Project Title: Cass County Highway 10 Roadway Improvements
Benefit-Cost Analysis Narrative
Date: February 28, 2024
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SUMMARY

Overview

This memo provides detailed documentation of the Benefit-Cost Analysis (BCA) performed to evaluate the public benefits generated by the Cass County Safety and Mobility Improvement Project within the State of North Dakota. The BCA demonstrates the cost effectiveness of the project for which the project sponsor Cass County is seeking Federal support, measured in terms of a benefit-cost ratio (BCR). The Project has independent utility with benefits exceeding cost.

Based upon the BCA presented in the remainder of this document, the project is expected to generate over $26.4 million in total discounted user benefits and cost just under $13.1 million in capital expenditures. Therefore, the project generates a Benefit/Cost Ratio of 2.01:1. **Table 1** below summarizes the long-term outcomes calculated in this BCA.

Table 1 Summary of Benefit/Cost Analysis

Capital Expenditures	Total Benefits	Benefit/ Cost Ratio
$ 13,134,410	**$ 26,433,813**	**2.01:1**

Project Background

Figure 1 shows the locations for the two unique project segments of the proposed conditions. **Table 2** lists the termini of each of the proposed roadway improvements that were modeled and monetized for the benefit/cost analysis and how those elements compare to a no build scenario. The project is broken down into three segments within western Cass County. The build improvements assumed in each segment are located in **Table 3**.

Table 2 Segment Location Description

Segment Description	Starting at	Ending at	Length
Cass County Route 10 West	County Route 1	ND 38	5.9 miles
Cass County Route 10 Buffalo	ND 38	140th Avenue SE	1.0 mile

