Memorandum

SRF No. 16182

To: James Hallgren, PE, Assistant District Engineer
Minnesota Department of Transportation District 3

From: Nick Semeja, PE
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Date: November 30, 2022

Subject: Highway 371/Highway 210/ BNSF Railroad Grade Separation Project – 2022 CRISI 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 Highway 371/Highway 210/BNSF Railroad Grade Separation Project – 2022 CRISI 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.

The intersection of Highway (Hwy) 371, Hwy 210, and Burlington Northern Santa Fe (BNSF) railroad, at-grade crossing ID 917433S, has significant traffic safety and operational issues. The intersection experiences frequent congestion, crashes, and restricted access due to heavy vehicular traffic (31,500 vehicles per day) and blocked at-grade highway-rail crossing (six daily freight trains). This intersection serves the primary commercial and retail center of Baxter and provides connection to the neighboring city of Brainerd, MN.

The proposed project would construct a grade-separated interchange in place of the at-grade signal at Highway 371/Highway 210 and would also provide a grade separated crossing of the BNSF route located just south of the intersection. This project would provide relief to existing and future mobility and safety problems in the study area.

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 Highway 371 and Highway 210 intersection in its current configuration of an at-grade signalized intersection.

Build Alternative

The proposed project will replace the existing signalized intersection with a full access interchange. The assumed layout for the benefit-cost analysis includes two sets of access ramps to/from Highway 210 and Highway 371 immediately west and east of Highway 371. The Highway 371 overpass would span the BNSF rail crossing on the south leg of the intersection, removing the at-grade rail conflicts between trains and vehicles, pedestrians, and bicyclists. Adjacent local access along Highway 210 at Elder Drive would also be consolidated with the interchange to maintain sufficient access spacing in the project area.

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, August 2022[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 and frontage road system.
2. **Analysis Years**: The analysis assumed that construction would take place over a two-year period and be completed in 2027. Therefore, year 2028 was assumed to be the first full year of benefits that will be accrued from the project. Since the project includes construction of an interchange and full reconstruction of the Highway 371 and Highway 210 pavement adjacent to the new interchange, the analysis focused on the estimated benefits for the thirty-year period from 2028 to 2057. The present value of all benefits and costs was calculated using 2020 as the year of constant dollars.

[1] Table 5: http://www.dot.state.mn.us/planning/program/benefitcost.html

2. **Economic Assumptions**: The 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. Remaining capital value assumptions were consistent with rates from *Recommended remaining capital value factors for use in benefit-cost analysis in SFY 2023*[2], Minnesota Department of Transportation (MnDOT), Office of Transportation System Management, August 2022 (values were adjusted to reflect discount rate). The analysis was completed using an assumed discount rate of seven percent.

3. **Development Travel Time Savings**: Travel time changes in the Highway 371/Highway 210 study area were captured using Synchro/SimTraffic microsimulation modeling. No Build and Build models were developed for morning and afternoon/evening peak hours as well as additional hours throughout the day including midday and overnight hours, and analysis was performed for existing year 2022 and forecast year 2045. Year 2022 turning movement counts and forecasted year 2045 turning movement volumes were provided by MnDOT. The growth rate between existing year 2022 and year 2045 turning movement volumes is approximately 0.5 percent per year at the intersection of Highway 371 and Highway 210.

   To capture travel time estimates in hours outside the morning, midday, afternoon, and overnight peak hours, volume-to-travel time relationships were developed and applied in the BCA. StreetLight Data[3] for trips through the Highway 371/Highway 210 intersection was used to identify hour-of-day, day-of-week, and month-of-year volume profiles for years 2021 and 2022. 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 hours between the morning and afternoon/evening peak periods. Predicted operations for the No Build and Build Alternatives outside 7 am to 7 pm (where volumes were relatively low) were similar and thus, were excluded in the analysis. Figure 1 illustrates network travel times for each scenario for modeled time periods and the interpolated travel times for the remaining nine hours between 7 am and 7 pm. Once the daily travel time for each modeling scenario was established, day-of-the-week and month-of-the-year adjustment factors for study area traffic volumes were applied based on the annual volume profile obtained from StreetLight Data. The adjustment factors (see Table 1) reflect the number of vehicle trips through the study area relative to the analysis weekday and month of a Tuesday in March (i.e. the day and month the turn movement counts used in the microsimulation model were collected).

