SRF No. 12151

To:	Joe Triplett, Chisago County Public Works Director
From:	Nick Semeja, PE Nicole Bitzan, AICP
Date:	February 27, 2023
Subject:	US Highway 8 Reconstruction Project – 2023 RAISE Discretionary Grant 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 US Highway 8 Reconstruction Project – 2023 RAISE Discretionary 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 allow for the fact that benefits accrue over a long period of time while costs are incurred primarily in the initial years. The primary elements that can be monetized are travel time, vehicle operating costs, crashes, environmental impacts, quality of life, 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 primary issues to be addressed by the project are the travel time, operations, and safety benefits associated with reconstructing US 8 from I-35 to Karmel Avenue to a 4-lane divided roadway with a median and 8' shoulders. Currently, US 8 is a rural two-lane undivided highway with limited shoulders and just under 60 public and private accesses with multiple uncontrolled full intersections; all contributing to major safety concerns and traffic delays. US 8 serves as an interregional corridor for freight, commuter, seasonal recreation, and local traffic. Commuters and freight travel from the Twin Cities approximately 18 miles south to the Wisconsin border in the east.

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 8-mile US 8 corridor from the cities of Forest Lake to Chisago City in its current geometric and operational condition: with no modifications or restrictions to current access. This includes the two-lane undivided roadway design with a posted speed limit of 55 miles per hour with just under 60 public and private accesses to US 8. The existing roadway is programmed to have a mill and overlay in year 2025 if the reconstruction project does not occur.

Build Alternative

The proposed project replaced the existing two-lane undivided sections with a four-lane divided roadway with 8' shoulders and a raised median. Over 40 private and public accesses will be closed and redirected to frontage or backage roads, when possible, to reduce vehicle conflict points and to improve traffic safety along the Project Corridor. Also, full access intersection improvements are proposed for the following eight intersections:

Intersection	Improvement
TH 8 and Greenway Ave	Signalized
TH 8 and Heath Ave	RCI and pedestrian underpass
TH 8 and Hale Ave	RCI
TH 8 and Pioneer Rd	Signalized
TH 8 and James Ave	RCI
TH 8 and 276th St	RCI
TH 8 and Viking Blvd	Signalized
TH 8 and Karmel Ave	Roundabout

Additional improvements considered in the BCA include:

- Installing concrete barriers and/or cable guardrail in the median areas
- Constructing dedicated turn lanes
- Constructing a 10-foot-wide multiuse trail along the northside of US 8
- Installing a shoulder rumble/mumble strip from Pioneer Rd to Karmel Ave (not located where there is curb and gutter)

BCA Methodology

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

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

- Quality of life benefits
- Initial capital costs: These costs were broken into distinct categories in accordance with service life (consistent with the recommendations from MnDOT Office of Transportation System Management[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. Project components were assumed to have a linear depreciation of service life over the benefit-cost analysis period.
- Maintenance costs

Analysis Years

This analysis assumed that the Build Alternative would be constructed would begin in year 2025 (right-of-way acquisition takes place in years 2023 and 2024) and be completed in year 2027. The analysis focused on the estimated benefits for the twenty-year period from 2027 to 2046[2]. The present value of all benefits and costs was calculated using 2021 as the year of current dollars.

Economic Assumptions

The value of time and cost of crashes were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023. Local values for vehicle operating costs (excluding emissions costs) were obtained from *Recommended standard values for use in cost-effectiveness and benefit-cost analysis in SFY2023* from MnDOT Office of Transportation System Management, August 2022[3]. The analysis was completed using an assumed discount rate of seven percent.

Development of Vehicle Hours Traveled (VHT) and Vehicle Miles Traveled (VMT)

Regional year 2014 and 2040 VMT and VHT from the Twin Cities Regional Travel Demand Model were summarized for the No Build and Build Alternatives. The project subarea as shown in Figure 1 was used for the VMT/VHT analysis. This subarea was selected as an "area of influence" to capture changes in travel patterns resulting from the improvement along US 8, as shown in Figure 2.