Figure 1 Proposed Build Improvements

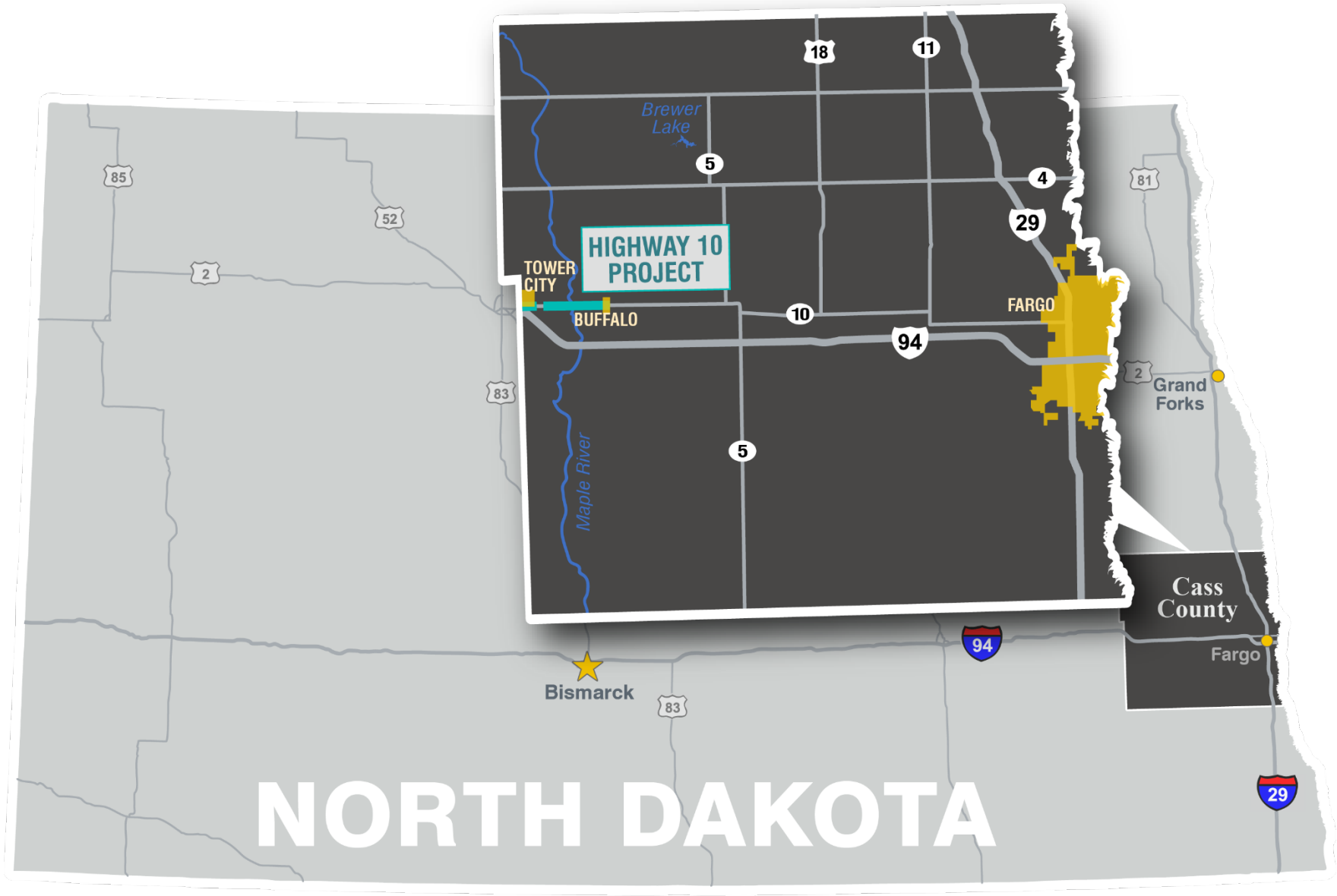

Table 3 Summary of Build Design Elements

Design Element Location	No Build	Proposed Build
Cass County Route 10 (from CR 1 to ND 38)	Two Lane undivided highway with no shoulder and edgeline rumble strips	Two Lane undivided highway with 6-foot shoulder, and shoulder/centerline rumble strips
Cass County Route 10 (ND 38 to 140th Ave SE)	Two Lane undivided highway with no shoulder and edgeline rumble strips	Two Lane undivided highway with 6-foot shoulder, and shoulder/centerline rumble strips
Cass County 10 at Maple River	Box culvert with the road sunken down into the stream's flood plane	Raise road elevation up 10 feet along 1,000 feet

BCA Approach

The BCA approach and methodology used in this analysis is consistent with the U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2023. **Figure 2** shows the categories that were monetized for BCA analysis. **Table 4** gives a short explanation of the categories, methodologies, and assumptions. More information for each category is provided in later sections of the report.

Figure 2 Summary of Benefit/Cost Monetized Categories

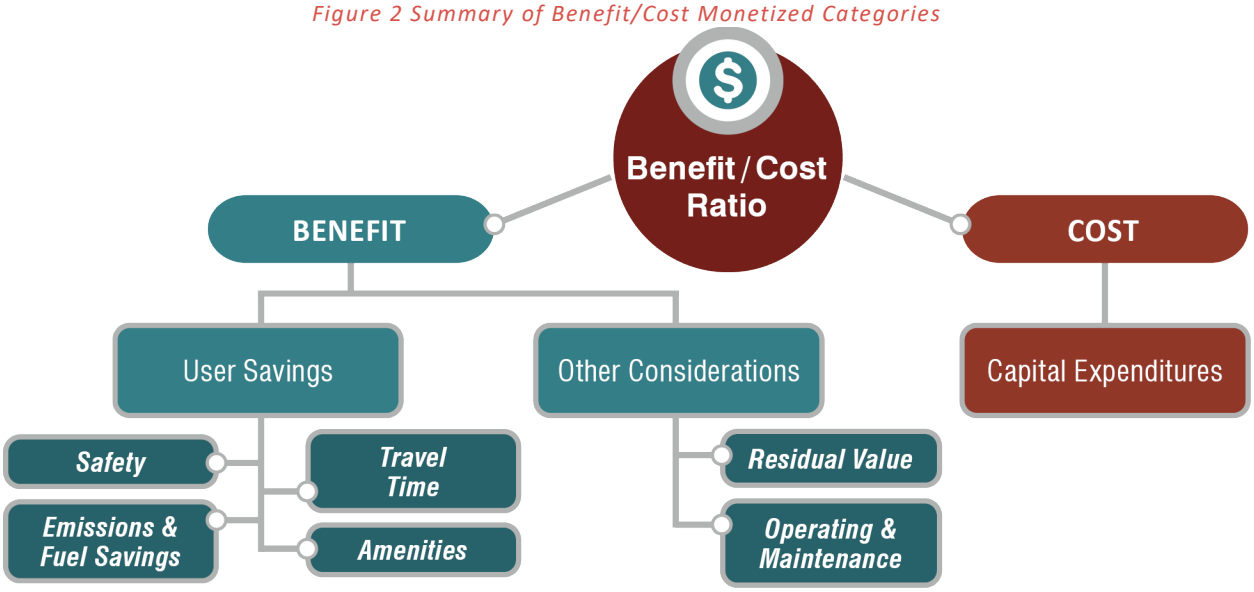

Table 4 Summary of Benefit/Cost Analysis Methodology

Category	Methodology Overview
Safety	Five-year crash data gathered from NDDOT along the segments. Future crash costs were calculated with the annual average crash rate over the 5-year history. Crash cost factors from CMF Clearinghouse were used to estimate safety benefits for the proposed build.
Travel Time	Travel time, Fuel, and Emission benefits from flood improvements at the Maple River culvert on the West CR 10 Segment were calculated from the added detour time and distance. EPA guidance was used to quantify the total emission. The other two segments are assumed to have no change in travel time or delay, therefore zero related benefits or costs.
Emissions & Fuel Savings	
Amenities	Preliminary layouts used to define amenity quantities for bike and pedestrian facilities. Annual pedestrian and bicycle trips were estimated with engineering judgment.
Residual Value	Appraisal of remaining value at the design year based on expected infrastructure life and linear approximation of loss in value.
Operating & Maintenance	Estimate of yearly operating and maintenance costs based on studies for roadway maintenance and multimodal facility maintenance snow removal.
Capital Expenditures	Preliminary layouts and straightforward quantity takeoff methods

BCA Results Summary

The results of the BCA analysis indicate a positive Benefit-Cost Ratio of 2.01:1. All costs in this summary are discussed in 2022 dollars and account for the appropriate discount rate of 3.1 percent.

