewalk Expansion | feet | 15 | North Carolina DOT Project Team |
| Multi-Use Path Length | miles | 1.20 | Google Earth Measurement of Proposed Multi-Use Path Length |
| Additional Sidewalk Width Monetization Factor | $ per person-mile per foot of added width | $0.11 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* January 2023. |
| Dedicated Cycling Lane Monetization Factor | $ per cycling-mile | $1.77 | |

#### BENEFIT ESTIMATES

The project is expected to yield $2.7 million in benefits through improved pedestrian conditions along the replacement bridge on an undiscounted basis over the analysis period, or $0.6 million when discounted using a 7 percent real discount rate.

**Table 38: Estimates of Journey Quality Benefits**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Pedestrian Journey Quality Benefits | $1,392,439 | $284,836 |
| Cyclist Journey Quality Benefits | $1,302,069 | $266,350 |
| **Total Benefits** | **$2,694,508** | **$551,186** |

### 5.6 Health Benefits

The new pedestrian and cycling facility will enable and enhance active transportation mobility. The increased participation in an active form of transportation will result in health benefits (mortality reduction) for certain users of the project.

#### METHODOLOGY

The analysis estimates the proportion of applicable active transportation trips (in the appropriate age range[23]) using age data from the Fall 2022 and Spring 2023 Replica data export for Front Street near the project area. Health benefits are monetized for these walking and biking trips using the dollar values for mortality reduction benefits per induced cycling and pedestrian trip recommended by the USDOT's BCA Guidance.

#### ASSUMPTIONS

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

**Table 39: Assumptions Used in the Estimation of Health Benefits**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| Cycling Value per Induced Trip | $ per cycling trip | $6.42 | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* January 2023. |
| Walking Value per Induced Trip | $ per pedestrian trip | $7.20 | |
| Portion of Cyclists Aged 20-64 | percent | 77% | HDR Calculation on Replica Export for Front Street, Fall 2022 and Spring 2023 Thursday & Saturday, Exported November 3, 2023. |
| Portion of Pedestrians Aged 20-74 | percent | 88% | |

#### BENEFIT ESTIMATES

Health benefits from mode-shifted trips contributes $15.0 million in benefits in 2021 constant dollars, and $3.1 million when discounted at 7 percent, by the end of the analysis period.

**Table 40: Estimate of Health Benefits**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Pedestrian Health Benefits | $8,957,213 | $1,832,277 |
| Cyclist Health Benefits | $6,074,390 | $1,242,570 |
| **Total Benefits** | **$15,031,602** | **$3,074,848** |

### 5.7 Operation and Maintenance Savings

By building the new structures and improving the existing roadways, the costs to maintain the assets will change from the No-Build scenario to the Build scenario. Specifically, once the project is complete NCDOT will see decreased annual routine maintenance costs, bridge inspection costs, and major rehabilitation costs.

[23] USDOT BCA Guidance states health benefits are accrued to new walking trip users between ages 20 and 74 and new biking trip users accrue benefits between ages 20 and 64.

### METHODOLOGY

There are three cost categories that relate to the operation and maintenance of the current CFMB structure, and four identified cost categories that relate to the proposed structure. The existing structure sees annual routine maintenance costs, bridge inspection costs, and major rehabilitation costs. The routine maintenance and inspection costs occur every year and every other year (respectively) and are expected to continue through the entirety of the analysis period in the No-Build scenario. Due to the age and state of the current structure, major rehabilitation costs are incurred infrequently to keep the structure in a state of good repair. Based on 16 years of historical data on major rehabilitation contracts from the NCDOT Bridge Maintenance Division, the probability of a major rehabilitation occurring in any given year and the average cost of a rehabilitation activity are calculated. The product of this probability and average cost creates an annualized cost for major rehabilitations, as the exact year and exact cost of such activities are uncertain.

