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Subject: North Dakota Freight Reliability and Preservation on US 52 Project
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 North Dakota Freight Reliability and Preservation on US 52 Project (Project) 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 changes in travel time, vehicle operating costs, vehicle crashes, capital costs, 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.

Description of Alternatives

For the purpose of this analysis, a No Build and Build Alternative were under consideration.

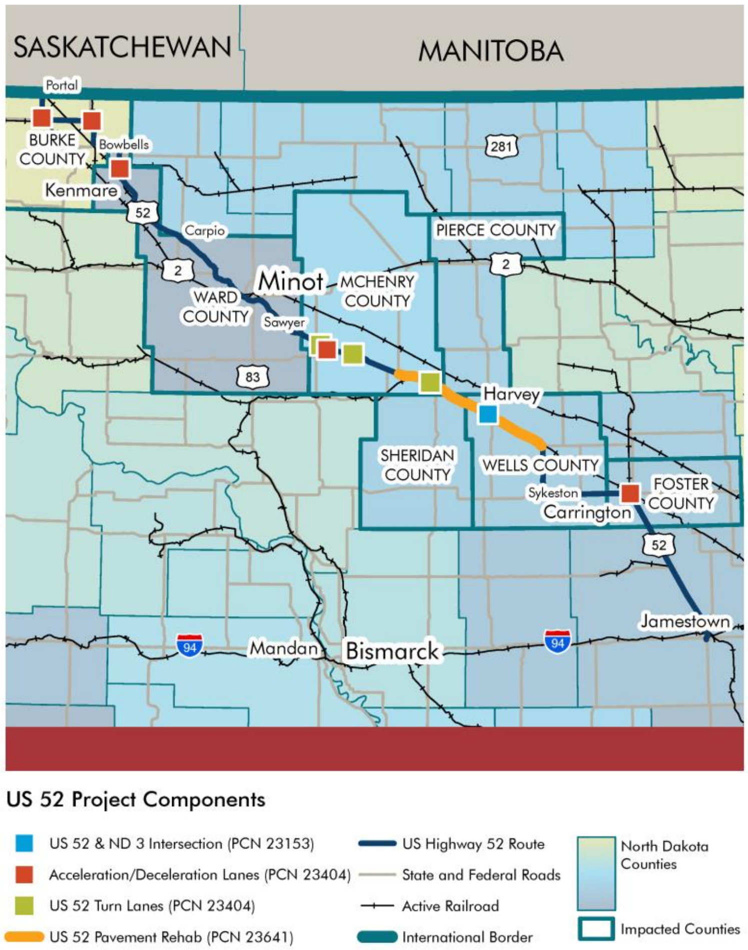
No Build Alternative

Under the No Build Alternative, the existing safety and road surface quality issues will persist. Without a complete resurface, US 52 will continue to degrade and will quickly reach a point where drivers will start slowing down to compensate for the poor road quality. This will increase travel time costs for US 52 users. It is expected that NDDOT will perform enough maintenance to keep the road open, but that the comfortable travel speed will be reduced over time as the surface quality continues to degrade. Reduced surface quality also increases vehicle maintenance costs for road users. Safety issues will persist where acceleration and deceleration lanes are being installed as part of the Build. There have been severe injury crashes as well as less severe crashes at these locations, and without the project improvements, observed crash rates are expected to remain unchanged.

Build Alternative

The Build Alternative includes resurfacing 44.5 miles of US 52 which will save drivers time by allowing them to travel at desirable speeds comfortably. The resurfacing will also create savings by avoiding increased vehicle maintenance costs resulting from driving on a poor-quality road. Intersection improvements and acceleration and deceleration lanes from sites south of Portage to Carrington will help keep motorists safe as they use this important corridor.

Figure 1 – Project Location Map



Maintenance costs associated with the project were expected to be incurred over the benefit cost analysis period.

BCA Methodology

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

1. Main Components: The main components analyzed included:
   - Crashes by severity
   - Travel time
   - Vehicle maintenance costs

- Road maintenance costs
- Initial capital costs: Capital costs were expected to be incurred in year 2025
- Remaining Capital Value: The remaining capital value (value of improvement beyond the analysis period) was considered a benefit and was added to other user benefits.

