Memorandum

To:	Steve Gramm, P.E, Planning Engineer South Dakota Department of Transportation
From:	Nick Semeja, PE, Transpiration Policy and Studies Lead Matt Flanagan, Engineer
Date:	May 18, 2022
Subject:	US 12 Rural Reconstruction (Morristown to Watagua) – 2022 MPDG Grant 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 US 12 Rural Reconstruction (Morristown to Watagua) – 2022 MPDG Grant 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.

Project Overview

The South Dakota Department of Transportation (SDDOT) is requesting $21.4 million of 2022 Multimodal Project Discretionary Grant (MPDG) funds for South Dakota US Highway 12 (US 12). The project limits are from Morristown to Watauga, South Dakota in Corson County, approximately nine miles. This project is of critical importance to South Dakotans because US 12, a National Highway System (NHS) route, is the only east-west highway serving a remote and rural area of South Dakota entirely within the boundaries of the 2.3 million acre Standing Rock Indian Reservation. This segment of US 12 is in an area of persistent and concentrated poverty, in a historically disadvantaged community, in one of the poorest areas in the nation with severely limited access to essentials, including groceries, fuel, and basic health care needs, and has a population with disproportionately high mortality rates.

The project will reconstruct the two-lane US 12 highway with new pavement, widen the roadway to include six-foot shoulders, replace a 143.5-foot deteriorating bridge over Hay Creek, install three box culverts where there are currently pipe culverts, and replace nearly 19 miles of right-of-way fencing. This portion of US 12 was constructed in 1949 and was resurfaced in 1959, 1998, and 2006. This

infrastructure, including the roadway, bridge, and culverts, will be 74 years old at time of replacement and will have reached the end of its useful life.

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 US 12 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. This analysis identified and monetized the impacts of three detours. Detour routes and travel times were determined using Google Maps.[1]

- Detour – Trucks: All detoured truck traffic follows this route. This detour starts in 2028, when the bridge over Hay Creek is assumed to no longer able to carry truck traffic. Trucks are assumed to detour to SD 73 per SDDOT staff guidance.
- Detour A - Cars: Impacts cars only and occurs between year 2028 and 2032. This detour occurs because the Hay Creek Bridge is determined to no longer be safe to accommodate traffic per discussion with SDDOT Staff.
- Detour B - Cars: Impacts cars only and occurs between year 2033 and the end of analysis period. This is the final assumed detour and impacts all traffic. All vehicles are diverted when the entire length of the project is assumed to be non-drivable. Detour B occurs from 2033 to end of analysis period. Cars are assumed to take the same SD 73 detour.

Additional details on detours are provided in Section 4 of this memorandum.

Build Alternative

The Build Alternative consists of reconstructing the US 12 pavement and right-of-way to current SDDOT standards and reconstructing a deficient bridge. Specific design elements considered in BCA are as follows:

- Reconstructs nine miles of roadway to new condition with some vertical curve improvements
- Expands and paves roadway shoulders from two feet to six feet
- Installs edge-line rumble strips
- Replaces one bridge built in 1949 (fair condition) over Hay Creek

The project will be constructed in two phases:

- Phase 1 – PCN 05HW – This phase will consist of grading and interim surfacing the entire nine-mile project area to increase the shoulder width and to flatten deficient vertical

[1] Google Maps: https://www.google.com/maps

curves. It will include the replacement of a bridge over Hay Creek (Structure # 16-154-005).

- Phase 2 – PCN 05U5 - This phase is the follow up asphalt concrete (AC) surfacing project, completing surfacing for the entire nine-mile project area. It will include installation of pavement markings, permanent signing, and grinding of edge rumble strips.