Total discounted benefits before Maintenance and Residual Value are estimated to be $24.2 million. The results of the four categories used to monetize user benefit in the benefit/cost analysis are described below and shown in **Table 5**:

- Safety – Crashes among all injury severities are forecasted to decrease by 50% and crash costs by 62% targeting the most severe crash types. Crash cost reduction in this project is primarily attributed adding 6-foot shoulders plus centerline rumble strips to CR 10.
- Travel Time – By raising the elevation of CR 10 over the Maple River, detouring during flood events is expected to be eliminated. It is predicted to save travelers over $190,000 in additional travel time and vehicle operating savings over the 20-year analysis period.
- Emissions – Along with travel time savings, raising CR 10 at the Maple River will cut down CO_2 emissions by 18 tons in 20 years and save users over $8,000 in emission benefits and fuel savings.
- Amenities – With adding 6-foot shoulders along CR 10 plus improving the existing sidewalks in Buffalo, total amenity benefits for pedestrians and bicyclists were calculated to be over $230,000.

Table 5 Summary of Discounted User Benefits in 2022 Dollars

Calendar Year	Safety Benefits	Travel Time Benefits	Emissions Benefits	Amenities Benefits	Total User Benefits
2027	$1,551,835	$10,211	$400	$13,138	$1,575,584
2028	$1,506,760	$10,227	$396	$12,998	$1,530,380
2029	$1,462,993	$10,233	$401	$12,859	$1,486,486
2030	$1,420,495	$10,230	$406	$12,722	$1,443,852
2031	$1,379,230	$10,217	$410	$12,586	$1,402,443
2032	$1,339,163	$10,196	$414	$12,452	$1,362,224
2033	$1,300,258	$10,167	$416	$12,319	$1,323,160
2034	$1,262,482	$10,131	$419	$12,188	$1,285,219
2035	$1,225,802	$10,087	$423	$12,058	$1,248,369
2036	$1,190,186	$10,037	$425	$11,929	$1,212,577
2037	$1,155,604	$9,981	$428	$11,802	$1,177,814
2038	$1,122,026	$9,919	$430	$11,676	$1,144,050
2039	$1,089,422	$9,852	$431	$11,551	$1,111,257
2040	$1,057,764	$9,780	$433	$11,428	$1,079,405
2041	$1,027,026	$9,703	$435	$11,306	$1,048,470
2042	$997,179	$9,622	$436	$11,185	$1,018,423
2043	$968,199	$9,538	$437	$11,066	$989,239
2044	$940,060	$9,449	$438	$10,948	$960,895
2045	$912,738	$9,358	$439	$10,831	$933,365
2046	$886,209	$9,263	$440	$10,716	$906,627
Total	**$23,795,428**	**$198,200**	$8,457	**$237,755**	**$24,239,841**

In addition to user benefits, operating & maintenance costs and residual value are included in the numerator of the benefit/cost ratio. No net maintenance costs are expected to incur for the build condition. The expected residual value of the project infrastructure at the design year (2046) is over $2.1 million.

When user benefits are added to operating & maintenance costs and residual value, the total benefits from the completion of the project are expected to be over $26.4 million as shown in **Table 6** below.

Total Capital Costs are estimated to be $13.1 million, producing a benefit/cost ratio of 2.01:1.

Table 6 Summary of Total Benefits and Costs

Calendar Year	Safety Benefits	VMT Benefits	Travel Time Benefits	Emissions Benefits	Amenities Benefits	Residual Value	Operating & Maintenance	Total Benefit
2027	$1,551,835	$5,159	$5,052	$400	$13,138	$0	$0	$1,575,584
2028	$1,506,760	$5,167	$5,060	$396	$12,998	$0	$0	$1,530,380
2029	$1,462,993	$5,170	$5,063	$401	$12,859	$0	$0	$1,486,486
2030	$1,420,495	$5,168	$5,061	$406	$12,722	$0	$0	$1,443,852
2031	$1,379,230	$5,162	$5,055	$410	$12,586	$0	$0	$1,402,443
2032	$1,339,163	$5,151	$5,045	$414	$12,452	$0	$0	$1,362,224
2033	$1,300,258	$5,137	$5,030	$416	$12,319	$0	$0	$1,323,160
2034	$1,262,482	$5,118	$5,012	$419	$12,188	$0	$0	$1,285,219
2035	$1,225,802	$5,096	$4,991	$423	$12,058	$0	$0	$1,248,369
2036	$1,190,186	$5,071	$4,966	$425	$11,929	$0	$0	$1,212,577
2037	$1,155,604	$5,043	$4,938	$428	$11,802	$0	$0	$1,177,814
2038	$1,122,026	$5,011	$4,908	$430	$11,676	$0	$0	$1,144,050
2039	$1,089,422	$4,978	$4,874	$431	$11,551	$0	$0	$1,111,257
2040	$1,057,764	$4,941	$4,839	$433	$11,428	$0	$0	$1,079,405
2041	$1,027,026	$4,902	$4,801	$435	$11,306	$0	$0	$1,048,470
2042	$997,179	$4,862	$4,761	$436	$11,185	$0	$0	$1,018,423
2043	$968,199	$4,819	$4,719	$437	$11,066	$0	$0	$989,239
2044	$940,060	$4,774	$4,675	$438	$10,948	$0	$0	$960,895
2045	$912,738	$4,728	$4,630	$439	$10,831	$0	$0	$933,365
2046	$886,209	$4,680	$4,583	$440	$10,716	$2,193,972	$0	$3,100,600
Total	**$23,795,428**	**$100,137**	**$98,063**	**$8,457**	**$237,755**	**$2,193,972**	**$0**	**$26,433,813**
							Capital Expenditures	**$13,134,410**
							Benefit/Cost Ratio	**2.01**

METHODOLOGY

A Benefit-Cost Analysis (BCA) is a conceptual framework that quantifies, in monetary terms, the value of costs and benefits of a project as possible. Benefits are broadly defined as cost savings or other quantifications of value. They represent the extent to which people impacted by the project are made better-off.

