Memorandum

To:	Scott Zainhofsky, Division Director Planning & Asset Management North Dakota Department of Transportation
From:	Erik Kappelman, Transportation Analysis Nick Semeja, P.E., Team Lead
Date:	July 29th, 2024
Subject:	BCA Changes

BCA Changes

Changes were made to the BCA workbook to reflect feedback from USDOT and FHWA. Feedback on the BCA included that it lacked construction disbenefits, so these benefits were calculated and added to the BCA. FHWA feedback also included issues regarding the treatment of weekend delays as compared to weekday delay when estimating total annual delay. This feedback was addressed in the BCA workbook, and the overall approach is clarified in this document. Additionally, a new crash modification factor was added to the safety analysis for the intersection of US 81 and 40th Avenue to reflect the correct pre-roundabout intersection alignment.

Construction Disbenefits

The construction season in North Dakota is approximately 22 weeks long (March to October), and construction at the Interstate 29 and 40th Avenue interchange is scheduled to take place over two construction seasons. During the two construction seasons, vehicle delays will occur at varying intensities depending on which closures, detours, and work zone speeds will be necessary during each phase of construction. The length of construction season as well as the various average daily impact of the different phases of the project were considered when calculating construction disbenefits. Delay is expected to occur due to work zone speed reductions and limited detours related to road closures that will impact Old US 81, north and south of 40th Avenue, as well as the northbound ramps at Interstate 29.

Intersection delays were modeled for the year 2028 as part of the transportation traffic control plan. NDDOT requires construction project plans include a temporary traffic management plan showing delay will not increase more than 15 minutes because of the construction. Delay resulting from changes in intersection level operations, independent of work zone speed delays, was modeled and operations level impacts were determined to be insignificant, therefore, these delays were not included in the construction disbenefit calculations.

Construction disbenefits were calculated to reflect expected work zone speeds during construction on 40th Ave and longer travel times due to detours during the closures on US 81 and the northbound Interstate 29 ramps compared to the observed free flow speeds at the interchange. For the first and second construction season, 40th Ave will have a work zone speed from east of the southbound Interstate 29 ramps to west of US 81. This speed is expected to be 30 mph instead of 40 mph. During the second construction season, there will be two respective one-month-long closures on US 81 north and south of 40th Avenue. There will also be a three-month closure of the northbound Interstate 29 ramps.

Work zone delay was incorporated as a construction disbenefit using the same monetization process as was used in the delay reduction benefit calculations. This means benefits from Build delay reductions and construction disbenefits were valued in the same way.

Delay Reduction Benefits

The project planning process included creating models of traffic delay under the Build and No Build scenarios at Interstate 29 and 40th Avenue, and this modeling found significant increases in peak hour congestion under the No Build scenario compared to the Build scenario.

The previously performed modeling focused on two peak hours, one in the morning and one in the afternoon, but delay increases in the No Build scenario are also expected during the off-peak hours. Off-peak travel delay was accounted for in the BCA while considering the lower travel demand during the off-peak hours. Additionally, the traffic models only reflect non-holiday weekdays but delay on weekends also needs to be included in an annual estimation of delay for the BCA. To annualize daily delay estimates, the expected difference in delay between the weekend and weekdays was estimated by comparing daily travel demand profiles of average weekday and weekend days in Fargo-Moorhead.

Peak Hour Factor

Estimating delay throughout the entire day was achieved by calculating a "peak hour factor" that shows the ratio of combined AM and PM peak hour delay to the delay from the rest of the day. The peak hour factor estimation process includes finding a mathematical function for average delay per vehicle at the interchange and then using this function to estimate the relationship between peak hour and off-peak delay.

Delay Per Vehicle

Delay per vehicle was based on the estimated time between vehicles arriving at the Interstate 29 interchange ramp terminals. The intersections at the ramp terminals and the intersection of 40th Avenue and Old US 81 are stop-controlled and so the delay per vehicle was estimated based on the average number of seconds between vehicles arriving at these intersections. A stop at a stop-sign without any conflicting traffic on the mainline could take somewhere between three and six seconds to perform, when vehicles are arriving at intervals faster than this, a queue forms; delay begins to occur even without any traffic on 40th Avenue. As the traffic on 40th Avenue increases, queuing and delays from the stop-controlled intersections also increase.

An equation was estimated relating the demand at the interchange to the average number of seconds between arriving vehicles to average per vehicle delay at the interchange. Then average per vehicle delay was estimated for each hour based on the intensity of arrivals at the intersections, this value was multiplied by the demand during that hour to estimate total delay. This allows for an estimation of the ratio between off peak and peak delays which allows for estimating the daily delay based on the sum of the AM and PM peak hour delay modeled as part of the project planning effort.

Factor Calculations

Per vehicle delay calculations were performed to find the peak hour factor necessary to approximate daily delay from the AM and PM peak hours. These calculations do not directly estimate delay valued in the BCA and are not intended to represent a complete approach to estimating per vehicle delay at this interchange.

Monetized Values

The daily delay was annualized and monetized in the BCA by multiplying the daily difference in VHT under the No Build compared to Build by an annualization factor estimate from ATR count data. A relative lack of data has forced a conservative approach for this estimation, and it is likely that even more delay will be present under the No Build scenario than was valued within this BCA.

Annualization Factor

After daily delays have been estimated, they are annualized to represent an entire year's worth of delays. The model values used to estimate daily delays reflect a "typical" non-holiday weekday. In 52 weeks, there are 260 weekdays. If 5 days are holidays, then the total number of non-holiday weekdays in a year is 255, so multiplying the estimated daily delay by 255 would be the total delay on non-holiday weekdays throughout a year. But there are also 104 weekend days in 52 weeks, and assuming zero delay for all hours of the weekend does not reflect traffic operations at an interstate interchange in an urban area like Fargo-Moorhead, so a weekend day versus weekday factor was calculated to estimate the total delay on the 104 weekend days.

Using continuous traffic counts from nearby automatic traffic recorders (ATRs) hourly travel demand data for all days in 2023 was summarized for weekdays and weekends. Then hourly weekend demand was estimated by dividing average hourly weekend demand by average hourly weekday demand at the ATRs and multiplying by the corresponding hourly weekday traffic counts at the interchange.

Each estimate of hourly weekday demand was input into the same delay estimation function that was used to estimate weekday delay as part of peak hour factor calculations. While travel demand may differ between the weekdays and the weekends, at a stop-controlled intersection the average delay per vehicle is based on how often vehicles arrive at the intersection. This relationship should remain consistent regardless of the day of the week that is being analyzed. The primary determining factor of delay is how often vehicles arrive and how long it takes to execute a stop at a stop sign. This means a smooth mathematical relationship describing time between arriving vehicles and per vehicle delay should be consistent between a weekday and a weekend day.

Daily weekend delay was calculated by summing all weekend day hourly delay estimates, then daily weekend delay was divided by the weekday delay which resulted in a value of 0.13. This means that an average weekend day has about 13% of the total congestion as an average weekday. This proportion was multiplied by the number of weekend days in 52 weeks, 104, to estimate the effective number of non-holiday weekdays while considering the difference between weekday and weekend daily delay.