2. **Analysis Years**: This analysis assumed that the Build Alternative would be constructed over a one-year period in 2025. Therefore, 2026 was assumed to be the first full year that benefits will be accrued from the project. The analysis primarily focused on annual benefits for the twenty-year period from 2026 to 2045. The present value of all benefits and costs was calculated using 2022 as the year of constant dollars.
3. **Economic Assumptions**: Value of time, vehicle operating costs, and cost of crashes were obtained from the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, dated December 2023.[1] The analysis was completed using an assumed discount rate of 3.1 percent.
4. **Development of Vehicle Hours Traveled (VHT)**: The road surface that will be replaced as part of this project has sections that are already in mediocre condition. Without repaving, this section of US 52 will soon become rough enough that travelers will slow down in response to vibrations coming from their wheels. This assumption of slowing down once a road reaches a certain roughness was the basis for travel time savings estimated for the project.

   NDDOT provided the current international roughness index (IRI) measurements for the relevant sections of US 52. IRI measures the distance an average car's wheels move up and down as the car travels along one mile of road. The more the wheels move up and down, the rougher the road and the higher the IRI. In general, IRI units are either inches per mile or meters per kilometer. If a speed is set, then the IRI statistics can be further broken down to represent the number of inches an average wheel moves per second which corresponds to vibration felt by the driver. By solving for the miles traveled per second at the posted speed limit, 65 mph, that fraction of a mile is the fraction of the total IRI value the wheel moves in one second. The equations below show an example of this relationship for an IRI measurement of 120 inches per mile and a speed of 65 mph.

$$IRI = 120\frac{inches}{mile}\ ;\ Speed = 65\frac{miles}{hour} = 0.0181\frac{miles}{second}$$

$$0.0181\frac{miles}{second} * 120\frac{inches}{mile} = 2.17\frac{inches}{second}$$

   When the road has an IRI of 120 inches per mile and a car is traveling at 65 mph the wheel is expected to move up and down an average of 2.17 inches per second. This value is an

[1] https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

expression of the vibration the driver feels while traveling 65 mph on a road with an IRI value of 120.

At higher speeds, a road is considered "mediocre" by FHWA standards[2] when the IRI is between 120 and 170 and "poor" for an IRI greater than 170. For the purposes of this analysis, it is assumed that at an IRI measurement of 120, motorists will begin to modify their speed in response to the vibration they experience. An IRI of 120 was chosen because it corresponds to the beginning of the "mediocre" FHWA road quality category. Additionally, research[3] shows that it is around the 120 IRI level of roughness that vehicle maintenance costs begin to be impacted by road quality, suggesting vibrations caused at that point of road roughness are significant and noticeable.

To estimate how speed will change in the future as the road continues to degrade, present road deterioration rates were provide by NDDOT and these rates were used to fore IRI values for each section of road were estimated throughout the study period. Once estimated, these IRI values were used to find the speed that holds wheel vibration constant at 2.17 inches per second at that IRI. A wheel vibration rate of 2.17 inches was chosen because it reflects 120 IRI at 65 mph, which was the point at which motorists were expected to begin to slow down in response to road roughness. Drivers were expected to slow down to keep wheel vibration at or below 2.17 inches per second, the assumed comfortable limit, and so future comfortable travel speed was forecast according to the algebraic relationship between IRI, speed, and the targeted wheel vibration rate. This relationship is shown in the equation below.

$$if\ IRI > 120\,\frac{inches}{mile}\ then\ Comfortable\ Speed\,\frac{miles}{hour} = \frac{2.17\,\frac{inches}{second}}{IRI\,\frac{inches}{mile}} * 3600\,\frac{seconds}{hour}$$

5. **Vehicle Operating Costs:** As described in the previous section, IRI increases were forecast through the study period and were averaged by segment length. This weighted average IRI was used to estimate operating cost increases. NCHRP guidance regarding how different levels of road roughness increase the cost of maintenance to cars and trucks was then used to estimate changes in vehicle operating costs. The relationship between IRI and vehicle operating costs, estimated by NCHRP, is shown in Table 1.

   In an effort to avoid overestimating project benefits, it was assumed that as vehicles slowdown in response to vibration from road roughness, vehicle maintenance costs would also decline proportional to speed decreases. This means both road roughness and vehicle speed were taken into account when increased vehicle operating cost was estimated.

