Memorandum

To: Andrew Witter, PE, Publics Work Director
Sherburne County

From: Nick Semeja, PE

Date: May 17, 2022

Subject: US Highway 169/CR 4 Rural Safety and Mobility Interchange Project – 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 Highway 169/CR 4 Rural Safety and Mobility Interchange Project – 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.

The US 169 and County Road (CR) 4 intersection is characterized by having a high rate of severe crashes and extensive mobility issues. Traffic delay at the signal is experienced for many hours of the day and during recreational time periods throughout the year, often resulting in mile-long queues on US 169 approaching the signal. The US 169 corridor is programmed to be converted to a freeway facility through the city of Elk River, located just south of the US 169/CR 4 intersection. Once the freeway conversion takes place, the CR 4 intersection will be the last signalized intersection on US 169 in Central Minnesota, likely exacerbating the existing delay and safety issues.

The proposed project would construct a grade separated interchange in place of the at-grade signal at US 169/CR 4. This project would connect the freeway facilities to the north and south and provide relief to the existing and future mobility and safety problems on the US 169 corridor.

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 included leaving the US 169 and CR 4 interchange in its current configuration of an at-grade signalized intersection. Traffic impacts associated with programmed regional roadway improvements were included in the analysis.

Build Alternative

The proposed project will replace the existing signalized intersection with a full access interchange. The interchange will be configured as a peanut roundabout with US 169 going over CR 4. The interchange will also include a multimodal trail facility along the north side of CR 4. See Figure 1 for a concept of the improvements.

Figure 1. Build Interchange Concept

The BCA for the Build Alternative also assumed the same programmed improvements to the regional transportation system that were assumed in the No Build Alternative.

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: These costs were broken into distinct categories in accordance with service life (consistent with the recommendations of MnDOT Office of Transportation

System Management, July 2021[1]) and were applied evenly over the duration of the construction period.

- 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: These costs included annual inspection required for the new bridge and routine maintenance on the additional pavement associated with the interchange.

2. **Analysis Years**: This analysis assumed that construction would take place over a two-year period and be completed in 2024. Therefore, year 2025 was assumed to be the first full year that benefits will be accrued from the project. Since the project includes construction of a grade separated interchange and full reconstruction of the US 169 and CR 4 pavement adjacent to the new interchange, the analysis focused on the estimated benefits for the thirty-year period from 2025 to 2054 based on anticipated service life of the improvements. 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 quality of life benefits were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated March 2022 (Revised)[2]. Remaining capital value assumptions were consistent with rates from *Recommended remaining capital value factors for use in benefit-cost analysis in SFY 2022*[3], Minnesota Department of Transportation (MnDOT), Office of Transportation System Management, July 2021 (values were adjusted to reflect discount rate). The analysis was completed using an assumed discount rate of seven percent.

4. **Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)**: Travel time changes in the US 169/CR 4 study area were captured using Synchro/SimTraffic microsimulation modeling. No Build and Build models were developed for morning, midday, and afternoon peak hours, and analysis was performed for existing year 2019 and forecast year 2040. Year 2019 turn movement counts were used for the existing year analysis, and year 2040 forecast volumes were developed by applying a 20-year growth factor of 1.4 to reflect the overall traffic growth expected in Sherburne County, as stated on page 66 of the Sherburne County Transportation Plan[4]. A higher growth rate of three percent per year is also stated in the Plan. However, the BCA used the lower of the two potential expected growth rates to keep the estimate of benefits conservative.

   Changes in VMT equivalents between the No Build and Build Alternatives were estimated based on the change in vehicle idling. It was assumed that time vehicles spend idling would produce wear and tear on the vehicle similar to time moving. The change in intersection delay between No Build and Build conditions was obtained from microsimulation modeling and converted to equivalents of vehicle-miles traveled (VMT) by applying fuel consumption for idling vehicles to average miles per gallon for passenger cars.