This analysis found that adding up all the delay during the 104 weekend days throughout an entire year would be about the same as the delay during 13 weekdays, so to calculate annual delay the 255 non-holiday weekdays was increased by a value equivalent to the delay during the weekends, 13 weekdays. This effectively means that there are about 268 non-holiday weekdays worth of delay per year at the interchange. The annualization factor is equal to the equivalent number of days, 268, and multiplying this factor by the daily weekday delay calculates the total annual delay at the interchange.

SRF

Memorandum

To: Scott Zainhofsky, Division Director
Planning & Asset Management
North Dakota Department of Transportation

From: Erik Kappelman, Transportation Analysis
Nick Semeja, P.E., Team Lead

Date: March 18, 2024
REVISED: July 26, 2024

Subject: Reconstruction of Interstate 29 Exit 69 Bridges BCA Memo
REVISED

Introduction

This memorandum summarizes the assumptions, methodology and results developed for the benefit-cost analysis of the Bridge Improvement Program (BIP) Interstate 29 – 40th Avenue Interchange Project. 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 impacts of this project that can be monetized are travel time, vehicle crashes, environmental impacts, capital costs, land value, and remaining capital value. 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 initial benefit-cost ratio for this project analysis was 3.1 and the revised ratio is 1.8. This change reflects the change made due to feedback from FHWA and USDOT. The project team maintains the position that the BCR of the project is 3.1, however, the more conservative BCR resulting from requested change of 1.8 still shows the project is cost effective.

Project Overview

The North Dakota Department of Transportation (NDDOT) is requesting Bridge Investment Program (BIP) funds to reconstruct the Interstate 29 Exit 69 Bridge Replacement Project (hereafter referred to as the "Project"). The Project includes reconstruction of the two bridges, structure numbers 29-69.374 and 29-69.374 N along 40th Avenue North in Fargo, ND, over Interstate 29 and the Burlington Northern Santa Fe (BNSF) railroad directly east of the northbound Interstate 29 on and off ramps, respectively, and associated roadway improvements to match the revised bridge profiles.

Bridge number 29-69.374 was built in 1966 and bridge number 29-69.374 N was built in 1965. Both bridges were reconstructed in 1983.

Bridge number 29-69.374 provides grade separation of 40th Avenue North over Interstate 29, which is a part of the National Multimodal Freight Network, National Highway Freight Network, and Primary Highway Freight System and is considered one of the most critical highway segments of the U.S. freight transportation system. Structure 29-69.374 N provides grade separation of 40th Avenue North over the BNSF railroad. This specific BNSF railroad is part of the BNSF Hillsboro Subdivision, a critical line of rail which runs between three of the top five agricultural commodity producing counties in the state (2022, by dollar value), including Cass County (first), Grand Forks County (fifth), and Walsh County (fourth). The bridges associated with the Project are approximately 550 feet apart, from bridge deck to bridge deck, and operate as a critical system at the Interstate 29 Exit 69 interchange.

Current and future development growth on either side of Interstate 29 Exit 69 in the Project area is driving more traffic across both bridges on 40th Avenue North. The interchange ramp terminals are approaching capacity and experiencing negative transportation operations impacts, decreased mobility and reliability, and safety risks. Traffic operations are degrading as traffic is forecast to grow through 2045.

In the Project area, there were 39 total crashes between 2014 and 2023 including two minor injuries and seven possible injury crashes. The most common (54 percent) were rear end crashes, symptomatic of the increased traffic volumes and poor sight distances across the Project area. Sight distance is a primary factor of safety challenges at the Exit 69 interchange, caused by the steep grade of 40th Avenue North over Interstate 29 and the BNSF railway. With six cross-traffic conflict points, growing traffic, and sight distance deficiencies, the crash rate in the Project area is expected to rise. Given the age and rural design of the structures, the width of the bridges provides no space for critical traffic operational improvements necessary to safely move traffic through the Project area.

Description of Alternatives

For the purpose of this analysis, a No Build and Build Alternative were under consideration. The Table below provides an overview of project impacts.

No Build Alternative

Bridge maintenance and operations would continue as expected. Routine maintenance activities will continue, and major rehabilitation activities will be required as the bridge continues to age. Existing safety issues will continue to influence crash rates, increasing property damage and human injury. Forecasted traffic growth is expected to cause the interchange ramp terminals to be over capacity, resulting in significant traffic delays under the existing side-street stop control.

Build Alternative

The Project improvements address current and projected vulnerabilities, through full reconstruction of the bridges to a state of good repairs, and safer sight distances over Interstate 29 and the BNSF railroad, associated modernization and reconfiguration of the 40th Avenue North interchange with Interstate 29, traffic operations enhancements, and modernization of the bridges and bridge components to a safer standard. The Project enhances mobility of goods, services, and intermodal freight and sustains economic growth in Fargo and throughout the region.

Table 1. Example Project Impacts

Baseline/Current Status and Problem to be Addressed	Change to Baseline/Proposed Project to Address Problem	Example Impacts
Ramp terminal design at the interchange does not meet the capacity needs.	Construction of a dumbbell interchange: roundabouts at both ramp terminals	The dumbbell interchange design adds capacity at the interchange ramp terminals, resulting in reduced vehicle delay
Ramp terminal intersection design allows for easy wrong way entry onto the interstate ramp and/or interstate for impaired or distracted drivers	Construction of roundabouts at the ramp terminals	The dumbbell interchange design makes it less likely drivers will erroneously enter the wrong way with the physical and mental reference guide points created by the roundabout
Both terminals have significant and numerous conflict points which increase the likelihood and severity of crashes	Construction of roundabouts at the ramp terminals	The roundabouts significantly reduce the number of conflict points and their overall significance. This will reduce the likelihood and severity of crashes
The bridges are already in the latter half of their useful life and will need an increasing amount of maintenance as time goes on.	Newly constructed bridges require less maintenance and rehabilitation activities	Lower maintenance and rehabilitation costs create cost savings.

The following provides an overview of assumptions used in analysis for the No Build and Build Alternatives.

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)
   - Crashes by severity
   - Environmental and air quality impacts
   - Maintenance savings
   - Construction Disbenefits
   - Initial capital costs: These costs 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.
2. **Analysis Years**: This analysis assumed that construction would take place over a two-year period and be completed in 2029. Therefore, 2030 was assumed to be the first full year that benefits will be accrued from the project. Benefits are estimated for a twenty-year period based on the anticipated service life of certain components of the project. The present value of all benefits and costs was calculated using 2022 as the year of constant dollars.
3. **Economic Assumptions**: Value of time, crash costs, and emissions costs were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated December 2023 (hereafter, BCA Guidance). The analysis was completed using an assumed discount rate of 3.1 percent. Project costs were deflated using the Bureau of Labor Statistics GDP deflator table 1.1.9. in accordance with the BCA Guidance.
4. **Development of Vehicle Hours Traveled (VHT)**: Industrial development, including an Amazon fulfillment center and Hector International Airport, are located east of the interchange. As these areas draw more trips, the existing intersection designs will no longer efficiently move traffic. VHT changes were estimated with traffic models[1] analyzing operations under existing (i.e., No Build) and the proposed Build configurations. These traffic models provided two hours of output, a morning peak hour and an afternoon peak hour, which were then translated into a daily delay and VHT.