The replacement bridge structure is projected to have an annual routine maintenance[24] and routine inspection[25] costs (occurring, respectively, every year and every other year), similar to the current structure's routine maintenance and inspection. Additionally, the replacement bridge will have an underwater bridge inspection cost that occurs once every four years after project completion. The final cost category is a "less robust" maintenance cost that will occur once after 20 years of operations.[26]

The No-Build scenario will have the current structure's associated operations and maintenance costs accrue through the entirety of the analysis period. The Build scenario will have the same maintenance costs as the No-Build scenario until completion of the project to keep the bridge in working order through the construction period. Upon completion of the replacement bridge, the new set of operations and maintenance costs will take effect, with no further operations and maintenance costs assumed to be spent on the older structure. Operation and maintenance savings are calculated to be the difference between the No-Build and Build costs.

### ASSUMPTIONS

The assumptions used to estimate operation and maintenance cost savings are summarized in Table 41. For several cost factors, the original dollar values provided by the project team were translated to 2021 dollars for this analysis.

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[24] Annual routine maintenance for new structure is estimated from the Cape Fear River Bridge, upstream from the proposed Cape Fear Memorial Bridge replacement (NCDOT Project Team).
[25] Inspection costs (and underwater inspection costs) for the first 30 years of the replacement bridge operations is sourced from the 2019 NCDOT Transportation Asset Management Plan.
[26] "Less robust" maintenance cost is estimated from NCDOT historic cyclical maintenance costs of two comparable bridges in the area (NCDOT Project Team)

**Table 41: Assumptions Used in the Estimation of Operating and Maintenance Savings**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| **Current Bridge Structure (No-Build & Build)** | | | |
| Routine Maintenance Cost (Frequency) | 2021 $ (every x years) | $513,822 (1) | NCDOT Project Team |
| Bridge Inspection Cost (Frequency) | 2021 $ (every x years) | $280,267 (2) | 2019 NCDOT Transportation Asset Management Plan |
| Major Rehabilitation Average Cost | 2021 $ | $8,640,000 | |
| Major Rehabilitation Probability of Occurrence | percent per year | 38% | Calculation from past major rehabilitation projects for the CFM Bridge, based on data from NCDOT Bridge Maintenance Division, email correspondence received November 7, 2023. |
| **Replacement Bridge Structure (Build)** | | | |
| Routine Maintenance Cost (0-30 years) (Frequency) | 2021 $ (every x years) | $49,989 (1) | NCDOT, Cape Fear Memorial Bridge Life-Cycle Cost Analysis: Detailed. (Wilmington, North Carolina: Prepared by HDR on behalf of NCDOT, 21/6/2022), p.2, Table 1: Bridge Life-Cycle Maintenance Items |
| Bridge Inspection Cost (Frequency) | 2021 $ (every x years) | $254,057 (2) | |
| Underwater Bridge Inspection Cost (Frequency) | 2021 $ (every x years) | $37,369 (4) | |
| "Less Robust" Maintenance (occurs after 20 years) | 2021 $ | $8,747,722 | |

### BENEFIT ESTIMATES

Operation and maintenance cost savings of the project is estimated to save $139.1 million in benefits in 2021 constant dollars. Discounted at 7 percent, operation and maintenance cost savings contribute $46.5 million in benefits at the end of the analysis period.

**Table 42: Estimates of Operation and Maintenance Cost Savings**

| Over 30-year Period of Analysis | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Annual Routine Maintenance | $18,539,388 | $6,054,582 |
| Bridge Inspection | $1,514,211 | $895,247 |
| Underwater Bridge Inspection | ($261,582) | ($51,929) |
| Major Rehabilitation/"Less Robust" Maintenance | $119,297,078 | $39,553,092 |
| **Total Savings** | **$139,089,095** | **$46,450,992** |

## 5.8 Residual Value

The CFMB Replacement Project will rebuild the bridge and approaches that will have remaining value at the end of the analysis horizon. The value is based on the service life of the relevant project components. These components include surfacing, the bridge, retaining walls, the earthwork completed, the drainage/utility assets, and right-of-way costs expended. Each of these assets have a separate useful life, and as such have different rates of depreciation.

