Memorandum

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Minnesota Department of Transportation

From: Matt Flanagan, Engineer
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Date: August 14, 2023

Subject: TH 11 Rainy River Slide Realignment and Resiliency Project

FY 2022/2023 PROTECT 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 TH 11 Rainy River Slide Realignment and Resiliency Project – FY 2022/2023 PROTECT 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. Other, non-monetized benefits are described in this report as well. 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 Minnesota Department of Transportation (MnDOT) is requesting $2.56 million of Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Grant funding for the construction of the Highway 11 Rainy River Slide Realignment and Resiliency Project. The project is in Koochiching County, approximately 30 miles west of the city of International Falls, MN, and 40 miles east of the City of Baudette, MN, along Highway 11 (TH 11). Highway 11 is the northernmost east/west running highway in the Minnesota, running along the US and Canada border from International Falls to Baudette, MN and beyond. Figure 1, below, provides a project location map.

Figure 1. Project Location Map

Located between the unincorporated communities of Loman and Indus, Minnesota, in Koochiching County, the project will address two critical slope failures along Highway 11 and the Rainy River. The project will realign 1.2 miles of the highway about 150 feet to the west (Figure 2, below), removing the roadway from the slide areas and allowing MnDOT to complete the necessary work to stabilize the slopes.

Since 2012, two locations along the project area have experienced two significant slope failures, where landslides have begun moving towards the Rainy River. Both slide events have impacted proper and safe function of the Highway and necessitated temporary fixes. In total, MnDOT has spent $1.1 million to install temporary measures to keep Highway 11 operational.

Figure 2. Proposed Alignment and Location of Existing Slides

The slope stability issues were triggered in 2012, shortly after MnDOT reconstructed Highway 11 to address safety problems by widening the road and addressing roadway geometric deficiencies. After completion of the reconstruction project, MnDOT maintenance staff noticed impacts to the roadway from the southern slide. Since that time, MnDOT has completed periodic fixes to mitigate and slow the impacts of the slide area.

Some fixes have included soil nailing and foam installation to solidify slope stability and reduce the overall weight of the slide area (see Figure 3). Despite these emergency repairs, the southern slide on TH 11 threatens closure to the roadway in the immediate future.

Figure 3. Foam Installation for Slope Stability

Approximately ten years after the southern slide began, the northern slide developed in spring of 2022. Since spring 2022, the slope stability has deteriorated quickly. Due to a sizeable crack forming in the westbound lane, during the summer of 2022, MnDOT was forced to reduce the roadway to a single lane and control traffic using a temporary signal. As an emergency and temporary fix, the road was relocated as far as possible within the existing right-of-way (approximately 20 feet to the west). These temporary fixes created deficient roadway geometrics, that will be corrected through this project. Figure 5, below, shows the north slide area.

Figure 4. Slope Instability After Emergency Measures Were Taken

To monitor the slide, MnDOT installed slide sensors in November 2022 to remotely monitor the rate of slide movement. The monitors provide real time measures of horizontal displacement. Between November 2022 and August 2023, the northern slide has moved approximately 48 inches, and is **currently moving at a rate of over a half an inch a day (graphs can be seen in the other sections within this memorandum)**. Testimony from MnDOT staff who have visited the site indicates that other sections have seen more movement. Figure 5 shows an aerial image of the North Slide area in August 2023, after the roadway had been realigned 20 feet west.

Figure 5. North Slide Area (August 2023)

If the slide continues at its current rate, MnDOT will have to close portions or all of Highway 11 in the near future. Without FY 2022/2023 PROTECT funding to complete a permanent fix, MnDOT will be forced to continue with temporary fixes, and could require near-term closure of the roadway. Since 2012, MnDOT has incurred project costs of approximately $1.1 million to keep Highway 11 in operation.

Description of Alternatives

A No Build and Build Alternative were both analyzed as part of this project.

No Build Alternative

The No Build Alternative assumes full closure of TH 11 in Year 2027 (see "Slide Displacement for Closure Scenario" on page six for more details) . Traffic impacts due to closure are assumed to begin on January 1, 2028.