   VHT savings were extrapolated from peak hour delay data using modeled delay and hourly ATR counts from the year 2023. Average delay was estimated, for all hours of the day, based

[1] North Dakota. North Dakota Department of Transportation. (2023). *I-29 & 40th Ave N (CR 20) Interchange Feasibility Study: Traffic Operations Report* (Project No. 8-029(213)069). - Table/diagrams in Attachment B used show delay results from modeling No Build existing results and No Build future results as well as Build existing results and Build future results.

on the observed relationship during peak hours between the average length of time between vehicles arriving and individual vehicle delay.

Delay per vehicle was based on the estimated time between vehicles arriving at the Interstate 29 interchange ramp terminals. The intersections at the ramp terminals and the intersection of 40th Avenue and Old US 81 are stop-controlled and so the delay per vehicle was estimated based on the average number of seconds between vehicles arriving at these intersections. A stop at a stop-sign without any conflicting traffic on the mainline could take somewhere between three and six seconds to perform, when vehicles are arriving at intervals faster than this, a queue forms; delay begins to occur even without any traffic on 40th Avenue. As the traffic on 40th Avenue increases, queuing and delays from the stop-controlled intersections also increase.

An equation was estimated relating the demand at the interchange to the average number of seconds between arriving vehicles to average per vehicle delay at the interchange. Then average per vehicle delay was estimated for each hour based on the intensity of arrivals at the intersections, this value was multiplied by the demand during that hour to estimate total delay. This allows for an estimation of the ratio between off peak and peak delays which allows for estimating the daily delay based on the sum of the AM and PM peak hour delay modeled as part of the project planning effort.

Per vehicle delay calculations were performed to find the peak hour factor necessary to approximate daily delay from the AM and PM peak hours. These calculations do not directly estimate delay valued in the BCA and are not intended to represent a complete approach to estimating per vehicle delay at this interchange.

The daily delay was annualized and monetized in the BCA by multiplying the daily difference in VHT under the No Build compared to Build by an annualization factor estimate from ATR count data. A relative lack of data has forced a conservative approach for this estimation, and it is likely that even more delay will be present under the No Build scenario than was valued within this BCA

After daily delays have been estimated, they are annualized to represent an entire year's worth of delays. The model values used to estimate daily delays reflect a "typical" non-holiday weekday. In 52 weeks, there are 260 weekdays. If 5 days are holidays, then the total number of non-holiday weekdays in a year is 255, so multiplying the estimated daily delay by 255 would be the total delay on non-holiday weekdays throughout a year. But there are also 104 weekend days in 52 weeks, and assuming zero delay for all hours of the weekend does not reflect traffic operations at an interstate interchange in an urban area like Fargo-Moorhead, so a weekend day versus weekday factor was calculated to estimate the total delay on the 104 weekend days.

Using continuous traffic counts from nearby automatic traffic recorders (ATRs) hourly travel demand data for all days in 2023 was summarized for weekdays and weekends. Then hourly weekend demand was estimated by dividing average hourly weekend demand by average hourly weekday demand at the ATRs and multiplying by the corresponding hourly weekday traffic counts at the interchange.

Each estimate of hourly weekday demand was input into the same delay estimation function that was used to estimate weekday delay as part of peak hour factor calculations. While travel demand may differ between the weekdays and the weekends, at a stop-controlled intersection the average delay per vehicle is based on how often vehicles arrive at the intersection. This relationship should remain consistent regardless of the day of the week that is being analyzed. The primary determining factor of delay is how often vehicles arrive and how long it takes to execute a stop at a stop sign. This means a smooth mathematical relationship describing time between arriving vehicles and per vehicle delay should be consistent between a weekday and a weekend day.

Daily weekend delay was calculated by summing all weekend day hourly delay estimates, then daily weekend delay was divided by the weekday delay which resulted in a value of 0.13. This means that an average weekend day has about 13% of the total congestion as an average weekday. This proportion was multiplied by the number of weekend days in 52 weeks, 104, to estimate the effective number of non-holiday weekdays while considering the difference between weekday and weekend daily delay.

This analysis found that adding up all the delay during the 104 weekend days throughout an entire year would be about the same as the delay during 13 weekdays, so to calculate annual delay the 255 non-holiday weekdays was increased by a value equivalent to the delay during the weekends, 13 weekdays. This effectively means that there are about 268 non-holiday weekdays worth of delay per year at the interchange. The annualization factor is equal to the equivalent number of days, 268, and multiplying this factor by the daily weekday delay calculates the total annual delay at the interchange.

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 to represent the intersections in the analysis, 13 percent, was based on year 2021 daily traffic and heavy truck counts provided in the NDDOT Traffic Mapping Application.[2] National Bridge Inventory data for truck percentage is based on 2019 information, this data does not take into account the increased industrial development in the area between 2019 and 2021, so using 2021 NDDOT counts was preferential.

[2] https://gis.dot.nd.gov/external/ge_html/?viewer=ext_transinfo

- Vehicle occupancy values were provided by BCA Guidance, for this analysis occupancy values of 1.67 people per automobile and 1.00 people per truck were used.

6. **Safety Analysis:** The safety benefit was quantified for years 2030 to 2049 using crash cost assumptions and methodologies published in the BCA Guidance. The project is expected to reduce crashes in the interchange area by converting the side-street stop-controlled ramp terminals to a safer dumbbell roundabout design. Crash modification factors are referenced in the BCA workbook and include factors related to converting the ramp terminals to roundabouts. A crash modification factor to represent the prior condition at Old US 81 and 40th Avenue, a four-way stop controlled intersection, was used to account for safety changes at that intersection. Crashes are reduced due to the inherent safety improvements a roundabout creates compared to many other intersection types including the current intersection designs. Roundabouts have a reduced number of conflict points, and the remaining conflict points are significantly less likely to cause fatal or injurious crashes. Existing crash data is attached in Attachment C and crash modification factors and their sources[3] are outlined in the BCA workbook.

7. **Environmental and Air Quality Impacts:** Changes in emissions are expected to be impacted by the reduction delay, and idling,[4] after the interchange is converted to the dumbbell design. VHT savings after delay reduction are converted into VMT equivalents based on fleet fuel efficiency and consumption. 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 BCA Guidance.

8. **Operating and Maintenance Costs**: Maintenance costs for pavement repairs were estimated based on average values that were provided by NDDOT. The bridge was built in 1966 and rebuilt in 1983, so costs also include 50-year maintenance activities that would take place in 2033 in the No Build Alternative. Costs and maintenance schedules were provided by NDDOT. These maintenance schedules were applied the Build Alternative where necessary.