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1 https://www.dot.state.mn.us/planning/program/benefitcost.html
2 The study used 365 days per year.
3 https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-202

Figure 1. Project Subarea

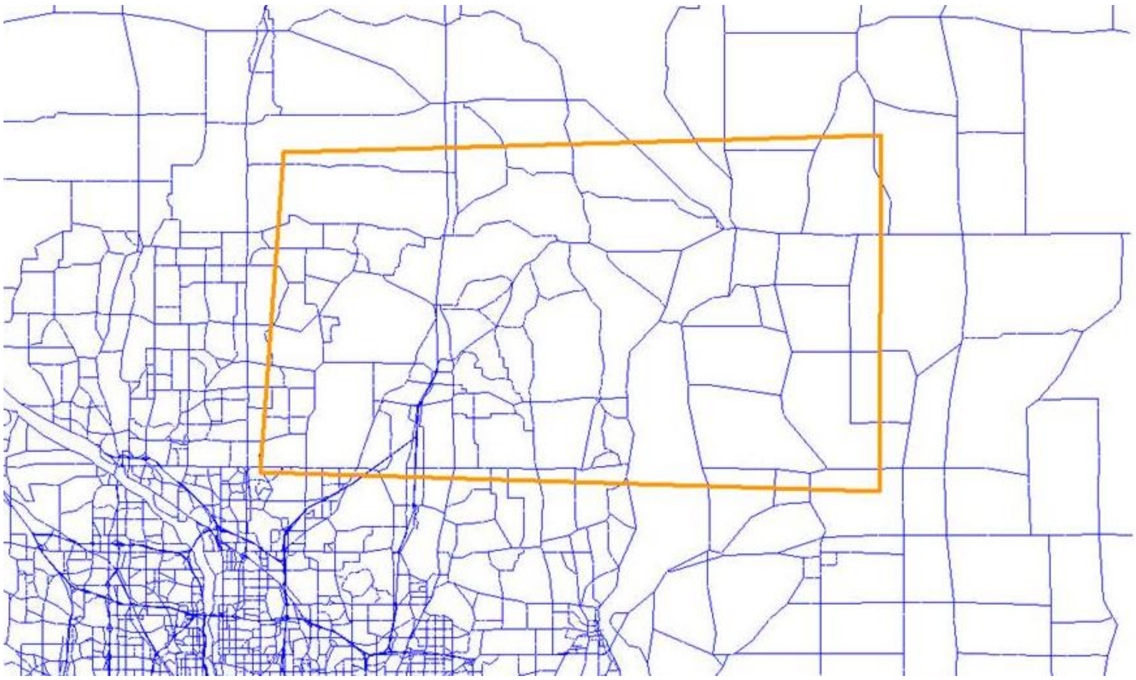
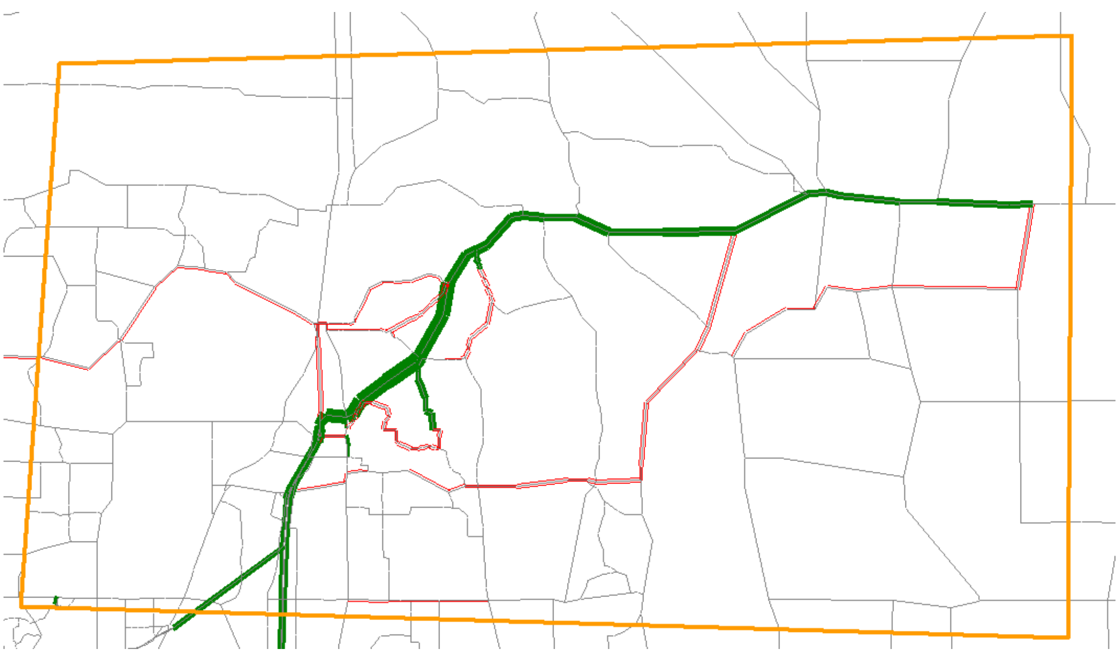