#### METHODOLOGY

The straight-line (linear) depreciation rates are calculated by taking the inverse of the useful life of each asset. Surfacing has a useful life of 30 years and will have no value at the end of the 30-year analysis period. The bridge structure has a useful life of 75 years and will have 60% of its initial asset value remaining at the end of the analysis period. The retaining walls, earthwork, and drainage/utility assets each have a useful life of 50 years. The straight-line depreciation rate indicates that 40% of the initial value of each of these assets will remain at the end of the analysis. The right-of-way expenditures are assumed to hold their value forever as land ownership doesn't depreciate (and will often appreciate). As such, 100% of the initial right-of-way value is expected to exist at the end of the analysis.

The sum of these values is defined as the residual value and counted among the benefits in the final year of the analysis.

#### ASSUMPTIONS

The assumptions used in the estimation of residual value are summarized in the table below.

**Table 43: Assumptions Used in the Estimation of Residual Value**

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| **Useful Life of Project Components** | | | |
| Bridge and Structures | years | 75 | NCDOT Project Team |
| Retaining Walls, Earthwork, and Drainage/Utility | years | 50 | NCDOT Project Team |
| Surfacing and Pavement | years | 30 | NCDOT Project Team |
| Right of Way | years | Infinite | NCDOT Project Team |
| **Annual Stright-Line Depreciation Rates** | | | |
| Bridge and Structures | % | 1.3% | USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. January 2023. |
| Retaining Walls, Earthwork, and Drainage/Utility | % | 2.0% | |
| Surfacing and Pavement | % | 3.3% | |
| Right of Way | % | 0% | |

| Variable Name | Unit | Value | Source |
|---|---|---|---|
| **Value of Assets** | | | |
| Bridge | 2023 $ | $296,648,241 | Bridge construction portion of cost estimate |
| Retaining Walls | 2023 $ | $0 | Retaining walls portion of cost estimate |
| Earthwork | 2023 $ | $3,268,405 | Earthwork portion of cost estimate |
| Drainage/Utility | 2023 $ | $9,556,687 | Drainage/Utility portion of cost estimate |
| Surfacing | 2023 $ | $7,098,274 | Surfacing portion of cost estimate |
| Right of Way | 2023 $ | $41,800,000 | Right-of-way portion of cost estimate |

#### BENEFIT ESTIMATES

The residual value of key project components contributes $219.7 million in benefits in 2021 constant dollars. Discounted at 7 percent, the Residual Value contributes $14.7 million in benefits at the end of the 30-year analysis period.

**Table 44: Estimate of Asset Residual Value**

| | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Residual Value of Asset | $219,723,754 | $14,673,236 |

## 6. Summary of Findings and BCA Outcomes

Annual costs and benefits are computed over the entire period of analysis (39 years). As stated previously, construction is expected to be completed in 2031, with the first full year of operations in 2032. Benefits accrue from the difference in traffic operations (VMT and VHT), crashes, active transportation journey quality and health, operation and maintenance costs, and the residual asset value of the proposed project. These benefits are broken down in Table 45. Considering all monetized benefits and costs, the estimated internal rate of return of the full project is 8.5%. With a 7 percent real discount rate,[27] $264.1 million capital investment would result in $328.5 million in total net benefits. This yields a benefit/cost ratio of approximately 1.2 and a net present value of $64.4 million.

**Table 45: Summary of BCA Benefits, millions of 2021 dollars**

| | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Travel Time Savings | $1,300.1 | $240.6 |
| Safety Benefits | $141.3 | $28.0 |
| Vehicle Operating Cost Savings | $68.9 | $12.9 |

[27] $CO_2$ discounted at 3 percent.

| | Monetized In Constant Dollars | Discounted at 7 Percent |
|---|---|---|
| Emissions Reduction Savings | $15.3 | $6.2 |
| Journey Quality Benefits | $2.7 | $0.6 |
| Health Benefits | $15.0 | $3.1 |
| Operation & Maintenance Cost Savings | $103.8 | $22.6 |
| Residual Value | $219.7 | $14.7 |
| **Total Benefits** | **$1,867.0** | **$328.5** |

It should be noted that the quantified benefits enumerated in this BCA do not consider all of the benefits created by the project, since some of them are difficult to quantify due to a lack of data or robust monetization methods, and some were not monetized to be conservative.

# 7. 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 uncertainty. Most of the uncertainty tests performed produced a positive NPV, indicating that though some inputs are uncertain, the analysis is fairly robust, and it is likely that project benefits will exceed costs.