Under the No Build Alternative, the impacts of two diversion routes associated with the closure of TH 11 were identified and monetized. The routes were determined through coordination with MnDOT Staff[1] and are based on anticipated diversion routes. The diversion routes for cars and heavy vehicles are different, as the car detour route contains inadequate facilities to support consistent loadings from heavy vehicle traffic. The start and end points for the routes of the car diversion route and the truck diversion routes are also different, this is only due to the methodology. This approach is taken to improve workbook and calculation clarity and allows for additional flexibility in sensitivity analysis. Additionally, automobile traffic is less likely to be "through traffic" as opposed to truck traffic. Refer to Attachment B – Map of Assumed Vehicle Routes.

Due to the rural nature of the project area, very few alternate regional routes are available that can safely carry traffic. One traffic diversion route is designated for cars and another diversion route is designated and signed for trucks. Additional details and hyperlinks to Google Maps travel routes are provided in the BCA Workbook. The travel times noted below assume no travel delays.

[1] Assumed traffic diversion routes due to closure of TH 11 obtained through coordination with MnDOT Staff.

Assumed No Build Route for Cars:

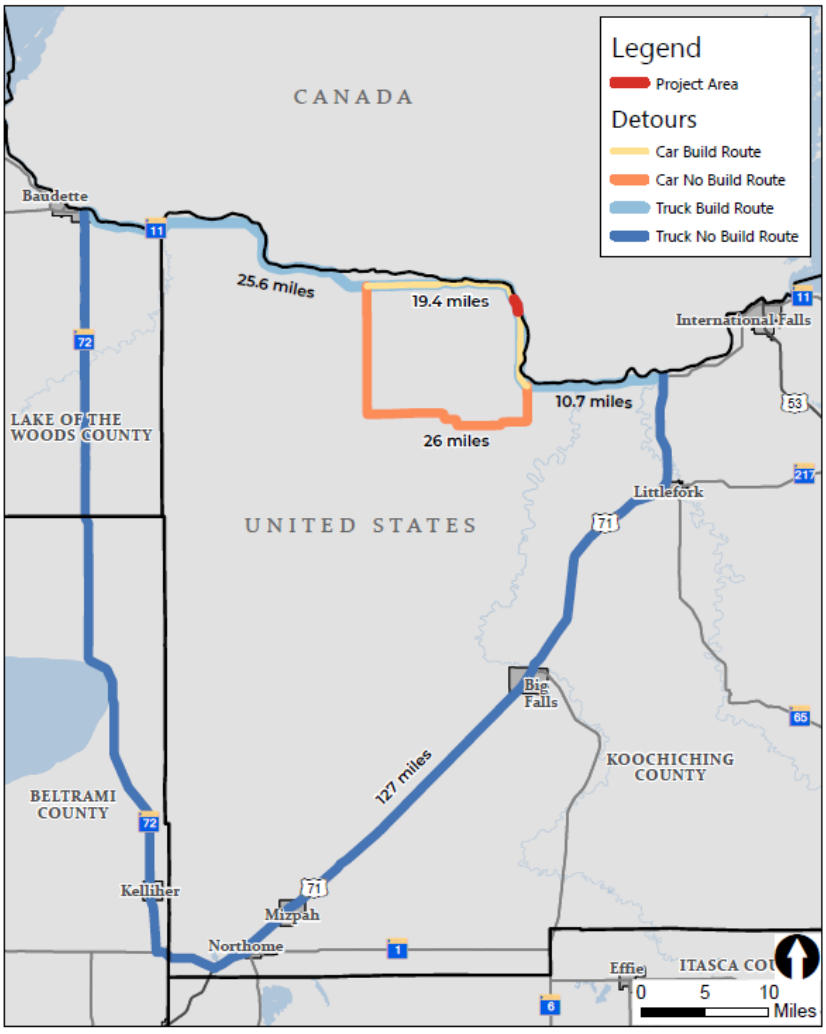
- TH 11 and CR 86 (Northwest Koochiching) to CR 11 and CSAH 32 (Loman)
- 26 miles total, 36-minute travel time

Assumed No Build Route for Trucks:

- TH 11 and TH 72 (Baudette) to TH 11 and US 71 (Pelland)
- 127 miles total, 116-minute travel time

The main reason that the car and truck routes differ is because of the assumed start and end points for each. Cars are able to take a short distance detour route, starting closer to the project location, whereas trucks must reroute much farther from the project location. The car reroute is a gravel road, which is why the travel time is longer than anticipated, and also why trucks cannot take the same detour route as cars. Figure 6, below, shows the different routes assumed for this project.