Figure 2. Project Delta Plot



The regional model captured travel time changes related to trip diversion and increased free-flow speed on US 8. Benefits for the years between 2014 and 2040 were interpolated based on model results using an annual growth rate. VMT and VHT for years beyond year 2040 were extrapolated using the same annual growth rate. Savings due to reduction of VMT and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types. Outcomes from travel demand modeling effort showed a 0.52% annual regional VMT growth under a build scenario.

Vehicle Occupancy, Vehicle Types and Peak Hours

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 6 percent, based on MnDOT's Traffic Volume Mapping Tool[4] for AADT and HCAADT counts along the project length and dividing HCAADT with AADT.
- 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 occupancy of 1.67 people per automobile and 1.00 people per truck. These values are from the 2017 National Household Travel Survey.

Safety Analysis

The Build Alternative improves the US 8 corridor by converting it from a two-lane undivided roadway to a four-lane expressway. Reconstruction to a four-lane expressway is expected to generate safety benefits by transferring daily traffic from the existing facility to a historically safer four-lane divided roadway. Additionally, the roadway and intersection improvements consisting of medians, right- and left- turn lanes along both major roads, shoulder rumbles, four J-Turn Intersection (or RCI), a roundabout, and access management to include closures and re-routes of accesses frontage/backage roads were also assumed to produce safety benefits at the corresponding intersections. The analysis used five-year existing (January 2018 to December 2022) crash data along the US 8 corridor between I-35 and Karmel Avenue to develop crash rates by severity for the No Build Alternative.

Detailed analysis was undertaken to identify crashes at each intersection undergoing improvements. Crash modification factors from CMF Clearinghouse, MnDOT, and AASHTO HSM were obtained for each pertinent improvement type:

- Conversion from 2-lane to 4-lane divided,
- Install raised median,
- Provide a channelized left-turn lane on both major- and minor- road approaches,
- Provide a right turn lane on two approaches to an intersection (minor-road stop-controlled)/(signalized),
- Reduce access point density,
- Install J-Turn Intersection (RCI)
- Install shoulder rumble strips

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[4] https://www.dot.state.mn.us/traffic/data/tma.html

- Convert to roundabout.

To determine estimated reduction of existing intersection crashes, CMFs for relevant improvements were applied to crashes tied to each intersection. To determine estimated reduction of existing segment crashes, the CMF to reduce access point density, conversion from 2-lane to 4-lane divided, install raised median, and the sum of all intersection crash savings within the segment were calculated and applied. Year 2040 crashes for the No Build Alternative were estimated based on VMT growth on the US 8 project extents. Similar assumptions used to estimate existing year Build Alternative crashes by severity were applied to produce year 2040 estimates. Detailed calculations and sources for each CMF are provided in the BCA Workbook.