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" input values are significantly altered by reasonable departures from those values.

Among the key assumptions tested are the traffic volume, growth, peak period length, and various assumptions that inform traffic impacts from maintenance and rehabilitation activities.

Some key outcomes of the quantitative sensitivity analysis for the project using a 7 percent discount rate, and 3 percent rate for $CO_2$ (unless stated otherwise) are summarized below.

- Discounting all benefits at a 3 percent discount rate gives a BCR of 2.4;

- Using truck percentage, AADT, and annual growth factors from the NCDOT Traffic Forecast[28] for the project in lieu of NBI data gives a BCR of 0.9;
- Increasing and decreasing the number of peak hours per day to minimum and maximum reasonable values gives BCRs of 1.3 and 1.1, respectively;
- Using shorter durations and less impactful lane closures[29] for routine maintenance activities gives a BCR of 0.9;
- Using longer durations and more impactful lane closures[30] for routine maintenance activities gives a BCR of 1.8;
- Using shorter durations and less impactful lane closures[31] for major rehabilitation activities gives a BCR of 1.1;
- Assuming half as many major rehabilitations are required also gives a BCR of 1.1;
- Using longer durations and more impactful lane closures[32] when major rehabilitation activities gives a BCR of 1.4;
- A 25 percent range in the project capital costs lead to a BCR range of 0.995 to 1.7;
- Using USDOT recommended lower and upper bounds for the Value of Time lead to a BCR range of 1.1 to 1.4; and
- Using a 20-year analysis period after project completion gives a BCR of 1.1.

All inputs that were subject to the quantitative sensitivity test and their respective outcomes are shown in Table 46.

[28] Traffic Forecast - Cape Fear Memorial Bridge Replacement (NCDOT Project HB-0039) Report. Prepared for NCDOT Transportation Planning Division, prepared by Clearbox Forecast Group. September 2023.
[29] Decreases lane closure times by 50% and assumes closures will occur more during the nighttime to avoid traffic impacts.
[30] Increases lane closure times by 50% and assumes closures will occur more during the daytime, which will increase the traffic impacts of closures.
[31] Decreases lane closure times by assuming quick fixes are more common and assumes closures will occur more during the nighttime to avoid traffic impacts.
[32] Decreases lane closure times by assuming longer maintenance times are more common and assumes closures will occur more during the daytime, increasing traffic impacts.

**Table 46: Quantitative Assessment of Sensitivity, Summary**

| Parameters | Change in Parameter Value | New NPV ($ M) | Change in NPV | New B/C Ratio |
|---|---|---|---|---|
| **Base Results** | **N/A** | $64.4 | $0.0 | 1.2 |
| Discount Rate | Discount Rate of 3% for all benefits | $478.3 | $413.9 | 2.4 |
| Traffic Inputs | Use NCDOT Traffic Forecast in lieu of NBI Data for truck percentage, AADT, and AADT annual growth | ($31.7) | ($96.1) | 0.9 |
| Peak Hours | Decrease peak hours per day | $36.7 | ($27.7) | 1.1 |
| | Increase peak hours per day | $85.0 | $20.6 | 1.3 |
| AVO & Travel Patterns | National average AVO with no long-distance trips (in lieu of Replica-informed assumptions) | $81.8 | $17.4 | 1.3 |
| Routine Maintenance | Shorter duration and less impactful lane closures | ($14.1) | ($78.5) | 0.9 |
| | Longer duration and more impactful lane closures | $212.6 | $148.2 | 1.8 |
| Major Rehab Closure Impacts | Shorter duration and less impactful lane closures | $17.3 | ($47.1) | 1.1 |
| | Longer duration and more impactful lane closures | $96.9 | $32.5 | 1.4 |
| | Half as many major rehabilitations required in future | $14.3 | ($50.1) | 1.1 |
| Bridge Lift Frequency | No future increase in frequency | $62.7 | ($1.7) | 1.2 |
| Capital Cost Estimate | 25% Reduction | $130.4 | $66.0 | 1.7 |
| | 25% Increase | ($1.6) | ($66.0) | 0.995 |
| Value of Time | Lower Bound of Range Recommended by US DOT | $19.5 | ($44.9) | 1.1 |
| | Upper Bound of Range Recommended by US DOT | $96.7 | $32.3 | 1.4 |
| Value of Statistical Life | Lower Bound of Range Recommended by US DOT | $59.9 | ($4.5) | 1.2 |
| | Upper Bound of Range Recommended by US DOT | $68.9 | $4.5 | 1.3 |
| Analysis Period | 20-year analysis period | $21.4 | ($43.0) | 1.1 |