Key Assumptions

Key assumptions for the benefit/cost analysis include parameters that apply to all categories and elements of the analysis. All key assumptions are consistent with the U.S. Department of Transportation (USDOT), Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2023. These key assumptions include:e

- **Analysis Period:** The benefit/cost analysis assumes a construction year of 2026 and evaluates a 20-year period resulting in a first analysis year of 2027 to a design year of 2046.
- **Discounting**: Except for the emissions benefits, a 3.1% discount was applied to all monetized values to express values in 2022 dollars. CO_2 emissions were the only exception and were discounted at a 2% rate based on USDOT guidance.
- **User Benefit Unit Values:** USDOT guidance for the valuation of travel time savings, safety benefits, amenities, and reductions in air emissions were used.

Safety Benefits Methodology

In estimating preventable crashes, NDDOT provided a 5-year crash history from 2018-2022. The safety benefits for the Build condition were calculated from Crash Modification Factors (CMF) from CMF Clearinghouse matching injury severity and crash types (see **Table 7**). Crashes along the segments were estimated for 20 years based on the average crash rates from the 5-year historical crash data (see **Table 8**).

A few crash patterns show up in the crash history. The following location with recurring crashes is:

- CR 10 West segment had 5 crashes in the 5.9-mile section or 1.0 crash per year over the 5-year crash history, while incurring $2.6 million in crash costs. Lane departure crashes (sideswipe, run-off road, head-on) accounted for 80% of crashes and 99% of crash costs.

Table 7 Crash Modification Factors (CMF) used

ID	CMF	Treatment	Location	Crash Type	Injury Severity
3360	0.55	Install Centerline Rumble Strips	CR 10 West, CR 10 Buffalo	Head On, Sideswipe	K, A, B, C
7755	0.68	Widen Shoulders	CR 10 West, CR 10 Buffalo	All	All

Table 8 20 Year Crash Forecasts and Costs

	O	C	B	A	K	All Crashes	Discounted to 2022 $
No Build	4.1	0.0	12.4	4.1	4.1	24.7	**$38,652,911**
Build	4.1	0.0	7.2	1.5	1.5	14.4	**$14,857,483**
Crash Reduction Benefits	0.0	0.0	5.2	2.6	2.6	10.3	**$23,795,428**

To reduce future crashes, Crash Modification Factors (CMF) were applied to the No Build crash rates with the most detailed CMF on a crash-by-crash basis. The Build Scenario addresses the historical crashes using mitigation through targeted improvements based upon CMF research that maximizes safety along CR 10 with widening and installing rumbles.

Travel Time/Mile Benefits Methodology

The travel time and travel mile savings were derived from the flood improvements to CR 10 at Maple River, located in the west segment. This addresses an average of 3 days of flooding on average every year (based on a 10-year average) that shuts the roadway down from through traffic. Flooding is assumed to worsen to 5 days in 2045 through deterioration of the roadway. The Buffalo CR 10 segment has no flooding concerns to generate any user from. Travel time costs for the No Build condition were calculated from the detour via I-94 and ND 38 which is used during flood events compared to the normal travel time using CR 10. Assumed annual values are shown in **Table 9** and travel time benefits by year are in **Table 10**, while benefits derived by vehicle operations by miles travel are in **Table 11**.

Table 9 Flood Detour Values

Year	Base Travel Time (min)	Detour Travel Time (min)	Travel time difference	Detour Miles	AADT	Truck Percentage	Average Annual Flood Days
2022	8	14	6	5.4	500	12.6%	3
2045	8	14	6	5.4	569	12.6%	5

Table 10 Travel Time Benefits Annual Vehicle Hours Traveled (VHT) data

Calendar Year	Annual VHT	Travel Time Savings	Discounted 3.1% to 2022 Savings
2027	179	$5,885	$5,052
2028	185	$6,077	$5,060
2029	191	$6,269	$5,063
2030	197	$6,461	$5,061
2031	203	$6,654	$5,055
2032	209	$6,846	$5,045
2033	214	$7,038	$5,030
2034	220	$7,230	$5,012
2035	226	$7,422	$4,991
2036	232	$7,614	$4,966
2037	238	$7,806	$4,938
2038	244	$7,999	$4,908
2039	249	$8,191	$4,874
2040	255	$8,383	$4,839
2041	261	$8,575	$4,801
2042	267	$8,767	$4,761
2043	273	$8,959	$4,719
2044	279	$9,151	$4,675
2045	285	$9,344	$4,630
2046	290	$9,536	$4,583
Total	**4,697**	**$154,207**	**$98,063**

Table 11 Travel Benefits from Vehicle Miles Traveled (VMT)