The analysis also considered a change in crashes on other corridors in the network where traffic volumes are expected to change between alternatives. VMT by facility type (e.g. collector, expressway, freeway, etc.) was extracted from the regional travel demand model to capture the level of diversion on adjacent corridors in the network. Metro district average crash rates by facility type and severity were obtained from the MnDOT Section Toolkit. Model VMT by facility type was applied to facility crash rates to project a weighted crash rate by severity for each scenario. The number of crashes by severity for each scenario were then estimated by applying scenario VMT to the weighted crash rates by severity. VMT for the project extents of US 8 was excluded from the regional crash analysis to isolate impacts of VMT shifts to other facilities and to avoid double counting US 8 crashes. The safety benefit was quantified for years 2015 and 2040 and interpolated/extrapolated based on an annual growth rate to determine total safety benefits for the period from year 2027 to 2046. 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.

Environmental and Air Quality Impacts

Annual VMT in the surrounding transportation network is expected to increase since motorists would be more likely to take a longer route on local roadways to experience less travel time on an expressway facility. The change in VMT between No Build and Build conditions was obtained from the regional travel demand model and 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 January 2023.

Maintenance Costs

Roadway maintenance costs, associated with maintaining the additional roadway infrastructure under the Build Alternative, were considered as an additional cost to the Build Alternative. An annual maintenance cost of $8,100 per lane mile, which derived from maintenance reports for similar facility types within Minnesota was applied in this analysis. This maintenance cost included costs associated with striping, minor repairs, and shoulder maintenance. Other maintenance costs between the alternatives were assumed to be similar.

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 2021 dollars and was added to other user benefits in accordance with

USDOT guidance. In determining remaining capital value, the initial costs of the proposed alternatives were separated into the following categories:

- Right of Way
- Major Structures
- Grading and Drainage
- Sub-Base and Base
- Surface
- Miscellaneous Costs – Includes mobilization, temporary pavement and drainage, traffic control, contingency (risk), and program delivery. These were assumed to be sunk costs and assigned zero remaining capital value.

Factors Not Quantified

Several factors were not quantified as part of the analysis because review of initial data indicates low potential to yield substantial benefit. These factors included the following:

- Trips lying outside the specified subarea may accrue benefits that were not accounted for.
- Operating cost savings from improved vehicle efficiency due to increased average vehicle speeds in Build Alternative.
- Crash costs associated with network trips diverting to/from different facility types outside of the specified sub-area were not quantified.
- The methodology does not specifically monetize any transit benefits.

Monetizing Qualitative Benefits

Since the project includes multi-use trails, it is important to quantify the qualitative benefits of the improvements. The methodology used in this section has been previously used in Minnesota and was approved by Minnesota Department of Transportation. The following methodology and assumptions are recommended.

Main Components

The main components include:

- Cyclists' Mobility
- Cyclists' Mortality (Health)
- Cyclists' Recreation
- Cyclists' Facility Improvement (Amenity)
- Reduced Auto-Use

Demand Model

Cycling demand was calculated using the methodology developed by National Cooperative Highway Research Program's *National Cooperative Highway Research Program's (NCHRP) Report 552: Guidelines for*

Analysis of Investments in Bicycle Facilities (2006)[5] for Build Alternative in comparison with No Build Alternative. The models and methodologies were complemented with engineering judgment, locally developed demand models and knowledge to identify the most likely value within the possible range.

Population Near Project Area

GIS buffer analysis using 2015-2019 American Community Survey Estimates with 2020 census tracts were used for estimating the population within 0.25-mile, 0.25-0.5 mile and 0.5-1 mile distance from the multi-use trail.