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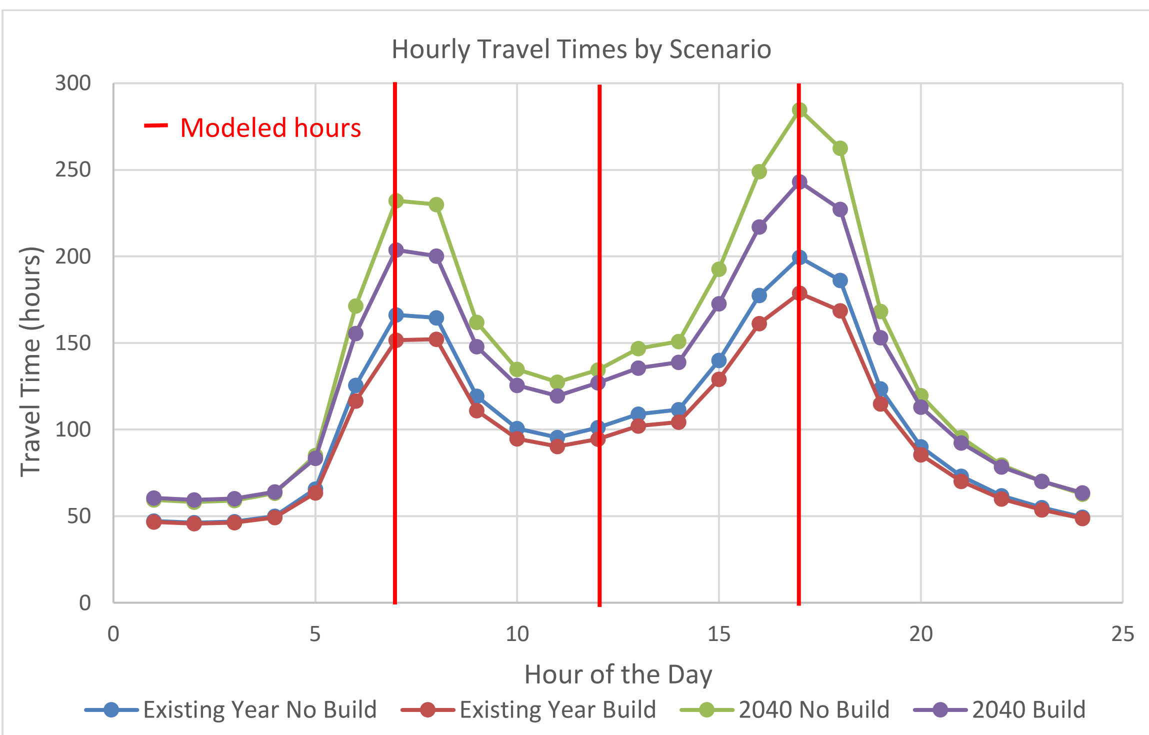
[1] Table 5: http://www.dot.state.mn.us/planning/program/benefitcost.html
[2] https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf
[3] http://www.dot.state.mn.us/planning/program/appendix_a.html
[4] https://www.co.sherburne.mn.us/DocumentCenter/View/4535/Sherburne-County-Transportation-Plan---Complete

To capture travel time and idling estimates in hours outside the morning, midday, and afternoon peak hours, volume-to-travel time relationships were developed and applied in the BCA. StreetLight[5] data for trips through the US 169/CR 4 intersection was used to identify hour-of-day and month-of-year volume profiles for the entirety of year 2019. Travel time-to-volume curves were developed based on study network entering volume and travel time output from each of the microsimulation modeling scenarios (existing year and forecast year, no build and build). These curves were used to predict travel time for the remaining 21 hours of the day outside the morning, midday, and afternoon peak hours (see Figure 2). Once daily travel time for each modeling scenario was established, monthly adjustment factors for study area traffic volumes were applied based on the annual volume profile obtained from the StreetLight data. These adjustment factors (see Table 1) reflect the number of vehicle trips through the study area relative to the analysis base month of March (i.e. month the turn movements counts were collected).

Outcomes from the analysis estimate full-year VMT equivalents and VHT for the No Build and Build Alternatives in years 2019 and 2040. Benefits for years between existing year 2019 and forecast year 2040 were interpolated based on an annual growth rate, and benefits for years beyond year 2040 were extrapolated using the same annual growth rate. Savings due to reduction of VMT equivalents and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types.

Figure 2. Hourly Travel Times by Scenario



[5] StreetLight is a data analytics tool that processes annual vehicle probe data to determine detailed trip information. https://www.streetlightdata.com/

Table 1 – Monthly Traffic Volume Adjustment Factors

Month	Adjustment Factor
January	0.89
February	0.92
March	0.97
April	1.07
May	1.03
June	1.04
July	0.96
August	0.93
September	1.06
October	1.06
November	1.03
December	1.02

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 truck percentage used in the analysis was 8.3 percent and was based on year 2018 daily traffic and heavy truck counts provided in the MnDOT Traffic Mapping Application[6].
   - 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). The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.

6. **Safety Analysis:** The Build Alternative improves safety in the project area by providing grade separation at the existing US 169/CR 4 signal. This eliminates the high-speed at-grade crossing and reduces both congestion and conflicting volumes at intersections in the area.

   Safety benefits were monetized using the Interactive Highway Safety Design Manual program (IHSDM-HSM Predictive Method - 2019 Release, v 15.0.0). IHSDM is a tool developed by the U.S. Department of Transportation – Federal Highway Administration (US DOT – FHWA) and is intended to help justify the need for proposed roadway designs and modifications by predicting crashes based on existing or proposed roadway geometry and traffic volumes. Results from the IHSDM Analysis are provided in the Appendix.