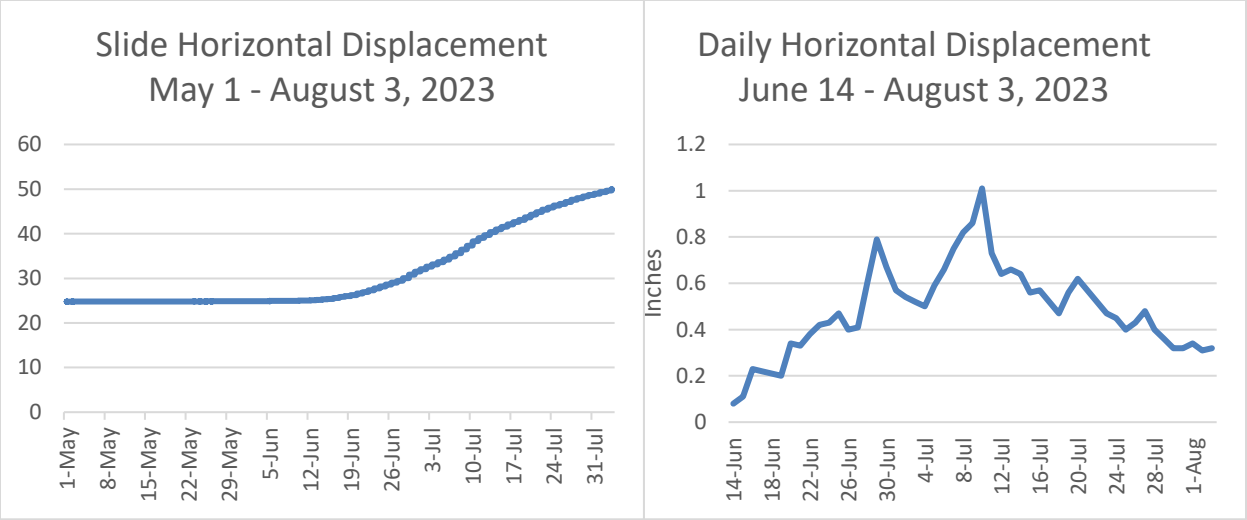
Figure 6. North Slide Area (August 2023)



Slide Displacement for Closure Scenario

It is important to determine the year of closure according to the No Build conditions as these slides continue to degrade the roadway conditions. The methodology and data collection to determine the year of closure of TH 11 heavily relies on Slide Horizontal Displacement Data and the geometrics of the roadway. In particular, the northern slide has demonstrated significant risk over the past year. In summer of 2022, the original slope failure was initially identified due to the presence of a pronounced crack through the center of the westbound lane (see Figure 4). MnDOT quickly responded, closing the travel lane, and initiating a temporary project to keep the roadway open in the short term. In the fall of 2022, the roadway was shifted to the west, out of the immediate slide area, as far as the existing right-of-way would allow. Despite these efforts, the slope failures continue to threaten the operation of Highway 11 as the slide areas have already reached the edge of the new roadway (see Figure 5).

Figure 7. Slide Displacement Data



As was discussed above, MnDOT installed remote monitoring sensors to track the rate of the slide. Each monitor takes hourly readings of horizontal displacement. Between their installation in August 2022 and the end of July 2023, the northern slide area has seen significant movement, being displaced over 48 inches horizontally (see Figure 7). More recent information indicates a concerning trend. **During the month of July 2023, the slide moved 17.5 total inches, a rate of 0.56 inches per day.** As the slide continues to move, additional temporary measures, costs, and staff time will be needed to slow the rate of decline and keep Highway 11 in operation. Figure 7, above, displays the total displacement (inches) and the daily displacement (inches) of the northern slide. While the daily displacement does peak in the month of July, the values for daily displacement are never equal to zero, meaning that the slide is never fully stationary. The amount of displacement may depend on or be tied to precipitation or other factors, though it is certain that the slide is consistently moving.

Figure 8 displays photographic history of the northern slide area and is shown below. Despite temporary measures, TH 11 is still vulnerable to near term closure due to the concerning rate of slide.

Figure 8. Photographic history of the northern slide area.