Calendar Year	Annual VMT	Travel Savings	Discounted 3.1% to 2022 Savings
2027	9,680	$6,010	$5,159
2028	9,996	$6,206	$5,167
2029	10,312	$6,402	$5,170
2030	10,628	$6,598	$5,168
2031	10,944	$6,794	$5,162
2032	11,261	$6,991	$5,151
2033	11,577	$7,187	$5,137
2034	11,893	$7,383	$5,118
2035	12,209	$7,579	$5,096
2036	12,525	$7,775	$5,071
2037	12,841	$7,972	$5,043
2038	13,157	$8,168	$5,011
2039	13,473	$8,364	$4,978
2040	13,789	$8,560	$4,941
2041	14,105	$8,756	$4,902
2042	14,421	$8,953	$4,862
2043	14,737	$9,149	$4,819

2044	15,053	$9,345	$4,774
2045	15,369	$9,541	$4,728
2046	15,685	$9,737	$4,680
Total	**253,655**	**$157,469**	**$100,137**

Emissions Benefits Methodology

Emissions benefits were calculated from the assumptions from the Travel Time Benefits Methodology in the above section. The additional travel time during flood events was translated directly to additional vehicle hours traveled (VHT) for emission benefits.

For CO_2 Emission savings, the VHT savings was converted to an annual fuel savings in gasoline for all purpose vehicles and diesel for trucks. The conversion factor from VHT to fuel comes from the U.S. Department of Energy. The annual fuel savings were then converted to CO_2 metric tons using Environmental Protection Agency (EPA) standard values shown in **Table 11**. Other emissions savings were converted to grams and metric tons directly from the VHT also using EPA standard values.

The amount of gasoline and diesel gallons saved used in the CO2 calculation were used to calculate fuel savings by the vehicles based on national average fuel price from January 2023.

All emissions were monetized using yearly values given in Table A-6 of the appendix of the U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023- Revised. For emissions data that was not based on VHT, additional values were based on US Environmental Protection Agency and other national sources. The other notable difference is that guidance states CO_2 emissions are to be discounted at a 2% yearly rate instead of the 3.1% discount that is applied to all other categories and emissions.

Table 12 Emissions Benefits Conversion Factors

	Gasoline fuel (All-purpose vehicles)	Diesel fuel (trucks)
VHT to fuel conversion (gallons/hour)	0.39	0.64
Average price per gallon of Fuel 2022	$3.809	$4.898
Co2 production (metric tons/gallon)	0.008887	0.010180
NOX production (grams/hour)	3.515	39.0515
PM2.5 production (grams/hour)	0	1.092

Amenities Benefits Methodology

The amenities of the Build option for this project include the addition of a 6-foot-wide shoulder on both sides of both segments of County Route 10 in the project area, and a 6-foot-wide sidewalk on the north side of County Route 10 from Wilcox Avenue to west of 5th Avenue. The No Build

condition has no pedestrian or bicycle facilities outside of Buffalo and there is only 1,500 feet of sidewalk within Buffalo. Therefore, each foot of facility width for the multipurpose wide shoulder and sidewalk will be considered a new benefit on the CR 10 West Segment for the pedestrian amenity calculation. While in the CR 10 Buffalo Segment, the sidewalk will be improved to current ADA standards and the shoulder will be expanded through the 1.0-mile segment giving benefits outside of the existing facilities. The pedestrian trips and bicycle trips were calculated separated between within and outside of Buffalo. The user value per cycle-mile used was based on classifying the multi-purpose path as "Cycling Path with At-Grade Crossings".

Table 13 shows the pedestrian and bike user assumptions made for the amenity analysis. Ped and bike volumes were annually grown at 2% to reflect population growth (2.11% historic yearly growth rate from U.S Census Data) for Cass County from 2010 (169,778) to 2020 (184,525).

Table 13 Amenities Benefits Data and Assumptions

	Rural Segments Pedestrians	Buffalo Segment Pedestrians	Rural Segments Bicyclists	Buffalo Segment Bicyclists
Pedestrian Average Trip Length (miles)	1	0.1	8	1.5
Unit Benefit	10-ft wide path $1.10 per pedestrian-mile	6-ft wide path $1.10 per pedestrian-mile	At-Grade Cycling Path $1.57 per cycle-mile	
Existing Annual Trips	360	22,500	900	900
Future Annual Trips	524	32,778	1,311	1,311
20-year Amenities Benefits	**$29,221**		**$206,139**	

Operating & Maintenance Costs Methodology

The operating and maintenance costs for the proposed project are expected to be similar as the project is primarily a reconstruct and not a facility that did not exist before.

The annual operating and maintenance cost assumptions were approximated based on the following national sources.

- The cost of roadway maintenance per lane mile was approximated from two studies and rounded to $8,000 per mile, scaled to $9,760 in 2022 dollars:
  - The first study was completed by the US Forestry service entitled "Average Annual Cost for Road Maintenance by Operational Maintenance Level". ND 18 was attributed as Maintenance Level 4 (ML4) which according to the study would approximate $7,517 in annual costs to operate and maintain foliage, cleaning of drainage structures, refresh pavement markings, repair/patch potholing, replace signs, etc.
  - The second study was completed by Caroll County Department of Public Works in Maryland. The study goal was to inform citizens about road maintenance for the goal of transparency and efforts to use the most cost-effective tools available. The

study found that paved roadways cost an average of $8,500 per mile to maintain in 2014.