Relevant Population Characteristics

The characteristics were obtained from multiple sources including:

- Chisago County Transportation Plan Update (2017) to obtain the population growth[6]
- 2015-2019 American Community Survey Estimates to determine the portion of the population between 20-65 years old
- 2019 ACS 5-Year Estimates (Table S0801) for MN to determine cycling commuters[7]
- *NCHRP Report 552 (2006)*[5] to determine the percentage of adults who commute.
- *Benefit-Cost Analysis Guidance for Discretionary Grant Programs - March 2022 (Revised)* to determine the average cycling trip length (miles).

Cycling Demand - New and Existing Daily Cyclists (Commuters and Recreational)

The first step to determine cycling demand is to estimate the population residing near the assumed facilities. Bicycle demand and benefit calculations were based on a methodology described in the *NCHRP Report 552 (2006)*[5]. A buffer analysis was performed around the project area using 2015-2019 American Community Survey Estimates with 2020 census tracts. The census tract data was apportioned based on the area meaning if 25% of the tract was in the buffer than 25% of the population from the 2015-2019 ACS estimates was included in the buffer. Buffers were created at the quarter-mile, half-mile, and one-mile distances from the project (Figure 3). The population residing within these distances of the project was the population assumed to use the new facilities at propensities that vary with distance. Of the population residing in the buffers, the number of commuters for cycling was estimated and the state average of bicycle commuters (.7 percent) was used. The *NCHRP Report 552 (2006)*[5] supplied multipliers to estimate new commuters and existing and new total riders based on the number of existing commuters. For the existing total riders, the report suggests three different models to calculate low, moderate and high estimates of riders due to large variability in bicycle usage in different cities and even larger differences between different neighborhoods within a city. The study allows applying local knowledge and judgement to choose a most likely point estimate within the range of demand levels estimated by those three models. The

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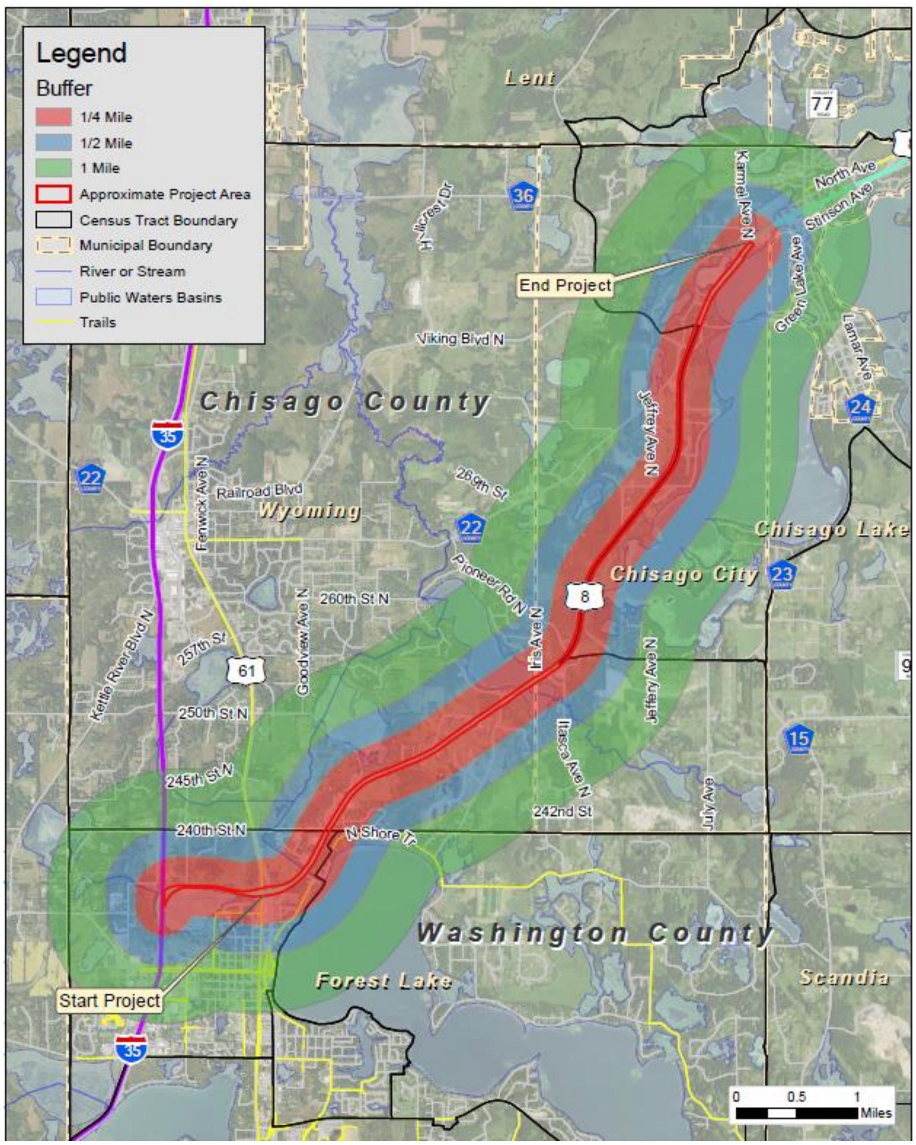
[5] *National Cooperative Highway Research Program's (NCHRP) Report 552: Guidelines for Analysis of Investments in Bicycle Facilities (2006)*
[6] https://www.chisagocountymn.gov/DocumentCenter/View/9483/Comprehensive-Plan-2017-PDF?bidId=
[7] https://data.census.gov/cedsci/table?q=cycling%20commuter&g=0400000US27&tid=ACSST5Y2019.S0801