Summer 2022— northern slide area identified. Photographs taken in August 2022 show damage to the westbound lane. MnDOT responded quickly by reducing the roadway to one lane and controlling the flow of traffic with a temporary signal and began seeking a solution to the slope failure.

Fall 2022— to get the roadway back in operation, MnDOT moved the roadway as far as possible outside the slope failure within the existing ROW.

May 2023— MnDOT maintenance crews remove several feet of soil in an effort to reduce the driving force behind the slide to slow or stop it movement.

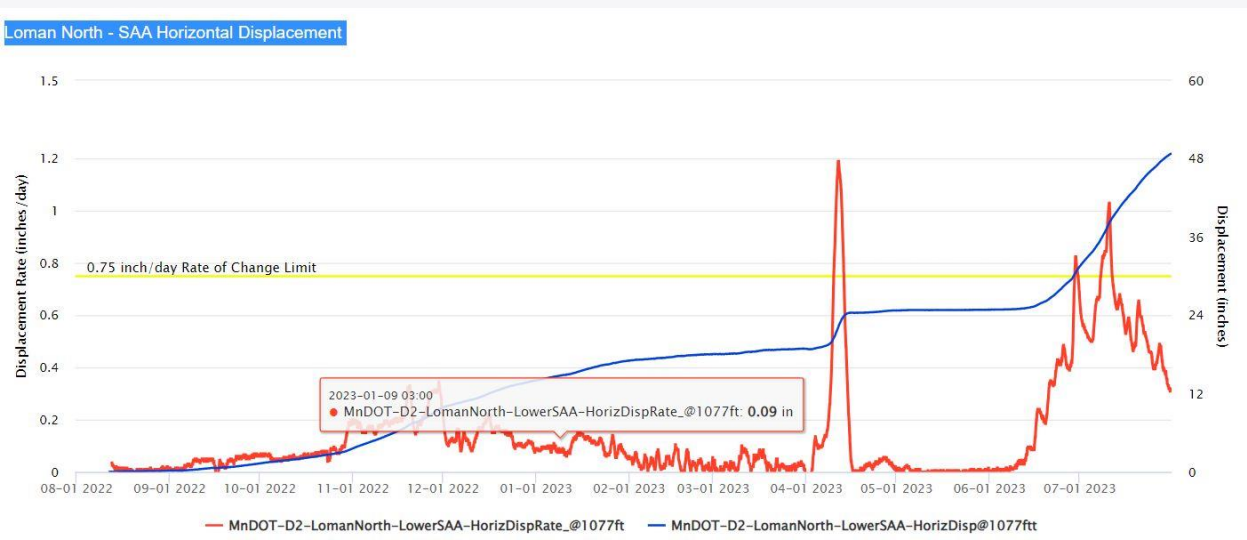
July 5, 2023— continued slope movement captured.

July 17, 2023— Significant slope deterioration

In addition to the implementation of displacement sensors, MnDOT uses an online portal to track displacement readings. The graph below shows daily readings from the monitor, throughout the life

of the monitoring station. The blue line shows total horizontal displacement, and the red line shows daily horizontal displacement. Figure 9 shows that the total displacement on the northern slide within the last year is just over 48 inches.

Figure 9. Horizontal Slide Displacement Data



The No Build Alternative assumes full closure of TH 11 in the Year 2028. Attachment A – BCA Workbook contains detailed calculations used to determine this year of closure. Based on the figure above, an average annual slide displacement rate of four feet per year was determined based on data collected between August 1, 2022 and August 1, 2023.

The No Build Alternative assumes that TH 11 requires full closure if the slide moves 12 feet from its existing location. This distance is based on recent measurements and extrapolation from recent photographs (July 2023). This analysis applies a conservative four feet per year (linear) slide displacement rate and assumes full closure of TH 11 beginning January 1, of 2028.

Build Alternative

The Build Alternative will mitigate the impacts of the slope failures by realigning the portion of TH 11 that is being impacted by the slides. By realigning TH 11, the roadway will be removed from the immediate slide areas, which will allow the slope failures to be remediated through the installation of slope stability measures which will reduce or eliminate any future soil instability.

The location of the new road will be approximately 200 feet west of the current location and far enough away from the slide area to remain unaffected by future slides or stability issues caused by erosion from floodwaters. Stabilization work will be completed on the slope where sliding is currently occurring to ensure the continued stability of the realigned section of highway.