While these studies do not give the most accurate representation of maintenance costs as they were completed in varying years and may not be fully applicable to the project, they offer a solid approximation for comparison between the no build and build condition.

Residual Value Methodology

The residual value in year 2046 was estimated by breaking the project into the elements of preliminary engineering, right-of-way, major structures, roadway grading and drainage, roadway sub-base and base, and roadway surface borrowed from MnDOT guidance for its benefit/cost processes. **Table 14** shows the MnDOT guidance for useful life for the categories listed. Any capital expenditures that do not fit into these categories will assume to have a useful life less than 20 years and will not be included in the residual value calculation.

Table 14 Residual Value Categories and Useful Life Assumptions

Category	Useful Life
Preliminary Engineering & Final Design	0
Right-of-Way	100
Major Structures & Associated Removals	60
Utilities, Stormwater, Grading & Drainage	50
Sub-Base and Base	40
Surface	25

After determining the useful life, the residual value at the final year of analysis was calculated with the assumption of linear depreciation for each category.

Capital Expenditure Methodology

Capital expenditures were calculated using length, width, depth methods for each of the two sections of roadways. These included pavement, class-5 base, cement stabilization, multimodal element costs. Engineering costs were than calculated from each segments construction costs to identify design environmental, right-of-way, and construction engineering costs associated with the project. **Table 15** shows a cost breakdown and approximate schedule for the project capital expenditures and **Table 16** shows the costs by Funding Source separated between county and federal funding. It is expected that costs for the ND 18 left-turn lanes will be used from RAISE grant funds through the Cass County led project.

Table 15 Project Capital Expenditures

Year	PE / Environmental	Right of Way / Easements / Relocation	Final Design / Construction Engineering	Construction	Total
2026	$0	$0	$0	$13,134,410	**$13,134,410**
Total	**$0**	**$0**	**$0**	**$13,134,410**	**$13,134,410**

Table 16 Funding Sources

Funding Source	Amount	%
RAISE	$6,567,205	50%
Cass County	$6,567,205	50%
Total	**$13,134,410**	**100.0%**

RESULTS

User Benefit Results

Total user benefits after applying the appropriate discount values came to a 20-year total benefit of over $24.2 million. **Table 17 s**hows how that benefit is split out between the different categories.

Table 17 Summary of User Benefits Revisited

Safety Benefits	Travel Time / Mile Benefits	Emissions Benefits	Amenities Benefits	Total User Benefits
$23,795,428	**$198,200**	**$8,457**	**$237,755**	**$24,239,841**

The safety benefits of $23.8 million reflects an approximately 50% decrease in overall injury and a decrease in crash cost by 62%. Installing centerline rumble strips and widening the shoulders to 6 feet will provide benefits to sideswipe, head-on, and run-off road crashes that are common on the West Segment of CR 10.

Table 18 Safety Benefit Summary

Year	Predicted Crashes By Severity										Total Safety Savings	Discounted 3.1% to 2021 Dollars
	No Build					Build						
	O	C	B	A	K	O	C	B	A	K		
2027	0.20	0.00	0.61	0.20	0.20	0.71	0.20	0.00	0.36	0.08	$1,807,752	$1,551,835
2028	0.20	0.00	0.61	0.20	0.20	0.71	0.20	0.00	0.36	0.08	$1,809,656	$1,506,760
2029	0.20	0.00	0.61	0.20	0.20	0.71	0.20	0.00	0.36	0.08	$1,811,560	$1,462,993
2030	0.20	0.00	0.61	0.20	0.20	0.71	0.20	0.00	0.36	0.08	$1,813,464	$1,420,495
2031	0.20	0.00	0.61	0.20	0.20	0.72	0.20	0.00	0.36	0.08	$1,815,368	$1,379,230
2032	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,817,272	$1,339,163
2033	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,819,176	$1,300,258
2034	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,821,080	$1,262,482
2035	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,822,984	$1,225,802
2036	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,824,888	$1,190,186
2037	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,826,792	$1,155,604
2038	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,828,696	$1,122,026
2039	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,830,600	$1,089,422
2040	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,832,504	$1,057,764
2041	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,834,408	$1,027,026
2042	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,836,312	$997,179
2043	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,838,216	$968,199
2044	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,840,120	$940,060
2045	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,842,024	$912,738
2046	0.21	0.00	0.62	0.21	0.21	0.72	0.20	0.00	0.36	0.08	$1,843,928	$886,209
Total	**4.1**	**0.0**	**12.4**	**4.1**	**4.1**	**14.4**	**4.1**	**0.0**	**7.2**	**1.5**	**$36,516,800**	**$23,795,428**

O – No Injury Crashes
C – Possible Injury Crashes
B – Non-Incapacitating Injury Crash
A – Incapacitating Injury Crash
K – Killed