[2] http://www.dot.state.mn.us/planning/program/appendix_a.html
[3] StreetLight is a data analytics tool that processes annual vehicle probe data to determine detailed trip information. https://www.streetlightdata.com/

Figure 1. Network Travel Time

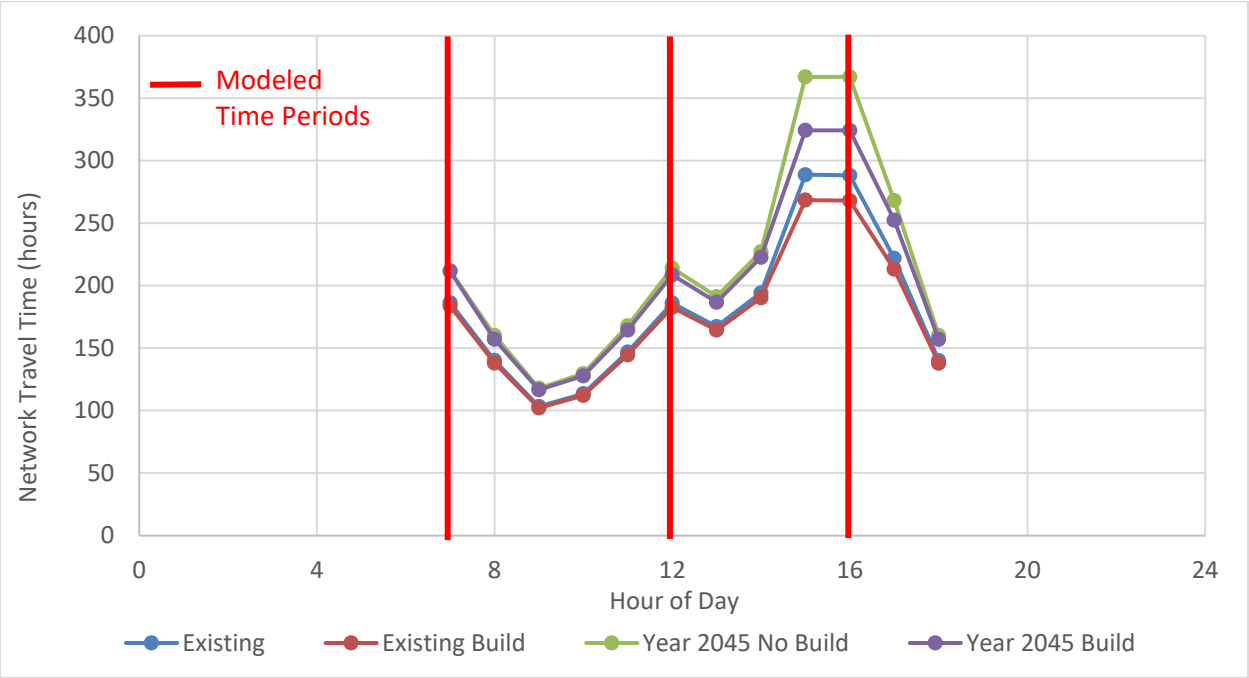

Table 1. Weekday and Monthly Volume Adjustment Factors

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	0.92	0.90	0.91	0.96	1.11	1.02	0.93
Feb	0.90	0.89	0.90	0.95	1.10	1.01	0.92
Mar	1.02	1	1.01	1.07	1.24	1.13	1.04
Apr	1.00	0.99	1.00	1.05	1.22	1.12	1.02
May	1.06	1.05	1.06	1.11	1.29	1.19	1.08
June	1.08	1.07	1.08	1.14	1.32	1.21	1.11
July	1.11	1.09	1.11	1.17	1.35	1.24	1.13
Aug	1.09	1.07	1.09	1.14	1.32	1.22	1.11
Sept	1.06	1.04	1.06	1.11	1.29	1.19	1.08
Oct	1.03	1.01	1.03	1.08	1.25	1.15	1.05
Nov	0.99	0.97	0.98	1.03	1.20	1.10	1.01
Dec	0.93	0.92	0.93	0.98	1.13	1.04	0.95

Outcomes from the analysis estimate full-year travel time for the No Build and Build Alternatives in years 2022 and 2045. Benefits for years between existing year 2022 and forecast year 2045 were interpolated based on an annual growth rate, and benefits for years beyond year 2045 were extrapolated using the same annual growth rate. Savings due to the reduction of travel time were calculated using costs per hour that account for vehicle occupancy and different vehicle types.