Condition-Based Preventative Maintenance	Frequency	No Build Estimated Timeframe	Build Estimated Timeframe	Cost per Application (2022$)
Concrete Bridge Deck Overlay	Once @ 25 Years	2008	2051	$988,502
Bridge Barrier/Railing Repairs	Once @ 25 Years	2008	2051	$119,749

[3] Claros, B., B. Burdett, M. Chitturi, A. Bill, and D.A. Noyce. "Are Roundabouts Safe and Economically Viable Replacing Conventional Diamond Interchange Ramp Terminals?". Transportation Research Record No. 2675, Transportation Research Board of the National Academies of Science, Washington, D.C., (2021).
K,A,B,C CMF: https://www.cmfclearinghouse.org/detail.php?facid=11130
O CMF: https://www.cmfclearinghouse.org/detail.php?facid=11131
[4] https://www.energy.gov/eere/vehicles/fact-861-february-23-2015-idle-fuel-consumption-selected-gasoline-and-diesel-vehicles

Concrete Substructure Repairs	Every 25 years	2008, 2033	2051, 2076	$ 31,066
Repair Slope Protection	Every 25 years	2008, 2033	2051, 2076	$23,299
Replace Approach Slabs	Once @ 50 years	2033	2076	$585,437
Concrete Bridge Deck Replacement	Once @ 50 years	2033	2076	$5,637,940

Additional routine maintenance is included for completeness but does not have a significant impact on the overall benefits and costs.

9. **Calculation of Remaining Capital Value**: Because many components of the initial capital costs have a service life well beyond the 20-year analysis period, the remaining capital value was calculated for the Build Alternative. The bridges built at this interchange will have service lives of over 80 years. Based on the service lives, the remaining value was calculated and added to other project benefits in accordance with BCA Guidance.

   Remaining capital value represents the ongoing value the project has after the end of the BCA analysis period. This can be conceptualized as both the future value of the materials used to construct a project as well as all of the social gains the project will create after the end of the 20-year BCA analysis period. If the project's primary benefits stem from improved operations, those benefits will continue to accrue after the end of the BCA analysis period and this accrual is why remaining capital value is included in this and other BCAs.

   Remaining Capital Value calculation include the future maintenance costs associated with the Build structures after the end of the analysis period in accordance with BCA Guidance on calculating remaining capital value.

10. **Construction Disbenefits:** The construction season in North Dakota is approximately 22 weeks long (March to October), and construction at the Interstate 29 and 40th Avenue interchange is scheduled to take place over two construction seasons. During the two construction seasons, vehicle delays will occur at varying intensities depending on which closures, detours, and work zone speeds will be necessary during each phase of construction. The length of construction season as well as the various average daily impact of the different phases of the project were considered when calculating construction disbenefits. Delay is expected to occur due to work zone speed reductions and limited detours related to road closures that will impact Old US 81, north and south of 40th Avenue, as well as the northbound ramps at Interstate 29.

    Intersection delays were modeled for the year 2028 as part of the transportation traffic control plan. NDDOT requires construction project plans to include a temporary traffic management plan showing delay will not increase more than 15 minutes because of the construction. Delay resulting from changes in intersection level operations, independent of work zone speed delays, was modeled and operations level impacts were determined to be insignificant, therefore, these delays were not included in the construction disbenefit calculations.

Construction disbenefits were calculated to reflect expected work zone speeds during construction on 40th Ave and longer travel times due to detours during the closures on US 81 and the northbound Interstate 29 ramps compared to the observed free flow speeds at the interchange. For the first and second construction season, 40th Ave will have a work zone speed from east of the southbound Interstate 29 ramps to west of US 81. This speed is expected to be 30 mph instead of 40 mph. During the second construction season, there will be two respective one-month-long closures on US 81 north and south of 40th Avenue. There will also be a three-month closure of the northbound Interstate 29 ramps.

Work zone delay was incorporated as a construction disbenefit using the same monetization process as was used in the delay reduction benefit calculations. This means benefits from Build delay reductions and construction disbenefits were valued in the same way.

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:

- Safety and mobility benefits associated with the increased sight distance over Interstate 29 and the BNSF railroad.
- Routine annual maintenance costs may be higher for the No Build due to the aging infrastructure, however, costs were assumed to be equal to those required for the new bridge in the Build when calculating costs in the BCA.

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 Attachment A for the complete benefit-cost analysis workbook.

Table 2 – Total Project 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	$39.0 million	$68.1 million	1.75	$29.1 million

Attachment A

Benefit-Cost Analysis Workbook

Attachment B

Summary of Vissim Operations Analysis

23 U.S.C. § 407 Documents
NDDOT Reserves All Objections

Table 3. Existing Intersection 2022 Average Delay and LOS

Intersection	AM Peak Hour			PM Peak Hour		
	Vehicles	Avg Delay (sec.)	LOS	Vehicles	Avg Delay	LOS
45th Street North	273	1.0	A	234	0.5	A
Southbound I-29 Ramps	488	3.9	A	485	2.4	A
Northbound I-29 Ramps	581	4.8	A	706	4.9	A
County Route 81 (CR 81)*	622	6.9	A	694	8.3	A
37th Street North	527	0.2	A	584	0.5	A
33rd Street North	524	0.3	A	560	1.1	A
25th Street North	459	0.9	A	486	0.6	A

*Intersection with Traffic Signal

SIGNALIZED INTERSECTIONS

As **Table 3** illustrates, no capacity improvements are necessary for the seven identified intersections to operate with acceptable LOS for existing 2022 traffic volumes. While these intersections do not warrant signals under existing traffic conditions, the signalized intersections were analyzed with the base year 2022 trip tables as a test to ensure all movements and functionality work correctly. All signal timings plans were optimized to minimize average delay using TransModeler's optimization function and existing turning movement counts. As is typical of diamond interchanges, the traffic signal timing plans at the northbound and southbound ramp terminal intersections are coordinated with each other. The remaining five intersections operate independently. These intersections are shown in **Figure 2**.

Figure 2: Conceptual Signalized Intersection Locations

**23 U.S.C. § 407 Documents
NDDOT Reserves All Objections**

Table 5 presents a summary of average intersection delay and LOS for existing conditions for this concept.

Table 5. 2022 Average Delay and LOS with Roundabouts

Roundabout	AM Peak Hour			PM Peak Hour		
	Vehicles	Avg Delay (sec.)	LOS	Vehicles	Avg Delay	LOS
45th Street North	277	3.2	A	236	2.3	A
Southbound I-29 Ramps	493	4.2	A	486	4.1	A
Northbound I-29 Ramps	585	3.8	A	710	3.7	A
County Route 81 (CR 81)	631	4.2	A	698	4.0	A
37th Street North	531	3.8	A	594	3.7	A
33rd Street North	527	3.6	A	569	3.3	A
25th Street North	461	2.1	A	496	1.5	A

CORRIDOR LEVEL OF SERVICE

TransModeler also reports LOS at the corridor level, generally based on operational speed compared to free flow speed. This metric reflects the overall LOS from 45th Street North to 25th Street North. The free flow speed established for this corridor is 50 MPH. **Table 6** presents the corridor LOS for each corridor type for the 2022 base year. With low traffic volumes, the LOS of the corridor in the 2022 base year reflect optimal conditions.

Table 6. Base year 2022 Corridor LOS

AM Peak Hour			
Direction	Network	Average Speed (MPH)	LOS
Westbound	Existing	39	B
	Signalized	37	B
	Roundabouts	33	B
Eastbound	Existing	41	A
	Signalized	41	A
	Roundabouts	33	B
PM Peak Hour			
Direction	Network	Average Speed (MPH)	LOS
Westbound	Existing	40	A
	Signalized	37	B
	Roundabouts	33	B
Eastbound	Existing	41	A
	Signalized	40	B
	Roundabouts	32	B

23 U.S.C. § 407 Documents
NDDOT Reserves All Objections

FUTURE TRAFFIC COMPARISON

Model simulations of the three corridor models were run with the future 2045 trip tables. These test simulations are intended to assess the anticipated corridor function should no other improvements be made to the interchange. As may be expected, the **existing network configuration** fails immediately with the introduction of thousands of additional peak hour vehicles. Traffic queues form on both exit ramps, along 40th Avenue North, and on the side streets. Backups beyond the limits of the model network result in a significant number of scheduled trips that cannot be loaded onto the network before the simulation period ends. The independent performance of the other intersections away from the interchange are impossible to determine given the bottleneck created at the interchange.