[2] https://www.fhwa.dot.gov/policy/1999cpr/ch_03/cpg03_3.cfm

[3] National Academies of Sciences, Engineering, and Medicine. 2012. Estimating the Effects of Pavement Condition on Vehicle Operating Costs. Washington, DC: The National Academies Press. https://doi.org/10.17226/22808. Page 58 Table 7-5

Table 1. Vehicle Operating Cost Increase by International Roughness Index (IRI)

IRI (m/km)	**2**	**3**	**4**	**5**	**6**
IRI (in/mile)	**127**	**190**	**254**	**317**	**380**
Medium Car	2%	4%	8%	15%	22%
Van	1%	1%	5%	11%	17%
SUV	2%	3%	9%	20%	32%
Light Truck	1%	2%	5%	12%	20%
Articulated Truck	1%	2%	5%	10%	15%
Auto VOC	**2%**	**3%**	**7%**	**15%**	**23%**
Truck VOC	**1%**	**2%**	**5%**	**10%**	**15%**

A linear model was used to interpolate values between each of the thresholds in the table to provide a more precise estimate of maintenance cost impacts from changes in IRI.

6. **Vehicle Occupancy and Vehicle Types**: The composite wage used in the benefit-cost analysis accounted for the percentage split of autos and trucks in the travel area. The composite wage accounted for vehicle occupancy ratios and the split of autos and trucks traveling in the area. Key assumptions for these areas included:

   - Vehicle occupancy that was used in the analysis is consistent with values provided in USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, dated December 2023. The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.
   - The percentage of trucks (37 percent)[4] in the area was obtained from NDDOT traffic reports.

7. **Safety Analysis**: New intersection improvements under the Build scenario, like acceleration and deceleration lanes, at several points along US 52 improve safety in the project area. The five years of existing crash data used for this analysis represented years 2019 through 2023 and was gathered by NDDOT. The acceleration and deceleration lanes being added at intersection at sites 1, 3, 5, and 7 were the primary source of project safety benefits for the project. The other site improvements will improve safety outcomes, however, there were no records of nearby crashes within the time frame used for the crash analysis. So, benefits from these improvements were not included in the BCA, but these project components will still improve safety along the US 52 corridor.

   The safety benefit was quantified for the twenty-year period between 2026 and 2045. Crash cost assumptions for the KABCO scale were consistent with values and methodologies published in the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, dated December 2023.

[4] See BCA workbook for traffic count data. The average truck AADT is a larger proportion of the overall volume than is usually observed. This section of US 52 is a rural highway, connecting two small to medium sized cities in North Dakota. The small communities along this highway are largely agricultural. Together this means the traffic on US 52 predominantly consists of commercial freight, moving goods between cities and to the US-Canada border and trucks taking agricultural goods from farm to market.

8. **Road Maintenance:** Road maintenance for the Build and No Build scenarios was calculated and included in the BCA. These costs were based on the expected maintenance schedule for the Build scenario. Expected costs for the No Build scenario were assumed to be incurred according to the maintenance schedule of the Build scenario, but the No Build maintenance costs were assumed to be 30 percent higher per guidance from NDDOT. This increase was based on the general assumption that real maintenance costs increase as pavement ages.
9. **Calculation of Remaining Capital Value**: The reconstructed section of US 52, acceleration/deceleration lanes, and the intersection improvements were expected to have service lives longer than the 20-year analysis period, and so the remaining capital value of these project components was calculated for the Build Alternative. This value was expressed in terms of 2022 dollars and was added to other project benefits in accordance with USDOT guidance. In determining the remaining capital value of the Build Alternative, project components were assumed to have a linear depreciation from the time construction was completed to the end of their service lives.
10. **Factors Not Quantified**: Several factors were not quantified as part of the analysis that could potentially add to the benefits assumed in the BCA. These factors include the following:
    - Safety benefits of installing new pavement markings and new rumble strips throughout the project

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 2. See the BCA Workbook for the complete benefit-cost analysis calculations.

Table 2 – Project BCA Results

	Initial Capital Cost (2022 Dollars)	Project Benefits (2022 Dollars)	Benefit-Cost Ratio (3.1% Discount Rate)	Net Present Value (2022 Dollars)
No Build vs. Build	$28.5 million	$83.9 million	2.94	$55.3 million