Memorandum

To: Steve Gramm, P.E, Planning Engineer
South Dakota Department of Transportation

From: Nick Semeja, PE, Associate
Matt Flanagan, Engineer

Date: March 18, 2021

Subject: I-90 Reconstruction Project – 2021 INFRA Program Application Benefit-Cost Analysis Memorandum

Introduction

This memorandum summarizes the assumptions, methodology and results developed for the benefit-cost analysis of the No Build and Build Alternatives evaluated as part of the I-90 Reconstruction Project – 2021 INFRA Grant Program Application. The objective of a benefit-cost analysis (BCA) is to bring all the direct effects of a transportation investment into a common measure (dollars), and to account for the fact that benefits accrue over an extended period while costs are incurred primarily in the initial years. The primary elements that can be monetized are travel time, changes in vehicle operating costs, vehicle crashes, environmental impacts, capital costs and remaining capital value, and maintenance costs. The benefit-cost analysis can provide an indication of the economic desirability of an alternative, but decision-makers must weigh the results against other considerations, effects, and impacts of the project.

I-90 is the longest interstate in the United States, spanning 3,020 miles and in South Dakota, is the most highly traveled and freight critical corridor. Trucks account for 21-23 percent of the existing traffic volumes, and future traffic volumes are anticipated to rise by 37.7 percent by year 2037. I-90 connects the two key metropolitan areas of Rapid City (population 76,000) and Sioux Falls (178,000), which are the two largest taxable sales economies in the state.

The proposed project will reconstruct approximately 28 miles of I-90, through an area where the roadway surface has reached the end of its useful life, rebuild nine functionally obsolete and structurally deficient structures, provide additional truck parking, and provide numerous other safety and operational enhancements for the traveling public.

Description of Alternatives

For the purpose of this analysis, a No Build and Build Alternative were under consideration.

No Build Alternative

The No Build Alternative includes leaving the I-90 corridor in its current geometric and operational state. Intensified maintenance activities that were recently incurred to keep assets operational are expected to persist over the benefit-cost analysis period or until it is no longer feasible to keep them open to the public.

Build Alternative

The Build Alternative consists of reconstructing the I-90 pavement and right-of-way to current standards and reconstructing or rehabilitating deficient structures. Specific design elements considered in BCA are as follows:

- Remove and replace 28 miles of PCC surface on I-90 EB and WB lanes
- Reconstruction, rehabilitation, and/or maintenance on key structures in the project area
- Improving inslopes to 4:1 or flatter throughout the project area
- Extending acceleration and deceleration lanes along I-90 to meet design standards

The project was assumed to be constructed in three phases:

- PCN 05HQ: I-90 WB from two miles west of US 81 to the McCook/Minnehaha County line (MRM 377-362) – Construction 2022
- PCN 05T2: I-90 EB from the McCook/Minnehaha County line to SD Hwy 38 (MRM 377-390) – Construction 2024
- PCN 05T3: I-90 WB from the McCook/Minnehaha County line to SD Hwy 38 (MRM 390-377) – Construction 2023

BCA Methodology

The following methodology and assumptions were used for the benefit-cost analysis:

1. **Main Components**: The main components analyzed included:
    - Travel time/delay
    - Vehicle operating costs
    - Crashes by severity
    - Environmental and air quality impacts
    - Initial capital costs: Capital costs were expected to be incurred in years 2022 through 2024
    - Remaining Capital Value: The remaining capital value (value of improvement beyond the analysis period) was considered a benefit and was added to other user benefits.
    - Operating and maintenance costs
2. **Analysis Years**: This analysis assumed that the Build Alternative would be constructed over a three-year period, starting in year 2022, with completion in year 2024. Construction was assumed to be staged such that phase PCN 05HQ would be constructed in year 2022, phase PCN 05T3 would be constructed in year 2023, and PCN 05T2 would be constructed in year

2024. Therefore, year 2025 was assumed to be the first full year that benefits will be accrued from the entirety of the project. The analysis primarily focused on annual benefits for the twenty-year period from 2025 to 2044[1], while some user costs were quantified during the construction phases of the project and when certain segments of the project opened during the years 2022 through 2024. The present value of all benefits and costs was calculated using 2019 as the year of current dollars.

3. **Economic Assumptions**: Value of time, vehicle operating costs, emissions costs, and cost of crashes were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021[2]. Per-mile operating costs associated with additional impacts of pavement roughness were derived using values from NCHRP Report 720 - "Estimating the Effects of Pavement Condition on Vehicle Operating Costs"; Table 7-5[3]. The analysis was completed using an assumed discount rate of seven percent.