# 8. Annual BCA Results

Table 47 below presents discounted BCA costs and benefits, as well as net present value, presented on an annual basis for the period from 2023 through 2061.

**Table 47: Annual Monetized Estimates of Total Project Benefits and Costs, 2021 dollars (Discounted)**

| Calendar Year | Proj. Year | Travel Time Delay Reduction | Safety Improvements | Vehicle Operating Cost Savings | Emissions Reduction | Journey Quality Improvements | Health Benefits | Operation & Maintenance Cost Savings | Residual Value | Total Benefits | Total Costs | Net Present Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023 | 1 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $328,944 | ($328,944) |
| 2024 | 2 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $614,849 | ($614,849) |
| 2025 | 3 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $574,625 | ($574,625) |
| 2026 | 4 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $22,897,833 | ($22,897,833) |
| 2027 | 5 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $51,397,600 | ($51,397,600) |
| 2028 | 6 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $59,202,670 | ($59,202,670) |
| 2029 | 7 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $50,571,997 | ($50,571,997) |
| 2030 | 8 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $47,263,549 | ($47,263,549) |
| 2031 | 9 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $31,288,175 | ($31,288,175) |
| 2032 | 10 | $12,904,915 | $1,797,853 | $703,003 | $193,004 | $38,614 | $215,412 | $1,913,341 | $0 | $17,766,142 | $0 | $17,766,142 |
| 2033 | 11 | $12,482,325 | $1,707,461 | $679,469 | $239,162 | $36,379 | $202,942 | $1,550,923 | $0 | $16,898,660 | $0 | $16,898,660 |
| 2034 | 12 | $12,073,658 | $1,621,882 | $656,771 | $213,226 | $34,273 | $191,193 | $1,671,186 | $0 | $16,462,189 | $0 | $16,462,189 |
| 2035 | 13 | $11,678,453 | $1,540,849 | $634,876 | $206,209 | $32,289 | $180,125 | $1,340,144 | $0 | $15,612,945 | $0 | $15,612,945 |
| 2036 | 14 | $11,296,263 | $1,464,113 | $613,754 | $201,975 | $30,419 | $169,698 | $1,459,679 | $0 | $15,235,901 | $0 | $15,235,901 |
| 2037 | 15 | $10,926,657 | $1,391,437 | $593,375 | $195,884 | $28,658 | $159,874 | $1,183,192 | $0 | $14,479,076 | $0 | $14,479,076 |
| 2038 | 16 | $10,569,218 | $1,322,597 | $573,710 | $190,226 | $26,999 | $150,619 | $1,274,940 | $0 | $14,108,309 | $0 | $14,108,309 |
| 2039 | 17 | $10,223,544 | $1,257,382 | $554,733 | $184,969 | $25,436 | $141,899 | $1,022,389 | $0 | $13,410,354 | $0 | $13,410,354 |
| 2040 | 18 | $9,889,244 | $1,195,595 | $536,417 | $164,342 | $23,964 | $133,685 | $1,113,582 | $0 | $13,056,829 | $0 | $13,056,829 |
| 2041 | 19 | $9,565,942 | $1,137,046 | $518,739 | $237,371 | $22,577 | $125,946 | $902,651 | $0 | $12,510,273 | $0 | $12,510,273 |
| 2042 | 20 | $9,253,275 | $1,081,560 | $501,673 | $236,187 | $21,270 | $118,655 | $972,646 | $0 | $12,185,264 | $0 | $12,185,264 |
| 2043 | 21 | $8,950,889 | $1,028,968 | $485,197 | $235,068 | $20,038 | $111,786 | $779,976 | $0 | $11,611,922 | $0 | $11,611,922 |
| 2044 | 22 | $8,658,444 | $979,114 | $469,289 | $234,014 | $18,878 | $105,315 | $849,546 | $0 | $11,314,600 | $0 | $11,314,600 |
| 2045 | 23 | $8,375,613 | $931,847 | $453,928 | $185,718 | $17,785 | $99,218 | $688,628 | $0 | $10,752,738 | $0 | $10,752,738 |
| 2046 | 24 | $8,102,076 | $887,028 | $439,094 | $187,598 | $16,756 | $93,474 | $742,027 | $0 | $10,468,053 | $0 | $10,468,053 |
| 2047 | 25 | $7,837,528 | $844,523 | $424,768 | $187,405 | $15,786 | $88,063 | $595,040 | $0 | $9,993,112 | $0 | $9,993,112 |
| 2048 | 26 | $7,581,669 | $804,207 | $410,930 | $187,253 | $14,872 | $82,965 | $648,115 | $0 | $9,730,011 | $0 | $9,730,011 |
| 2049 | 27 | $7,334,214 | $765,962 | $397,564 | $187,141 | $14,011 | $78,162 | $525,351 | $0 | $9,302,404 | $0 | $9,302,404 |
| 2050 | 28 | $7,094,884 | $729,676 | $384,651 | $187,068 | $13,200 | $73,637 | $566,089 | $0 | $9,049,204 | $0 | $9,049,204 |