In the Build Alternative, the specific design elements considered in this BCA are as follows:

- Reconstruct 1.12 miles of TH 11 roadway, shifting alignment 200 feet to the west
- Slope stability countermeasures to be installed at the two slide areas
- Restoration of centerline and shoulder rumble strips

The Build Alternative relies on the same assumed travel patterns as used in the No Build Alternative. In the Build Alternative, all automobiles and trucks traveling along TH 11 are assumed to use their existing routes and their assumed respective destinations remain the same as in the No Build Alternative. A map and additional details on existing routes and assumptions are provided in the BCA Workbook, are shown in Attachment B – "Existing Traffic Routes and Traffic Diversion Routes Due to Closure of TH 11", and in Figure 6 above. The assumed existing travel routes for vehicles along TH 11 used in the Build analysis are described below. During construction years, it is assumed that trucks will take the long reroute (see the No Build Route for trucks), and cars will use TH 11 (which will have pilot car navigation, a simple way to allow one way travel along the roadway).

Assumed Build Route for Cars:

- TH 11 and County Road 86 (Birchdale)/Black River Road to TH 11 and CSAH 32 (Loman)
- 19.4 miles total, 18-minute travel time

Assumed Build Route for Trucks: TH 11

- TH 11 and TH 72 (Baudette) to TH 11 and US 71 (Pelland)
- 55.7 miles total, 54-minute travel time

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 Hours Traveled - VHT)
   - Operating costs (Vehicle Miles Traveled - VMT)
   - Crashes by severity
   - Environmental and air quality impacts
   - Initial capital costs: Capital costs were expected to be incurred in the years 2022-2025
   - 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. This analysis assumed a 20-year service for all project components.
   - Operation, maintenance, and rehabilitation costs: These costs included major rehabilitation activities over the analysis period and annual routine maintenance and operation costs.

2. **Analysis Years**: This analysis assumed that the Build Alternative would be constructed during a three month period in 2025 (May 1 – July 31). Year 2026 was assumed to be the first full year that most benefits will be accrued from the entirety of the project. The analysis primarily focused on annual benefits for the twenty-year period from 2026 to 2045.

3. **Economic Assumptions**: Value of time, vehicle operating costs, emissions costs, inflation adjustment factors, and cost of crashes were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023[2]. The analysis was completed using an assumed discount rate of seven percent. The present value of all benefits and costs was calculated using 2021 as the year of current dollars.

4. **Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)**: Existing Year 2021 VMT and VHT were calculated by vehicle type along existing routes and diversion routes due to closure of TH 11. The total network VMT and VHT were developed using the most recent year AADT data available, generally years 2021 or 2022 obtained from the MnDOT Traffic Mapping Application. Travel time and route lengths were obtained using Google Maps[3].

   TH 11 was assumed to close in Year 2027 and the first full year of traffic impacted in Year 2028 as described in the "Description of Alternatives – No Build Assumption" Section of this memorandum. Existing traffic routes and anticipated diversion routes associated with the closure of TH 11 beginning in are described above in the "No Build" and "Build" section of this memorandum.

   Assumed diversion routes were approved by MnDOT. Associated mileage and travel times were determined using Google Maps and were compared to trip distances and times along TH 11 (i.e., the route assumed for the Build Alternative). The BCA Workbook contains detailed information regarding pavement service life assumptions, diversion routes, and trip distances and times.

   Travel times and trip distances were applied to Year 2021 and Year 2045 daily traffic volumes to determine VHT and VMT, respectively. The benefits for the years between 2026 and 2045 were interpolated using an annual growth rate, and benefits for years beyond Year 2045 were extrapolated using the same growth rate. Total user costs per alternative is the sum of all user costs for the period from 2026 to 2045. 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.

[2] 2023 USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs: https://www.transportation.gov/sites/dot.gov/files/2023-01/Benefit%20Cost%20Analysis%20Guidance%202023%20Update.pdf
[3] Google Maps: https://www.google.com/maps

5. **Vehicle Occupancy and Vehicle Types**: Truck and auto travel time costs per hour and costs per vehicle mile traveled were used in addition to vehicle occupancy ratios, and the percentage split of autos and trucks traveling on each route. Key assumptions for these areas included:

    - The corridor-wide truck percentage used in the analysis was 22.3 percent, which was based on Year 2021 AADT. Heavy vehicle percentages were obtained from project scope documents.
    - The vehicle occupancy that was used in the analysis is consistent with values provided by *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023. The analysis assumed an occupancy of 1.67 people per automobile and 1.00 people per truck.