Table 19 Travel Time Benefit Summary

Year	Annual Vehicle Hour Benefits	Total Travel Time Savings	Annual Vehicle Mile Benefits	Total Vehicle Mile Benefits	Discounted 3.1% to 2022 dollars
2027	179	$5,885	9,680	$6,010	$10,211
2028	185	$6,077	9,996	$6,206	$10,227
2029	191	$6,269	10,312	$6,402	$10,233
2030	197	$6,461	10,628	$6,598	$10,230
2031	203	$6,654	10,944	$6,794	$10,217
2032	209	$6,846	11,261	$6,991	$10,196
2033	214	$7,038	11,577	$7,187	$10,167
2034	220	$7,230	11,893	$7,383	$10,131
2035	226	$7,422	12,209	$7,579	$10,087
2036	232	$7,614	12,525	$7,775	$10,037
2037	238	$7,806	12,841	$7,972	$9,981
2038	244	$7,999	13,157	$8,168	$9,919
2039	249	$8,191	13,473	$8,364	$9,852
2040	255	$8,383	13,789	$8,560	$9,780
2041	261	$8,575	14,105	$8,756	$9,703
2042	267	$8,767	14,421	$8,953	$9,622
2043	273	$8,959	14,737	$9,149	$9,538
2044	279	$9,151	15,053	$9,345	$9,449
2045	285	$9,344	15,369	$9,541	$9,358
2046	290	$9,536	15,685	$9,737	$9,263
Total	4,697	$154,207	253,655	$157,469	**$198,200**

Table 19 shows the forecasted vehicle hour and mile savings with build conditions and the corresponding annual savings. The travel time benefits of over $190,000 shows the savings that users will gain by not having to detour during flood events.

Table 20 shows the forecasted emissions savings with build conditions and the corresponding annual savings. The emissions benefits of $8,000 reflects the environmental cost of the 5.4 mile detour when Maple River floods, which based upon historical records floods and closes the road, thus, requiring a detour for 3 through 5 days per year.

The Amenities benefits which were calculated to be over $230,000. **Table 21** and **Table 22** show the forecasted amenities benefits for the build scenario. Benefits in the Build condition come from the added paved shoulders that will benefit pedestrians and bicycles through both segments along with improving the existing sidewalks within the City of Buffalo.

Table 20 Emissions and Fuel Benefit Summary

Year	Annual Benefits (Hour)	Fuel Savings		NO_X Savings	$PM_{2.5}$ Savings	CO_2 Savings	Total Emissions / Fuel Savings	Discounted 2%/3.1% to 2022 Dollars
		gasoline	diesel	metric tons	metric tons	metric tons		
2027	179	61	14	0.00	0.00	0.7	$457	$400
2028	185	63	15	0.00	0.00	0.7	$464	$396
2029	191	65	15	0.00	0.00	0.7	$483	$401
2030	197	67	16	0.00	0.00	0.8	$502	$406
2031	203	69	16	0.00	0.00	0.8	$520	$410
2032	209	71	17	0.00	0.00	0.8	$539	$414
2033	214	73	17	0.00	0.00	0.8	$556	$416
2034	220	75	18	0.00	0.00	0.8	$575	$419
2035	226	77	18	0.00	0.00	0.9	$595	$423
2036	232	79	19	0.00	0.00	0.9	$613	$425
2037	238	81	19	0.00	0.00	0.9	$633	$428
2038	244	83	20	0.00	0.00	0.9	$652	$430
2039	249	85	20	0.00	0.00	1.0	$672	$431
2040	255	87	21	0.00	0.00	1.0	$691	$433
2041	261	89	21	0.00	0.00	1.0	$712	$435
2042	267	91	22	0.00	0.00	1.0	$731	$436
2043	273	93	22	0.00	0.00	1.1	$751	$437
2044	279	95	22	0.00	0.00	1.1	$773	$438
2045	285	97	23	0.00	0.00	1.1	$793	$439
2046	290	99	23	0.00	0.00	1.1	$815	$440
Total	**4,697**	**1,601**	**379**	**0.04**	**0.00**	**18.1**	**$12,527**	**$8,457**

Table 21 Pedestrian Amenities Benefit Summary

Year	CR 10 West Segment		CR 10 Buffalo		Total Amenities Savings	Discounted 3.1% to 2022 Dollars
	Average Trip Length (miles)	Number of Annual Trips (trips/year)	Average Trip Length (miles)	Number of Annual Trips (trips/year)		
2027	0.5	360	0.1	22,500	$1,881	$1,615
2028	0.5	367	0.1	22,950	$1,919	$1,597
2029	0.5	375	0.1	23,409	$1,957	$1,580
2030	0.5	382	0.1	23,877	$1,996	$1,564
2031	0.5	390	0.1	24,355	$2,036	$1,547
2032	0.5	397	0.1	24,842	$2,077	$1,530
2033	0.5	405	0.1	25,339	$2,118	$1,514
2034	0.5	414	0.1	25,845	$2,161	$1,498
2035	0.5	422	0.1	26,362	$2,204	$1,482
2036	0.5	430	0.1	26,890	$2,248	$1,466
2037	0.5	439	0.1	27,427	$2,293	$1,450
2038	0.5	448	0.1	27,976	$2,339	$1,435
2039	0.5	457	0.1	28,535	$2,386	$1,420
2040	0.5	466	0.1	29,106	$2,433	$1,405
2041	0.5	475	0.1	29,688	$2,482	$1,390
2042	0.5	485	0.1	30,282	$2,532	$1,375
2043	0.5	494	0.1	30,888	$2,582	$1,360
2044	0.5	504	0.1	31,505	$2,634	$1,346
2045	0.5	514	0.1	32,136	$2,687	$1,331
2046	0.5	524	0.1	32,778	$2,740	$1,317
Total		**8,747**		**546,082**	**$45,703**	**$29,221**