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 2023 and 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 two-year period starting, starting in year 2023, with completion in year 2024. Construction was assumed to be staged such that phase PCN 05HW would be constructed in year 2023, phase PCN 05U5 would be constructed in year 2024. Year 2025 was assumed to be the first full year that most benefits will be accrued from the entirety of the project (except for the benefits associated with the installation of edge line rumble strips which begin benefits in year 2025). The analysis primarily focused on annual benefits for the twenty-year period from 2024 to 2043[2], while some user costs were quantified during the construction phases of the project and when certain segments of the project opened during the years 2023 through 2024. The present value of all benefits and costs was calculated using 2020 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 March 2022 (Revised)[3]. 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[4]. 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 2021 and year 2041 US 12 corridor VMT and VHT were developed using existing and

[2] The study assumed 365 days per year.

[3] https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf

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

forecast AADTs and travel time and route lengths were obtained using Google Maps. Existing year 2021 and forecast year 2041 corridor AADTs, and existing corridor length data were obtained from the SDDOT Online Interactive Needs Book[5].

Posted speed limits were anticipated to be maintained during construction. It was assumed that construction would take place during the entire 12-month period of construction for each year. Differences in travel times were quantified for each phase of the project and considered a disbenefit for the Build Alternative.

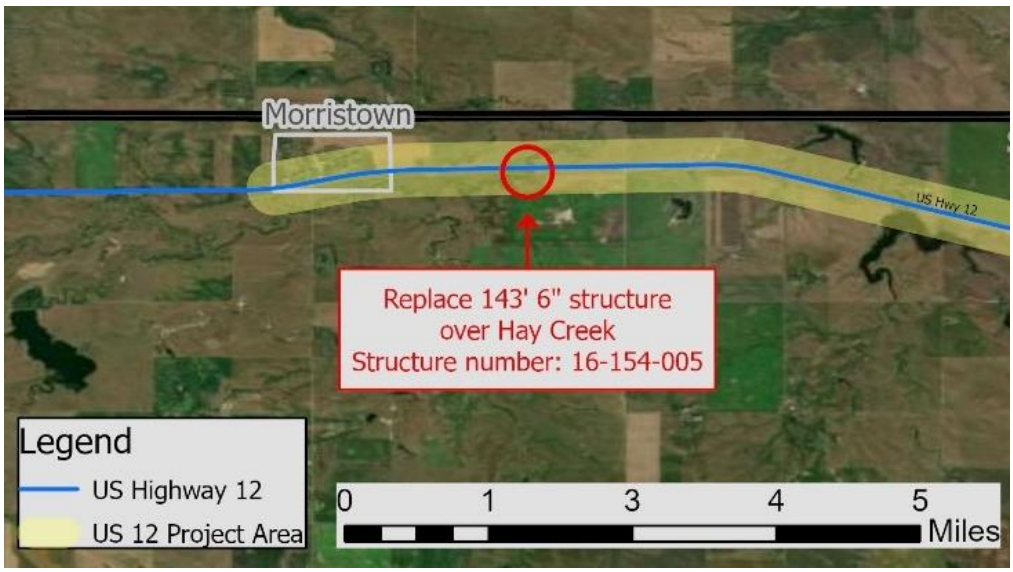
The bridge over Hay Creek was assumed to close at the appropriate time based on remaining service life under the No Build Alternative, as illustrated in Figure 1. Additionally, the current (Year 2022) pavement condition composite index value for US 12 is "fair" (3.34). Without the project, US 12 pavement will continue to degrade from its current rating of fair (3.34). By 2025, the pavement will decline to poor condition (2.09 or lower) and reach "0" by 2033, where the roadway and infrastructure would shut down completely.[6]

Detour routes and associated mileage and travel times were determined using Google Maps and were compared to trip distances and times along US 12 (i.e., the route assumed for the Build Alternative). The BCA Workbook contains detailed information regarding bridge service life assumptions, detour routes, and trip distances and times.

Travel times and trip distances were applied to year 2021 and year 2041 daily traffic volumes to determine VHT and VMT, respectively. Benefits for the years between 2021 and 2041 were interpolated using an annual growth rate, and benefits for years beyond 2041 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 2043 (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.