| Calendar Year | Proj. Year | Travel Time Delay Reduction | Safety Improvements | Vehicle Operating Cost Savings | Emissions Reduction | Journey Quality Improvements | Health Benefits | Operation & Maintenance Cost Savings | Residual Value | Total Benefits | Total Costs | Net Present Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2051 | 29 | $6,707,398 | $681,940 | $359,487 | $277,309 | $12,336 | $68,820 | ($695,210) | $0 | $7,412,081 | $0 | $7,412,081 |
| 2052 | 30 | $6,342,506 | $637,327 | $335,969 | $234,720 | $11,529 | $64,318 | $494,444 | $0 | $8,120,812 | $0 | $8,120,812 |
| 2053 | 31 | $5,998,827 | $595,633 | $313,990 | $228,632 | $10,775 | $60,110 | $400,788 | $0 | $7,608,755 | $0 | $7,608,755 |
| 2054 | 32 | $5,675,070 | $556,666 | $293,448 | $222,720 | $10,070 | $56,178 | $431,866 | $0 | $7,246,019 | $0 | $7,246,019 |
| 2055 | 33 | $5,354,265 | $520,249 | $274,251 | $216,978 | $9,411 | $52,502 | $346,319 | $0 | $6,773,976 | $0 | $6,773,976 |
| 2056 | 34 | $5,013,579 | $486,214 | $256,309 | $211,401 | $8,796 | $49,068 | $377,209 | $0 | $6,402,576 | $0 | $6,402,576 |
| 2057 | 35 | $4,694,836 | $454,405 | $239,541 | $205,983 | $8,220 | $45,858 | $305,759 | $0 | $5,954,603 | $0 | $5,954,603 |
| 2058 | 36 | $4,396,613 | $424,678 | $223,870 | $200,719 | $7,682 | $42,858 | $329,469 | $0 | $5,625,888 | $0 | $5,625,888 |
| 2059 | 37 | $4,117,579 | $396,895 | $209,225 | $195,603 | $7,180 | $40,054 | $264,205 | $0 | $5,230,740 | $0 | $5,230,740 |
| 2060 | 38 | $3,856,490 | $370,930 | $195,537 | $190,631 | $6,710 | $37,433 | $287,771 | $0 | $4,945,502 | $0 | $4,945,502 |
| 2061 | 39 | $3,612,184 | $346,664 | $182,745 | $185,797 | $6,271 | $34,985 | $233,262 | $14,673,236 | $19,275,144 | $0 | $19,275,144 |
| **Total** | | **$240,568,158** | **$27,960,702** | **$12,916,313** | **$6,224,313** | **$551,186** | **$3,074,848** | **$22,575,326** | **$14,673,236** | **$328,544,082** | **$264,140,245** | **$64,403,837** |