Table 22 Cyclist Amenities Benefit Summary

Year	CR 10 West Segment		CR 10 Buffalo		Total Amenities Savings	Discounted 7% to 2021 Dollars
	Average Trip Length (miles)	Number of Annual Trips (trips/year)	Average Trip Length (miles)	Number of Annual Trips (trips/year)		
2027	8	900	1.5	900	$13,424	$11,523
2028	8	918	1.5	918	$13,692	$11,400
2029	8	936	1.5	936	$13,966	$11,279
2030	8	955	1.5	955	$14,245	$11,158
2031	8	974	1.5	974	$14,530	$11,039
2032	8	994	1.5	994	$14,821	$10,921
2033	8	1,014	1.5	1,014	$15,117	$10,805
2034	8	1,034	1.5	1,034	$15,419	$10,690
2035	8	1,054	1.5	1,054	$15,728	$10,576
2036	8	1,076	1.5	1,076	$16,042	$10,463
2037	8	1,097	1.5	1,097	$16,363	$10,351
2038	8	1,119	1.5	1,119	$16,690	$10,241
2039	8	1,141	1.5	1,141	$17,024	$10,131
2040	8	1,164	1.5	1,164	$17,365	$10,023
2041	8	1,188	1.5	1,188	$17,712	$9,916
2042	8	1,211	1.5	1,211	$18,066	$9,811
2043	8	1,236	1.5	1,236	$18,428	$9,706
2044	8	1,260	1.5	1,260	$18,796	$9,602
2045	8	1,285	1.5	1,285	$19,172	$9,500
2046	8	1,311	1.5	1,311	$19,556	$9,399
Total		**21,868**		**21,868**	**$326,156**	**$208,534**

Benefit/Cost Ratio

In addition to the four user benefits there are operating & maintenance concerns, residual value, and capital expenditures that round out the benefit/cost analysis. The operating & maintenance considerations showed that there is very little difference between the no build and build scenarios. Adding left turn lanes onto ND 18 gives the minimal increase in costs in the build condition. **Table 23** shows a summary of the expected annual increase in operating and maintenance costs. **Table 24** shows a summary of the residual value calculation.

Table 23 Operating and Maintenance Cost Summary

Year	No Build	Build	Net Operating Benefit	Total Net Operating Benefits in 2022 Dollars
2027	$67,344	$67,344	$0	$0
2028	$67,344	$67,344	$0	$0
2029	$67,344	$67,344	$0	$0
2030	$67,344	$67,344	$0	$0
2031	$67,344	$67,344	$0	$0
2032	$67,344	$67,344	$0	$0
2033	$67,344	$67,344	$0	$0
2034	$67,344	$67,344	$0	$0
2035	$67,344	$67,344	$0	$0
2036	$67,344	$67,344	$0	$0
2037	$67,344	$67,344	$0	$0
2038	$67,344	$67,344	$0	$0
2039	$67,344	$67,344	$0	$0
2040	$67,344	$67,344	$0	$0
2041	$67,344	$67,344	$0	$0
2042	$67,344	$67,344	$0	$0
2043	$67,344	$67,344	$0	$0
2044	$67,344	$67,344	$0	$0
2045	$67,344	$67,344	$0	$0
2046	$67,344	$67,344	$0	$0
Total	**$1,346,880**	**$1,346,880**	**$0**	**$0**

Table 24 Residual Value Summary

Expenditure Category	Capital Costs		Asset Life (years)	2046 Remaining Value	Present Value discounted 3.1% to 2022 dollars
Preliminary Engineering & Final Design	$0	0%	0	$0	$0
Right-of-Way	$0	0%	100	$0	$0
Major Structures	$0	0%	60	$0	$0
Removals	$656,721	5%	60	$437,814	$204,090
Utilities and Stormwater	$1,313,441	10%	50	$788,065	$367,363
Grading and Drainage	$1,970,162	15%	50	$1,182,097	$551,044
Sub-base and Base	$3,283,603	25%	40	$1,641,721	$765,339
Surface	$3,283,603	25%	25	$656,721	$306,136
Remaining "Other" Project Costs	$2,626,882	20%	20	$0	$0
Total Project Cost	$13,134,410	100%			
Residual Value				$4,706,497	$2,193,972

The residual value showed that at the end of the 20-year analysis time frame the project is expected to retain over $4.7 million in useful life costs before discounting which equates to approximately 35% of its initial capital expenditure. After discounting the residual value became $2.2 million.

A Benefit Cost Summary is provided in **Table 25**. The capital expenditures which constitute the denominator of the benefit/cost ratio was calculated to be $13.1 million. When the user benefits, operating & maintenance costs, residual value, and capital expenditures are all added together, the Total Benefits equal $35.3 million. The result is a benefit/cost ratio of 2.01.

Table 25 Benefit/Cost Ratio Summary

20-year Time Period	Total User Benefits	Operating & Maintenance Costs	Residual Value	Capital Expenditures	Benefit/Cost Ratio
2027-2046	$24,239,841	$0	$2,193,972	$13,134,410	2.01

The 20-year period is for the analysis period post construction.