judgement criteria included design detail of the facility, land use, how suggested facility fits into a larger system, existing counts, etc. For the current project, moderate estimate of total daily cyclists and a 50 percent existing rate was assumed for benefit estimation. Existing rate is the share of daily cyclists in the project area that can be assumed to be existing cyclists and not induced by new infrastructure.

Since cycling demand estimated total daily cyclists, all calculated benefits were multiplied by the annual use. Annual use was determined by type of cyclist, recreational or commuter. All benefits impacting recreational use was multiplied by 275 days (9 months) while benefits impacting commuters were multiplied by 250 (50 weeks multiplied by 5 days).

Figure 3. Cycling Demand Buffers



Walking Demand

NCHRP Report 552 (2006) [5] states that building new walk facilities is not likely to tangibly increase walking demand as opposed to bicycling for a couple of reasons including: walking is much more common than bicycling and walking facilities are much more widespread than bike facilities. To be conservative in the benefit quantification, no new walkers (and consequently no pedestrian benefits) were assumed in the BCA.

Mobility Cost Savings

To estimate the value bicyclists place on mobility, the *NCHRP Report 552 (2006)* [5] recommends applying the value of time to the additional travel time bicycle commuters are willing to travel out of their way to get to the facilities. Researchers defined five facility types as:

A) Off-road facilities,
B) In-traffic facilities with bike lane and no on-street parking,
C) In-traffic facilities with a bike lane and on-street parking,
D) In-traffic facilities with no bike lane and no on-street parking, and
E) In-traffic facilities with no bike lane but with on-street parking

These facility types were used to conduct a stated preference survey. The resultant logit model suggests that bicyclists were willing to travel an additional 21.6 minutes to use an off-street facility instead of a street with no facility and no on-street parking. Table 1 summarizes some of NCHRP's suggested mobility benefits that are relevant to the project.

Table 1. Mobility benefits of different bicycle facility improvements

Base facility	Improved facility	Minutes
B	A	5.2
D	A	21.6
E	A	30.5
E	C	16.4

US Highway 8 Reconstruction Project area's existing conditions are assumed to be a 'D' facility type and the build scenario is assumed as category A.

After multiplying by the value of time ($16.60/hour)[8], the values were applied to new and existing commuters to calculate the mobility benefit. An adjustment factor was added to the NCHRP method to account for the existing facilities in the proximity of the segment of interest. The mobility yielded a total benefit of $470K (undiscounted) over the 20-year evaluation period. Mobility benefits of weekend travel were not included in this estimate.