4. **Vehicle Occupancy and Vehicle Types**: The composite cost per mile used in the BCA 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 4.8 percent and was based on year 2019 daily traffic and heavy truck counts provided in the MnDOT Traffic Mapping Application.
    - Vehicle occupancy that was used in the analysis is consistent with values provided by the *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, dated March 2022. The analysis assumed 1.67 people per automobile and 1.00 people per truck.

5. **Safety Analysis**: The Build Alternative improves the Highway 371/Highway 210 intersection by converting the existing at-grade intersection into a grade-separated interchange. Reconstruction to a grade-separated interchange is expected to generate safety benefits by reducing the number of crashes at the existing Highway 371/Highway 210 intersection as well as at the intersection of Highway 210 and Elder Drive where access will be consolidated with the proposed interchange. The analysis used three-year existing (2019-2021) crash data at the Highway 371/Highway 210 and Highway 210/Elder Drive intersections to develop annual crashes by severity for the No Build Alternative.

    The crash modification factor from CMF Clearinghouse used in the BCA was obtained for the project improvement: convert an at-grade intersection into a grade-separated interchange.[4] To determine estimated reduction of existing intersection crashes, the CMF was applied to crashes tied to each intersection. Year 2045 crashes for the No Build Alternative were estimated based on peak hour turning movement growth. Similar assumptions used to estimate existing year Build Alternative crashes by severity were applied to produce year 2045 estimates.

    Safety benefits were also quantified for the reduction in potential collisions with trains and other modes of transportation (e.g. vehicles, pedestrians, bicyclists, etc.). The Federal Railroad Administration's Web Accident Predictive System[5] was used to estimate the annual frequency of collisions. The Highway 371 rail crossing has a predicted annual frequency of 0.037 collisions. Since the FRA tool does not predict injury severity of collisions, a distribution of deaths and injuries for highway-rail incidents was obtained from the National Safety Council[6] (table provided in BCA Workbook) and applied to expected collisions in the analysis.

    The safety benefit for reduction in intersection crashes was quantified for years 2020 (i.e. the centroid of the existing crash analysis timeframe) and 2045 and interpolated/extrapolated based on the forecasted growth in intersection volume to determine total safety benefits for the period from year 2028 to 2057. Safety benefits for the reduction in potential highway-rail collisions used the same growth rate assumptions as the intersection crash reductions.

[4] https://www.cmfclearinghouse.org/detail.cfm?facid=459
[5] https://safetydata.fra.dot.gov/webaps/
[6] https://injuryfacts.nsc.org/home-and-community/safety-topics/railroad-deaths-and-injuries/

However, an existing year of 2022 was used based on the FRA database assumptions. Crash cost assumptions are consistent with values and methodologies published in the *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, dated March 2022. Detailed calculations on crash cost estimates are outlined in the attached BCA workbook.

6. **Environmental and Air Quality Impacts**: Changes in emissions are expected to be impacted by the time vehicles spend idling at the study intersection(s). The change in vehicle delay between No Build and Build conditions was obtained from the 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.

   The change in VMT equivalents was also assumed to impact vehicle operating costs. Total change in emissions and vehicle operating costs per mile traveled by mode were valued in accordance with the Benefit Cost Analysis Guidance for Discretionary Grant Programs, dated March 2022 (Updated).

7. **Operating and Maintenance Costs**: Routine annual roadway maintenance costs associated with maintaining the additional roadway infrastructure under the Build Alternative were considered in the BCA. An annual maintenance cost of $9,000 per lane mile, which was provided by MnDOT, was applied to the length of the new interchange pavement. An annual cost of $0.35 per square foot of bridge deck, resulting in $16,341 annually, was assumed for bridge inspection and maintenance and also provided by MnDOT.
8. **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:
   - Major Structures
   - Grading and Drainage
   - Sub-Base and Base
   - Surface
   - Miscellaneous Costs – Includes mobilization, removals, temporary pavement and drainage, traffic control, contingency, 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.

9. **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.
    - Savings on future rehabilitation costs required under a No Build scenario on the portions of Highway 371 and Highway 210 being reconstructed as part of the interchange construction.
    - Travel time, vehicle operating cost, and air quality benefits due to the reduction in vehicle delay at the existing at-grade rail crossing.

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 workbook

Table 1 - 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	$21.1 million	$32.5 million	1.5	$11.4 million

Attachment
BCA Workbook