4. **Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)**: Year 2020 and year 2040 I-90 corridor VMT and VHT were developed using existing and forecast AADTs and travel time and route lengths that were obtained using Google Maps. Existing year 2020 and forecast year 2040 corridor AADTs, and existing corridor length data were obtained from the SDDOT Online Interactive Needs Book[4].

   Posted speed limits were used for determining travel time changes during construction. It was assumed that posted speed would be decreased from 80 mph to 65 mph in work zones, and that construction would take place during the five-month construction seasons of each year. Differences in travel times were quantified for each phase of the project and considered a disbenefit for the Build Alternative.

   Several bridges on I-90 are nearing the end of their service lives and will no longer be able to safely carry traffic within the next 5-10 years. These bridges were assumed to close at appropriate times based on remaining service life under the No Build scenario, as illustrated in Figure 1. Detour routes and associated mileage and travel times were determined using Google Maps and were compared to trip distances and times along I-90 (i.e. the route assumed for the Build). The BCA Workbook contains detailed information regarding bridge service lives, detour routes, and trip distances and times.

   Travel times and trip distances were applied to year 2020 and year 2040 daily traffic volumes to determine VHT and VMT, respectively. Benefits for the years between 2020 and 2040 were interpolated using an annual growth rate, and benefits for years beyond 2040 were extrapolated using the same growth rate. Total user costs per alternative is the sum of all user costs for the period from 2022 to 2044 (i.e. includes construction years and 20 years after last project opening). Benefits due to change in VMT and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types.

---

[1] The study used 365 days per year.

[2] https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

[3] http://www.trb.org/Publications/Blurbs/166904.aspx

[4] https://apps.sd.gov/hr53needsbook/

Figure 1. I-90 Bridge Closures

5. **Vehicle Occupancy and Vehicle Types**: The composite cost per mile used in the benefit-cost analysis accounted for the percentage split of autos and trucks in the travel area. The composite cost per hour accounted for vehicle occupancy ratios, and the percent split of autos and trucks traveling in the area. Key assumptions for these areas included:

   - The corridor-wide truck percentage used in the analysis was 19.7 percent and was based on year 2020 daily traffic and heavy truck counts provided in the SDDOT Online Interactive Needs Book.
   - Vehicle occupancy that was used in the analysis is consistent with values provided by *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021. The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.

6. **Vehicle Operating Costs:** Improving pavement condition along I-90 is a primary objective of this project. The current pavement condition on I-90 is degraded such that further analysis is necessary to capture the additional user costs associated with vehicle operating costs compared to a facility with sufficient pavement quality. Methods for estimating these additional costs per mile associated with pavement roughness are described in the National Cooperative Highway Research Program (NCHRP) Report 720. These methods were applied along with an understanding of the current pavement condition on the I-90 corridor to develop localized per-mile vehicle operating costs due to pavement roughness. Construction phasing for each project impacted the years which these benefits were realized on certain segments of I-90. Additionally, travel on I-90 under the No Build was removed accordingly based on detours assumed due to future bridge closures. Benefits were developed for years 2023 through 2029 based on existing and forecast I-90 traffic volumes.

   Note that pavement damage to detour routes and associated additional vehicle operating costs were not quantified in the BCA but are expected to occur under a No Build scenario, which signifies a conservative estimate in overall benefits for the Build.

7. **Safety Analysis:** The Build Alternative improves safety in the project area by providing I-90 with extended acceleration lanes at ramp junctions and by improving the inslopes to 4:1 or

flatter throughout the project area. Five-year crash data on the I-90 corridor was obtained for years 2016 through 2020 from SDDOT to determine average annual number of crashes by severity. For further details on crash history, refer to the interactive Tableau-based mapping application developed by SRF Consulting Group[5]. Reductions in crashes along the I-90 corridor were estimated using crash modification factors for improving the inslopes and extending the acceleration lane lengths to the current design standard of 980 feet.

The crash modification factor for the treatment "Flatten Sideslope from 1V:3V to 1V:4V[6]" was obtained from the CMF Clearinghouse database. The crash modification factor was applied to all crashes throughout the I-90 project area.

The formula for the crash modification factor for the treatment "Modify Length of Acceleration Lane[7]" was also obtained from the CMF Clearinghouse database. The crash modification factor equation is an exponential function which relies on the change in length of the acceleration lane as the input variable and is applicable to all crash types. Each crash modification factor was calculated for applicable ramp junctions where existing crashes were located. Existing acceleration lane lengths were determined using measurements from Google Earth aerial imagery.