[8] Benefit Cost Analysis Guidance for Discretionary Grant Programs, dated January 2020

Mortality (Health) Cost Savings

Exercise helps to keep people healthy, thereby reducing their annual health costs. *The Benefit-Cost Analysis Guidance for Discretionary Grant Programs - March 2022 (Revised)* estimates that the daily physical activity of new cyclist, either commuter or recreational, saves each of them $6.31 daily. The first twenty years after project implementation, it was estimated that these savings totaled over $858K (undiscounted).

Recreation Cost Savings

Examining the value people place on different recreational activities, the *NCHRP Report 552 (2006)*[5] estimates that one hour of bicycle recreation is worth $10. The BCA assumed that a "typical" day of bicycling included one hour of activity. Applying this value to the new daily recreational riders yielded a total benefit of $1.6M (undiscounted) over the evaluation period.

Cycling Facility Improvement (Amenity) Cost Savings

Various dedicated cycling facility improvements can affect journey preferences among cyclists. The *Benefit-Cost Analysis Guidance for Discretionary Grant Programs – January 2023* estimates a benefit of $1.42 per new cyclist, either commuter or recreational, per cycling mile for a cycling path with at-grade crossing where no comparable parallel facility exists. Although the new trail length measures 7.48 miles, the estimated value per cyclist was capped at 2.38 miles, the average length of a cycling trip in the 2017 National Household Travel Survey. These values assume an average cycling trip speed of 9.8 miles per hour or, in the case of off-street paths with no at grade crossings, a free flow cycling speed of 12.1 miles per hour. The estimated savings for cycling facility improvement totaled over $481K (undiscounted) over the evaluation period.

Reduced Auto (Congestion) Cost Savings

As the new bicycle facilities encourage a mode shift to bicycle commuting from automobile commuting, it was assumed that the region would see benefits related to reduced congestion. These benefits include lower travel times through improved traffic flow, reduced emissions, and operational savings for bicyclists. The *NCHRP Report 552 (2006)*[5] estimated that the benefit derived per commuter is $0.13 per mile for city centers and $0.08 for suburban areas. Given the project location, land use, congestion and air pollution level, an average of these two values, $0.105, was used. Also, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs - March 2022 (Revised)* suggests using the average trip length, 2.38 miles. The project generated roughly $14K (undiscounted) in benefits over the evaluation period. This is a conservative estimate.

Factors Not Quantified

Several factors are not quantified as part of this methodology because review of initial data indicates low potential to yield substantial cost or benefit. These factors include the following:

- Operations costs due to being part of a currently functioning trail network and roadway facility.
- Trips lying outside the specified subarea may accrue benefits that were not accounted for.

- No safety benefit is assumed for the suggested facilities mainly because there is no consensus in the literature that bicycle facilities can necessarily decrease the total number of bicycle crashes and in some cases off-street facilities have been found to be riskier than bike lanes[9].
- Child cyclists: the official documentation in NCHRP Report 552 (2006) does not cover this category of facility beneficiaries.

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 greater than 1.0. The larger the ratio number, the greater the benefits per unit cost. Results of the benefit-cost analysis are included in Table 2 below. See link for the complete benefit-cost analysis workbook.

Table 2 – Results (7% Discount Rate)

	Project Benefits (2021 Dollars)	Project Costs (2021 Dollars)	Benefit-Cost Ratio	Net Present Value (2021 Dollars)
No Build vs. Build	$133.3 million	$58.9 million	2.26	$74.4 million

[9] NCHRP Report 552: Guidelines for Analysis and Investments in Bicycle Facilities (2006), p 34.
Jensen, S.U., "Bicycle Tracks and Lanes: a Before-After Study", Transportation Research Board 87th Annual Meeting. Washington, D.C., 2008.
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