[5] https://apps.sd.gov/hr53needsbook/
[6] Data obtained through coordination with SDDOT Area Engineer. Refer to BCA Workbook for Additional Detail

Figure 1. US 12 Bridge Closure



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 28.1 percent and was based on year 2021 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 March 2022 (Revised). The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.

6. **Vehicle Operating Costs:** Improving pavement condition along US 12 is a primary objective of this project. As noted previously, the current pavement condition on US 12 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 US 12 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 US 12. Additionally, travel on US 12 under the No Build Alternative was removed accordingly based on detours assumed due to future bridge closure. Benefits were developed for years 2024 through 2032 based on existing and forecast US 12 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 Alternative, which signifies a conservative estimate in overall benefits for the Build Alternative.

7. **Safety Analysis:** The Build Alternative improves safety in the project area by providing the following elements quantified in this Benefit-Cost Analysis:

   - Expansion and paving of roadway shoulders from two feet to six feet
   - Installation of edge-line rumble strips

   Five-years of crash data along the US 12 corridor was obtained for years 2014 through 2018 from SDDOT to determine average annual number of crashes by severity. Reductions in crashes along the US 12 corridor were estimated using crash modification factors for the expansion and paving of roadway shoulders from two to six feet and for the installation of edge line rumble strips.

   The crash modification factor for the "Install Edgeline Rumble Strips[7]" was obtained from the Crash Modification Factors (CMF) Clearinghouse database. The crash modification factor was applied to all crashes throughout the US 12 project area.

   The crash modification factor for the shoulder width treatment "Extend Shoulder Width From two feet to six feet" was obtained using values presented in AASHTO Highway Safety Manual (HSM) Chapter 12.[8]" The crash modification factor was also applied to all crashes throughout the US 12 project area.

   Expected number of crashes in year 2041 were calculated by multiplying the base year crashes by the percent change in traffic volumes between the base year (year 2016 being the center of the crash analysis period) and forecast year 2040. Forecast year crash costs were calculated for the No Build Alternative and Build Alternative crash costs were obtained by applying the appropriate crash modification factors to the No Build Alternative crash costs.

   The safety benefit associated with the installation of edge line rumble strips and the extension of the paved shoulder from two feet to six feet was quantified for years 2027, 2028 and 2033 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 US 12). 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 March 2022 (Revised).

8. **Environmental and Air Quality Impacts:** Annual VMT is expected to be impacted by a bridge closure along US 12 and the eventual pavement failure along the entire US 12 project corridor. The change in VMT between the No Build Alternative and Build Alternative 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[9]. 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 March 2022 (Revised).

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[7] http://www.cmfclearinghouse.org/study_detail.cfm?stid=606
[8] http://www.highwaysafetymanual.org
[9] Average emission rates per vehicle type were obtained from the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 3

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 Alternative serviceable compared to what will be required on new infrastructure under the Build Alternative. Anticipated costs for the No Build Alternative and Build Alternatives were provided by SDDOT and are shown in the BCA Workbook.

   Note that in the No Build Alternative, ongoing detours are expected to occur in year 2028 due to diversions associated with bridge failure. Thus, maintenance for segments where traffic is expected to detour around, is assumed to no longer be necessary and is not quantified. This assumption was made because the requirement for trucks to detour around the bridge closure.

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 2020 dollars and was added to other project benefits in accordance with USDOT guidance. The assumed service life for the Build Alternative was 30 years, which was provided through SDDOT US 12 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.
        - Improved resiliency to floods and associated detours due to profile enhancements along the corridor. Replacement of three large pipe culverts with box culverts
        - Mitigation of 14 deficient vertical curves with a design speed of 60 mph or less
        - Flattening of backslopes to help with the removal of snow traps and melting
        - Correction of inslopes to ensure proper roadway drainage
        - New pavement markings that are more visible and reflective during adverse driving conditions

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 (2020 Dollars)	Project Benefits (2020 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2020Dollars)
No Build vs. Build	$16.7 million	$43.9 million	2.6	$27.2 million

Attachment A

Benefit-Cost Analysis Worksheet