   The data used in this analysis included existing and forecasted annual average daily traffic (AADT) projections, geometric and operational design elements, and site-specific crash distributions provided by MnDOT. This safety analysis predicted the total number of crashes in accordance with methods outlined in the Highway Safety Manual (HSM) for each year between 2025 to 2054 by severity on the KABCO scale. The safety benefit was then

[6] https://mndot.maps.arcgis.com/apps/webappviewer/index.html?id=7b3be07daed84e7fa170a91059ce63bb

quantified for years 2025 to 2054 using crash cost assumptions for the KABCO scale and are consistent with values and methodologies published in the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated March 2022 (Revised).

It should be noted that annual crashes in the IHSDM analysis were estimated for years 2026 to 2055, as shown in the Appendix. Applying these crashes to the period from 2025 to 2054 can be considered conservative considering traffic volumes will likely be lower during timeframe.

7. **Environmental and Air Quality Impacts:** Changes in emissions are expected to be impacted by the time vehicles spend idling at each of the project intersections. The change in intersection delay between No Build and Build conditions was obtained from travel time analysis and converted to equivalents of vehicle-miles traveled (VMT) by applying fuel consumption for idling vehicles to average miles per gallon for passenger cars. The change in VMT equivalents was then applied to emission rates by vehicle type. 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 March 2022 (Revised).

8. **Water Quality Impacts:** Currently, nutrient runoff in the project area feeds downstream to the Tibbets Brook, which is listed by the Minesota Pollution Control Agency (MPCA) to hold excessive levels of e.coli bacteria and phosphorus levels. The project will incorporate sedimentation, filtration, plant uptake, and groundwater recharge methods to control nutrient runoff.

   Benefits from addressing nutrient runoff into the Mississippi River St. Cloud Watershed were derived by determining pollution costs per person and applying the rates to number of people impacted. National annual cost of water pollution from nutrients[7] was divided by the US population[8] to determine an average water pollution cost per person. This cost was then applied to the population of the City of Elk River[9], which is directly downstream from the runoff coming from the US 169 and CSAH 4 project area, to determine an estimate of potential water quality cost savings if nutrient runoff is to be mitigated.

   It is likely that additional individuals will be impacted by the reduction in nutrient runoff from the project area, as the Tibbet Brook flows into the drinking water intake for the Twin Cities, which contains more than 3 million residents. However, the water quality will likely be somewhat diluted from other sources by the time it reaches the Twin Cities. Thus, benefits to users outside of the City of Elk River were not monetized as part of the BCA but are likely to be realized. It was also assumed that these additional unquantified benefits may be offset from residual amounts of nutrient runoff possibly remaining after the project improvements are incorporated, rather than a full elimination of nutrient pollution in the Tibbets Brook and subsequently, the City of Elk River.

9. **Operating and Maintenance Costs**: Routine annual roadway maintenance costs associated with maintaining the additional roadway infrastructure under the Build Alternative were

[7] https://www.sciencedaily.com/releases/2008/11/081112124418.htm
[8] Table 1 from https://www.census.gov/data/tables/2008/demo/age-and-sex/2008-age-sex-composition.html
[9] https://www.census.gov/quickfacts/fact/table/elkrivercityminnesota/IPE120219

considered in the BCA. An annual maintenance cost of $8,100 per lane mile, which derived from maintenance reports for similar facility types within the Twin Cities metro area, was applied to the length of the new interchange pavement. This maintenance cost included costs associated with striping, snow plowing, minor repairs, and shoulder maintenance. An annual cost of $2,000 was also assumed for inspections of the new bridge in the Build Alternative based on recommendations from the MnDOT Bridge Office.

10. **Calculation of Remaining Capital Value**: Because many components of the initial capital costs have service lives well beyond the 30-year analysis period, the remaining capital value was calculated for the Build Alternative. These values were expressed in terms of 2020 dollars and were added to other project benefits in accordance with USDOT guidance. In determining remaining capital value of the initial capital cost, the costs of the Build Alternative were separated into the following categories:

    - Right of Way
    - Major Structures
    - Grading and Drainage
    - Sub-Base and Base
    - Surface
    - Miscellaneous Costs – Includes mobilization, removals, utility relocation, traffic control, and program delivery. These were assumed to be sunk costs and assigned zero remaining capital value.

    Project components in each cost category were assumed a service life based on recommendations provided by MnDOT Office of Transportation System Management.

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 the increase in roadway capacity.
    - Safety and quality of life benefits associated with connecting future trails on the east and west sides of US 169.
    - Savings on future rehabilitation costs required under a No Build scenario on the portions of US 169 and CR 4 being reconstructed as part of the realignment and interchange construction.
    - Benefits accrued in the second half of year 2025 after project opening. Accelerating the benefit-cost analysis period by a half-year is expected to produce approximately an additional $945 thousand in net present value.

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 2 – Total Project Results

	Initial Capital Cost (2020 Dollars)	Project Benefits (2020 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2020 Dollars)
No Build vs. Build	$24.4 million	$53.0 million	2.2	$28.6 million

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Appendix

IHSDM Predictive Crash Reports