Similar failed results occur with the **signalized corridor**. Without left turn lanes to store left turning vehicles at the interchange ramp intersections, the single through lanes on the bridge quickly congest and create queues that ultimately spread to include the entire 40th Avenue North corridor. As with the existing configuration, the performance of the signalized intersections away from the interchange cannot be accurately assessed.

The results for the **roundabout corridor** concept appear more promising overall, but still fail to adequately serve all movements. The ramp terminal roundabouts process significantly more vehicles than the other intersection alternatives and overall delay is much lower. However, in the AM peak hour, eastbound traffic on 40th Avenue North between 45th Street North and the southbound ramp terminal roundabout queues almost to 45th Street due to westbound-to-southbound traffic consistently flowing through the roundabout. Similar examples exist in the PM peak hour in the opposite direction as westbound traffic on 40th Avenue North must yield to northbound-to-westbound interstate exit ramp traffic inside the northbound I-29 ramp terminal roundabout. Similar queues exist for southbound CR 81 and 37th Street North traffic. These delays are reflected in the overall system delay, but not specifically in the delay recorded at the corresponding roundabouts.

Tables 9, 10, and **11** present the recorded delay and LOS for each of the corridor alternatives applying the future year 2045 trip tables. **Table 12** presents the corridor LOS for the 2045 future year for each network type.

Table 9. Existing Intersection Configuration 2045 Average Delay and LOS

	AM Peak Hour			PM Peak Hour		
Intersection	Vehicles	Avg Delay (sec.)	LOS	Vehicles	Avg Delay	LOS
45th Street North	1,081	57	F	998	10	F
Southbound I-29 Ramps	1,121	83	F	1,033	155	F
Northbound I-29 Ramps	815	251	F	890	252	F
County Route 81 (CR 81)*	904	169	F	925	223	F
37th Street North	696	163	F	655	331	F
33rd Street North	662	79	F	653	183	F
25th Street North	648	63	F	665	53	F

*Intersection with Traffic Signal

23 U.S.C. § 407 Documents
NDDOT Reserves All Objections

February 17, 2023
Jennifer Kern, PE, Chad Frisinger, PE
Reference: **40th Avenue North Corridor Improvement Concepts: Traffic Signals and Roundabouts**

Table 10. 2045 Average Intersection Delay and LOS for Signalized Corridor

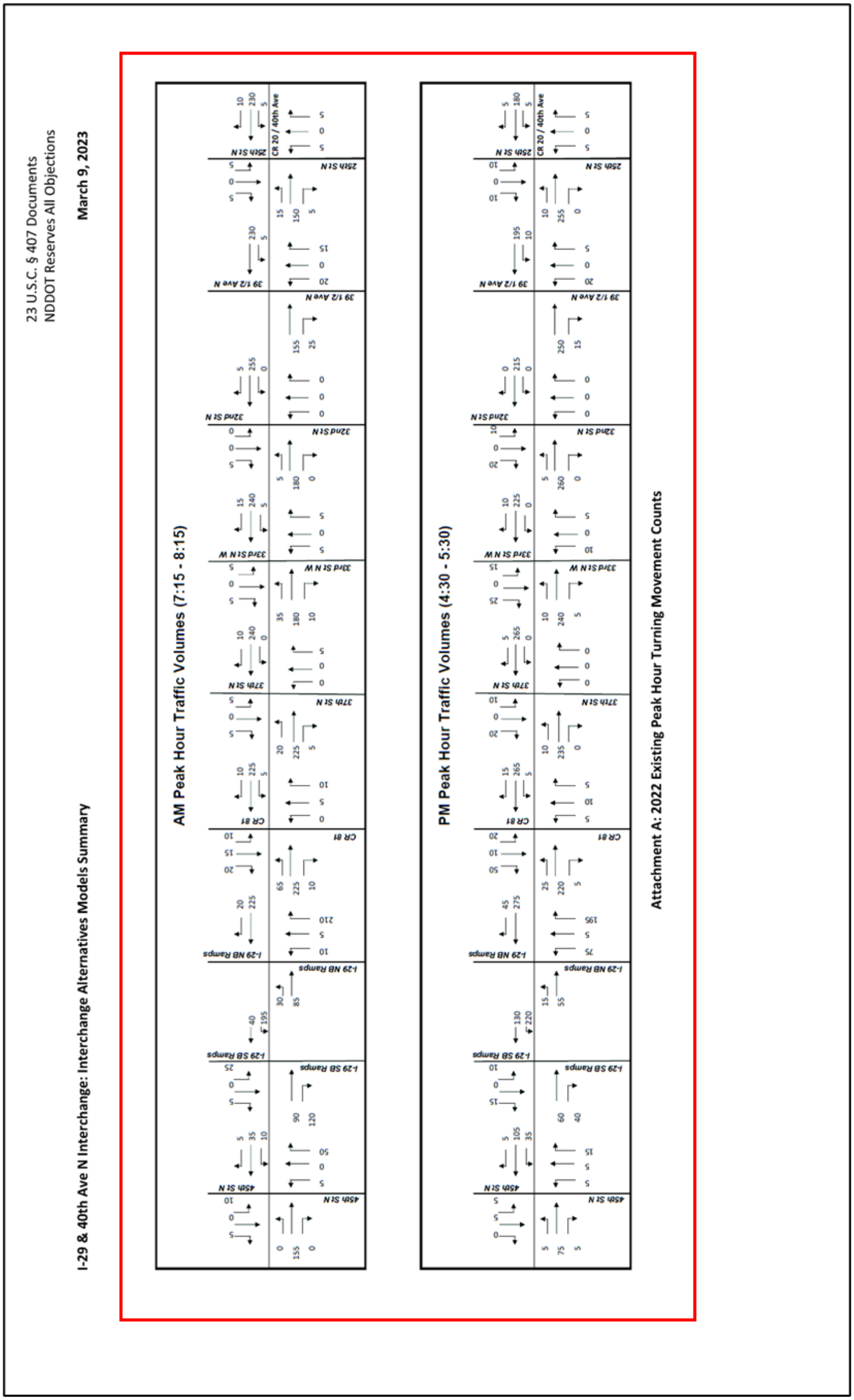
Intersection	AM Peak Hour			PM Peak Hour		
	Vehicles	Avg Delay (sec.)	LOS	Vehicles	Avg Delay	LOS
45th Street North	1,241	15	B	1,056	85	F
Southbound I-29 Ramps	1,335	88	F	1,073	189	F
Northbound I-29 Ramps	987	196	F	1,099	278	F
County Route 81 (CR 81)	1,061	154	F	1,000	232	F
37th Street North	786	122	F	703	308	F
33rd Street North	718	63	E	725	165	F
25th Street North	689	35	D	719	59	E