6. **Safety Analysis:** The Build Alternative is expected to improve safety in the project area in two ways. First by adding roadway safety elements TH 11 as part of the project, and secondly by keeping traffic on existing routes and not encouraging traffic to divert to higher-crash rate facilities.

    This safety analysis examined five years of crash data (2018-2022) along the routes described in the in the "No Build" and "Build" sections of this memorandum. Crash data was obtained from the MnDOT MnCMAT2[4] crash databased to determine annual crash costs and annual number of crashes by severity associated with this project.

    The Build Alternative directly improves safety along the project corridor by installing/restoring centerline and shoulder rumble strips. Crash Reductions along the TH 11 corridor were estimated using crash modification factor (CMFs) for the installation of centerline and shoulder rumble strips.

    The crash modification factor for the shoulder width treatment "Install Centerline and Shoulder Rumble Strips" was obtained using values presented in CMF Clearinghouse's website[5] for the installation of centerline and shoulder rumble strips. The crash modification factor was also applied to all crashes throughout the TH 11 project corridor. Note that in the Build Alternative, safety benefits associated with installation of shoulder rumble strips begin in Year 2026, the first full year after construction, and end at the end of the analysis period in Year 2045.

    Network Crash Reductions

    Crash costs and crashes by severity were calculated in the No Build Alternative by assuming the same traffic growth rates, existing travel patterns, and crash rates as in the Build Alternative. Crash costs and crashes by severity were calculated using existing crash rates along TH 11 for Year 2028, the first full year of TH 11 closure.

[4] MnCMAT2 Crash Database: https://www.dot.state.mn.us/stateaid/mncmat2.html
[5] CMF Clearinghouse: https://www.cmfclearinghouse.org/detail.cfm?facid=6942

Annual crashes by severity and crash costs for existing year 2021 and forecast year 2045 were calculated based on the change in VMT between the No Build Alternative and Build Alternative caused by the diversion routes associated with closure of TH 11 described in the "No Build" and Section 4 of this methodology, "Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)." The shift of traffic to diversion routes associated with closure of TH 11 is expected to result in increased crash costs for the No Build since severe crashes will occur more frequently along diversion routes than those along existing routes using TH 11 in the Build Alternative due to higher severe crash rates.

Annual crash costs and crashes by severity for years 2021 to 2045 were calculated by multiplying the base year crashes by the percent change in annual VMT between the base year (Year 2021 being the center of the crash analysis period) and the annual VMT along each existing and diversion route associated with users of the TH 11 project segment. 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 January 2023.

7. **Environmental and Air Quality Impacts:** Annual VMT is expected to be impacted due to the anticipated closure of TH 11. The change in VMT between the No Build Alternative and Build Alternative was caused by the diversion routes described in Section 4 – "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[6]. 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 January 2023.

8. **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 MnDOT and are shown in the BCA Workbook.

   Note that the No Build Alternative diversion routes are expected to occur in Year 2028 due to closure of TH 11. Thus, maintenance for this segment of TH 11 is assumed to no longer be necessary and is not quantified.

[6] Average emission rates per vehicle type were obtained from the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES), version 3

9. **Calculation of Remaining Capital Value**: Even though many components of the initial capital costs may have service lives well beyond the 20-year analysis period, the remaining capital value was not calculated for the Build Alternative. The assumed service life for the Build Alternative was 20 years and was obtained through coordination with MnDOT staff. Therefore, the Remaining Capital Value was calculated to be zero, and was not included in the benefit cost summary.
10. **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.
    - Improved resiliency to floods and associated detours due to profile enhancements along the corridor. Replacement of three large pipe culverts with box culverts.
    - Health and recreational benefits associated with improved accessibility to community resources and parks.

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 (2021 Dollars)	Project Benefits (2021 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2021 Dollars)
No Build vs. Build	$3.9 million	$71.3 million	23.12	$68.2 million

Attachment A

Benefit-Cost Analysis Worksheet

Attachment B

Existing Traffic Routes and Traffic Diversion Routes Due to Closure of TH 11