Expected number of crashes in year 2040 were calculated by multiplying the base year crashes by the percent change in traffic volumes between the base year (year 2017 being the center of the crash analysis period) and forecast year 2040. Forecast year crash costs were calculated for the No Build scenario and Build Alternative crash costs were obtained by applying the appropriate crash modification factors to the No Build scenario crash costs.

The safety benefit was quantified for years 2017 and 2040 and interpolated based on an annual growth rate to determine total safety benefits for the period from years 2022-2029 (prior to detours routing most traffic off I-90). Crash cost assumptions for the KABCO scale are consistent with values and methodologies published in the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021.

8. **Environmental and Air Quality Impacts:** Annual VMT is expected to be impacted by bridge closers along I-90 which require detours. The change in VMT between the No Build and Build conditions was caused by the diversions described in Section 4 of this memorandum "Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)." Average emission rates per vehicle type were obtained from the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 3. Emission rates per vehicle type are provided in the attached BCA Workbook. Total change in emissions was valued in accordance with the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021.

9. **Operating and Maintenance Costs**: Changes in annual roadway maintenance costs are expected due to intensified maintenance that will be required to keep the No Build

[5] https://public.tableau.com/views/S_DakotaInfraGrantBCA/I-90CrashHistoryAnalysis2016-2020?:language=en&:retry=yes&:display_count=y&:origin=viz_share_link
[6] http://www.cmfclearinghouse.org/detail.cfm?facid=4613
[7] http://www.cmfclearinghouse.org/detail.cfm?facid=5216

Alternative serviceable compared to what will be required on new infrastructure under the Build. Anticipated costs for the No Build and Build Alternatives were provided by SDDOT and were broken down into I-90 project segments, as shown in the BCA Workbook.

Note that ongoing detours are expected to occur in years 2025 and 2030 due to various permanent bridge closures. Thus, maintenance for segments where traffic is expected to detour around is assumed to no longer be necessary after the respective detours are in effect.

10. **Calculation of Remaining Capital Value**: Because many components of the initial capital costs have service lives well beyond the 20-year analysis period, the remaining capital value was calculated for the Build Alternative. This value was expressed in terms of 2019 dollars and was added to other project benefits in accordance with USDOT guidance. The assumed service life for the Build Alternative was 40 years, which was provided through SDDOT I-90 project life-cycle cost analysis. In determining the remaining capital value of the Build Alternative, project components were assumed to have a linear depreciation from the time each phase was completed to the end of the benefit-cost analysis period. The remaining capital value quantities were discounted and attributed to other project benefits for the Build Alternative.
11. **Factors Not Quantified**: Several factors were not quantified as part of the analysis that could potentially add to the benefits assumed in the BCA. These factors include the following:
    - Increased travel time reliability in the study area due to a reduction in crashes from safety improvements and enhanced pavement condition.
    - Safety benefits, changes in needed upkeep and maintenance, and vehicle operating costs on corridors associated with detour routes under the No Build Alternative due to a shift in VMT.
    - Reduction in crashes for truck strikes at bridges with inadequate vertical clearance.
    - Travel time reductions for trucks that must use ramps to bypass bridges with inadequate vertical clearance.
    - Operating cost savings for trucks that must travel further for extended parking due to lack of parking spaces along the corridor.
    - Improved resiliency to floods and associated detours due to profile enhancements along the corridor.
    - Benefits from detours due to potential bridge closures (other than those quantified in the analysis) under the No Build Alternative (see BCA Workbook for complete listing).
    - Safety benefits and vehicle operating cost savings on the two-mile project portion of I-90 west US 81 that would continue to be realized after detours take place.

BCA RESULTS

The benefit-cost analysis provides an indication of the economic desirability of a scenario, but results must be weighed by decision-makers along with the assessment of other effects and impacts. Projects are considered cost-effective if the benefit-cost ratio is at least 1.0. The larger the ratio number, the greater the benefits per unit cost. Results of the benefit-cost analysis are shown in Table 1. See Attachment A for the complete benefit-cost analysis workbook.

Table 1 – Total Project Results

	Initial Capital Cost (2019 Dollars)	Project Benefits (2019 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2019 Dollars)
No Build vs. Build	$80.6 million	$350.6 million	4.3	$270.0 million

Attachment A

Benefit-Cost Analysis Worksheet