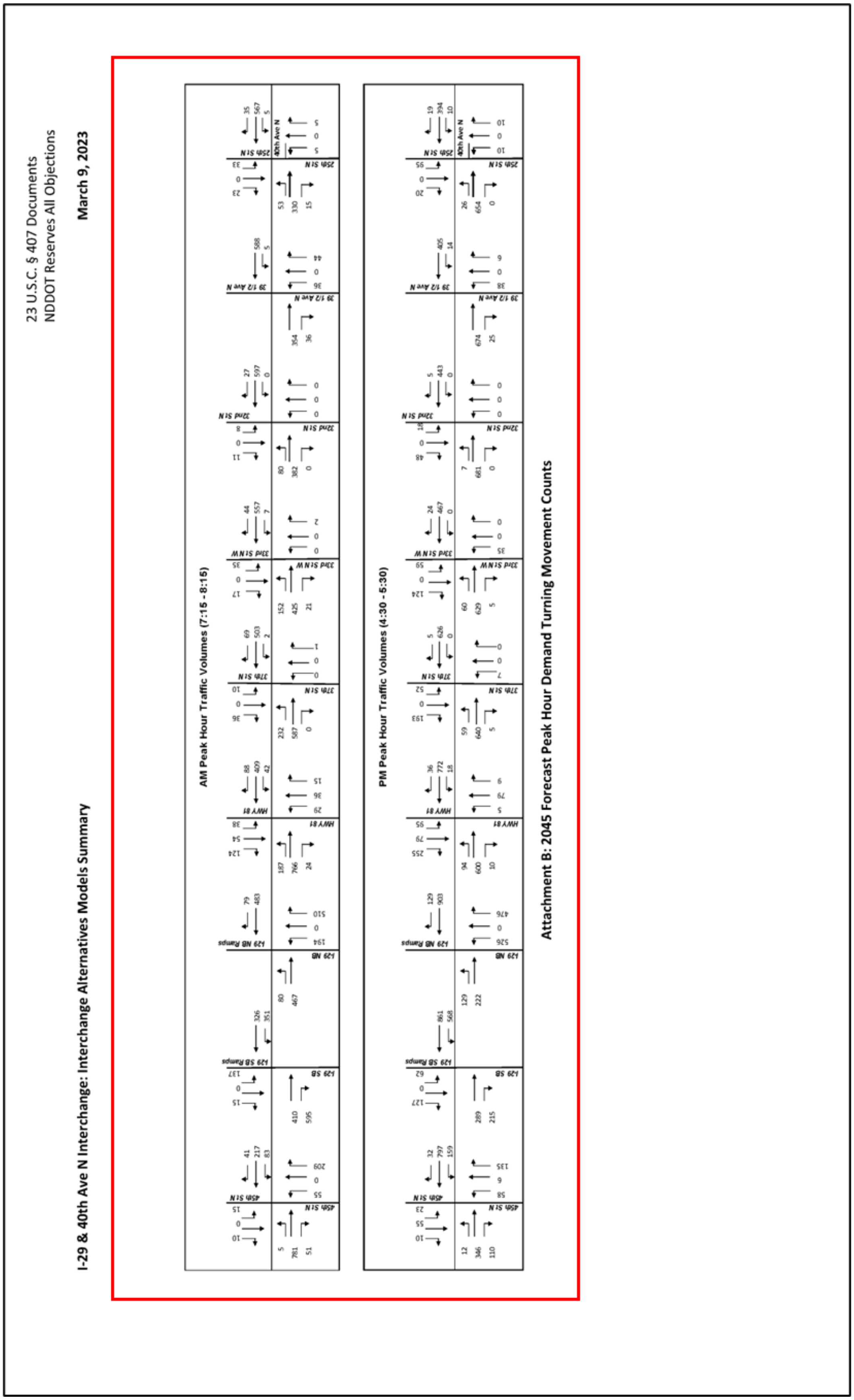
Table 11. 2045 Average Delay and LOS for Roundabout Corridor

Roundabout	AM Peak Hour			PM Peak Hour		
	Vehicles	Avg Delay (sec.)	LOS	Vehicles	Avg Delay	LOS
45th Street North	1,330	37	E	1,643	5	A
Southbound I-29 Ramps	1,661	50	E	1,797	13	B
Northbound I-29 Ramps	1,692	10	A	2,019	86	F
County Route 81 (CR 81)	1,792	9	A	1,545	81	F
37th Street North	1,333	5	A	1,359	62	F
33rd Street North	1,192	5	A	1,303	4	A
25th Street North	1,025	3	A	1,111	2	A

Table 12. 2045 Future Year Corridor LOS

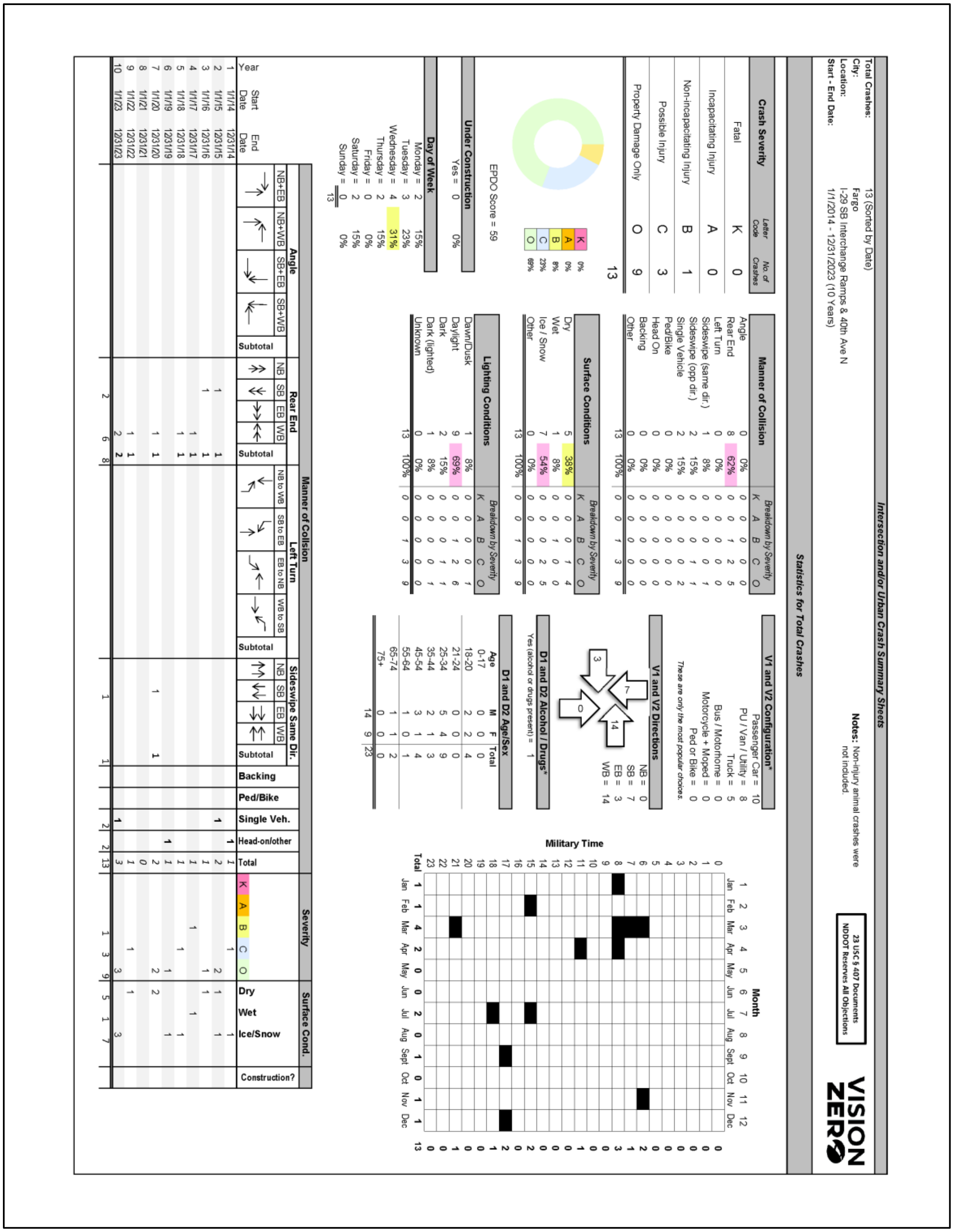
AM Peak Hour			
Direction	Network	Average Speed (MPH)	LOS
Westbound	Existing	9	F
	Signalized	10	F
	Roundabouts	31	B
Eastbound	Existing	38	B
	Signalized	25	C
	Roundabouts	24	C
PM Peak Hour			
Direction	Network	Average Speed (MPH)	LOS
Westbound	Existing	6	F
	Signalized	6	F
	Roundabouts	16	E
Eastbound	Existing	38	B
	Signalized	9	F
	Roundabouts	31	B


23 U.S.C. § 407 Documents
NDDOT Reserves All Objections
March 9, 2023
I-29 & 40th Ave N Interchange: Interchange Alternatives Models Summary
AM Peak Hour Traffic Volumes (7:15 - 8:15)
PM Peak Hour Traffic Volumes (4:30 - 5:30)
Attachment A: 2022 Existing Peak Hour Turning Movement Counts


23 U.S.C. § 407 Documents
NDDOT Reserves All Objections
March 9, 2023
I-29 & 40th Ave N Interchange: Interchange Alternatives Models Summary
AM Peak Hour Traffic Volumes (7:15 - 8:15)
PM Peak Hour Traffic Volumes (4:30 - 5:30)
Attachment B: 2045 Forecast Peak Hour Demand Turning Movement Counts

Attachment C

Crash Data Used Safety Analysis



Intersection and/or Urban Crash Summary Sheets

Total Crashes: 13 (Sorted by Date)
City: Fargo
Location: I-29 SB Interchange Ramps & 40th Ave N
Start - End Date: 1/1/2014 - 12/31/2023 (10 Years)

Notes: Non-injury animal crashes were not included.

23 USC § 407 Documents
NDDOT Reserves All Objections

VISION ZERO

Statistics for Total Crashes

Crash Severity	Letter Code	No. of Crashes
Fatal	K	0
Incapacitating Injury	A	0
Non-incapacitating Injury	B	1
Possible Injury	C	3
Property Damage Only	O	9
		13

K 0%, A 0%, B 8%, C 23%, O 69%

EPDO Score = 59

Under Construction
Yes = 0 0%

Day of Week

Monday =	2	15%
Tuesday =	3	23%
Wednesday =	4	31%
Thursday =	2	15%
Friday =	0	0%
Saturday =	2	15%
Sunday =	0	0%
	13	

Manner of Collision			K	A	B	C	O
Angle	0	0%	0	0	0	0	0
Rear End	8	62%	0	0	1	2	5
Left Turn	0	0%	0	0	0	0	0
Sideswipe (same dir.)	1	8%	0	0	0	0	1
Sideswipe (opp dir.)	2	15%	0	0	0	1	1
Single Vehicle	2	15%	0	0	0	0	2
Ped/Bike	0	0%	0	0	0	0	0
Head On	0	0%	0	0	0	0	0
Backing	0	0%	0	0	0	0	0
Other	0	0%	0	0	0	0	0
	13	100%	0	0	1	3	9

Surface Conditions			K	A	B	C	O
Dry	5	38%	0	0	0	1	4
Wet	1	8%	0	0	1	0	0
Ice / Snow	7	54%	0	0	0	2	5
Other	0	0%	0	0	0	0	0
	13	100%	0	0	1	3	9

Lighting Conditions			K	A	B	C	O
Dawn/Dusk	1	8%	0	0	0	0	1
Daylight	9	69%	0	0	1	2	6
Dark	2	15%	0	0	0	1	1
Dark (lighted)	1	8%	0	0	0	0	1
Unknown	0	0%	0	0	0	0	0
	13	100%	0	0	1	3	9

V1 and V2 Configuration*
Passenger Car = 10
PU / Van / Utility = 8
Truck = 5
Bus / Motorhome = 0
Motorcycle + Moped = 0
Ped or Bike = 0
These are only the most popular choices.

V1 and V2 Directions
NB = 0
SB = 7
EB = 3
WB = 14

D1 and D2 Alcohol / Drugs*
Yes (alcohol or drugs present) = 1

D1 and D2 Age/Sex

Age	M	F	Total
0-17	0	0	0
18-20	2	2	4
21-24	0	0	0
25-34	5	4	9
35-44	2	1	3
45-54	3	1	4
55-64	1	0	1
65-74	1	1	2
75+	0	0	0
	14	9	23

Military Time / Month

Hourly totals (0–23): 0, 0, 0, 0, 0, 0, 2, 1, 3, 0, 0, 1, 0, 0, 0, 2, 0, 2, 1, 0, 0, 1, 0, 0; Total 13

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Total	1	1	4	2	0	0	2	0	1	0	1	1	13

Manner of Collision / Severity / Surface Cond. by Year

Year	Start Date	End Date	Angle NB+EB	Angle NB+WB	Angle SB+EB	Angle SB+WB	Angle Subtotal	Rear End NB	Rear End SB	Rear End EB	Rear End WB	Rear End Subtotal	Left Turn NB to WB	Left Turn SB to EB	Left Turn EB to NB	Left Turn WB to SB	Left Turn Subtotal	Sideswipe NB	Sideswipe SB	Sideswipe EB	Sideswipe WB	Sideswipe Subtotal	Backing	Ped/Bike	Single Veh.	Head-on/other	Total	K	A	B	C	O	Dry	Wet	Ice/Snow	Construction?
1	1/1/14	12/31/14																								1	1				1				1	
2	1/1/15	12/31/15							1			1													1		2					2	1		1	
3	1/1/16	12/31/16							1			1															1					1	1			
4	1/1/17	12/31/17									1	1															1			1				1		
5	1/1/18	12/31/18									1	1															1				1				1	
6	1/1/19	12/31/19																								1	1					1			1	
7	1/1/20	12/31/20									1	1							1			1					2					2	2			
8	1/1/21	12/31/21																									0									
9	1/1/22	12/31/22									1	1															1				1		1			
10	1/1/23	12/31/23									2	2													1		3					3			3	
									2		6	8							1			1			2	2	13			1	3	9	5	1	7	

Intersection and/or Urban Crash Summary Sheets

Total Crashes: 19 (Sorted by Date)
City: Fargo
Location: I-29 Exit 69 NB Interchange Ramps & 40th Ave N
Start - End Date: 1/1/2014 - 12/31/2023 (10 Years)

Notes: Non-injury animal crashes were not included.

23 USC § 407 Documents
NDDOT Reserves All Objections

VISION ZERO

Statistics for Total Crashes

Crash Severity	Letter Code	No. of Crashes
Fatal	K	0
Incapacitating Injury	A	0
Non-incapacitating Injury	B	0
Possible Injury	C	2
Property Damage Only	O	17
		19

K	0%
A	0%
B	0%
C	11%
O	89%

EPDO Score = 39

Under Construction

Yes = 0 0%

Day of Week

Monday =	4	21%
Tuesday =	5	26%
Wednesday =	5	26%
Thursday =	3	16%
Friday =	2	11%
Saturday =	0	0%
Sunday =	0	0%
	19	

Manner of Collision			K	A	B	C	O
			Breakdown by Severity				
Angle	3	16%	0	0	0	1	2
Rear End	13	68%	0	0	0	1	12
Left Turn	0	0%	0	0	0	0	0
Sideswipe (same dir.)	2	11%	0	0	0	0	2
Sideswipe (opp dir.)	0	0%	0	0	0	0	0
Single Vehicle	0	0%	0	0	0	0	0
Ped/Bike	0	0%	0	0	0	0	0
Head On	0	0%	0	0	0	0	0
Backing	0	0%	0	0	0	0	0
Other	1	5%	0	0	0	0	1
	19	100%	0	0	0	2	17

Surface Conditions			K	A	B	C	O
			Breakdown by Severity				
Dry	13	68%	0	0	0	2	11
Wet	1	5%	0	0	0	0	1
Ice / Snow	5	26%	0	0	0	0	5
Other	0	0%	0	0	0	0	0
	19	100%	0	0	0	2	17

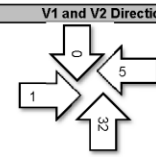
Lighting Conditions			K	A	B	C	O
			Breakdown by Severity				
Dawn/Dusk	0	0%	0	0	0	0	0
Daylight	17	89%	0	0	0	2	15
Dark	2	11%	0	0	0	0	2
Dark (lighted)	0	0%	0	0	0	0	0
Unknown	0	0%	0	0	0	0	0
	19	100%	0	0	0	2	17

V1 and V2 Configuration*

Passenger Car =	11
PU / Van / Utility =	24
Truck =	2
Bus / Motorhome =	0
Motorcycle + Moped =	0
Ped or Bike =	0

These are only the most popular choices.

V1 and V2 Directions



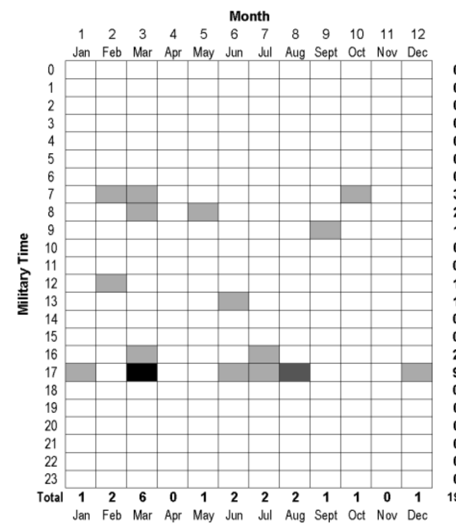
NB =	32
SB =	0
EB =	1
WB =	5

D1 and D2 Alcohol / Drugs*

Yes (alcohol or drugs present) = 0

D1 and D2 Age/Sex

Age	M	F	Total
0-17	2	1	3
18-20	1	2	3
21-24	0	1	1
25-34	7	4	11
35-44	4	4	8
45-54	2	3	5
55-64	3	2	5
65-74	1	0	1
75+	0	0	0
	20	17	37



Year	Start Date	End Date	Angle NB+EB	Angle NB+WB	Angle SB+EB	Angle SB+WB	Angle Subtotal	Rear End NB	Rear End SB	Rear End EB	Rear End WB	Rear End Subtotal	Left Turn NB to WB	Left Turn SB to EB	Left Turn EB to NB	Left Turn WB to SB	Left Turn Subtotal	Sideswipe Same Dir. NB	Sideswipe Same Dir. SB	Sideswipe Same Dir. EB	Sideswipe Same Dir. WB	Sideswipe Same Dir. Subtotal	Backing	Ped/Bike	Single Veh.	Head-on/other	Total	K	A	B	C	O	Dry	Wet	Ice/Snow	Construction?
1	1/1/14	12/31/14						2				2						1				1				1	4					4	1		3	
2	1/1/15	12/31/15						2				2															2					2	1	1		
3	1/1/16	12/31/16	1				1																				1					1	1			
4	1/1/17	12/31/17		1			1																				1				1		1			
5	1/1/18	12/31/18						3				3															3				1	2	3			
6	1/1/19	12/31/19						2				2															2					2	2			
7	1/1/20	12/31/20																									0									
8	1/1/21	12/31/21						1				1															1					1	1			
9	1/1/22	12/31/22									1	1															1					1			1	
10	1/1/23	12/31/23		1			1	2				2						1				1					4					4	3		1	
			1	2			3	12			1	13						2				2				1	19				2	17	13	1	5	

Intersection and/or Urban Crash Summary Sheets

Total Crashes: 7 (Sorted by Date)
City: Fargo
Location: 40th Ave N & Old US 81
Start - End Date: 1/1/2014 - 12/31/2023 (10 Years)

Notes: Non-injury animal crashes were not included.

23 USC § 407 Documents
NDDOT Reserves All Objections

VISION ZERO

Statistics for Total Crashes

Crash Severity	Letter Code	No. of Crashes
Fatal	K	0
Incapacitating Injury	A	0
Non-incapacitating Injury	B	1
Possible Injury	C	2
Property Damage Only	O	4
		7

K	0%
A	0%
B	14%
C	29%
O	57%

EPDO Score = 43

Under Construction

Yes = 1 14%

Day of Week

Monday =	1	14%
Tuesday =	0	0%
Wednesday =	3	43%
Thursday =	2	29%
Friday =	0	0%
Saturday =	1	14%
Sunday =	0	0%
	7	

Manner of Collision			K	A	B	C	O
			Breakdown by Severity				
Angle	5	71%	0	0	1	2	2
Rear End	1	14%	0	0	0	0	1
Left Turn	0	0%	0	0	0	0	0
Sideswipe (same dir.)	1	14%	0	0	0	0	1
Sideswipe (opp dir.)	0	0%	0	0	0	0	0
Single Vehicle	0	0%	0	0	0	0	0
Ped/Bike	0	0%	0	0	0	0	0
Head On	0	0%	0	0	0	0	0
Backing	0	0%	0	0	0	0	0
Other	0	0%	0	0	0	0	0
	7	100%	0	0	1	2	4

Surface Conditions			K	A	B	C	O
			Breakdown by Severity				
Dry	4	57%	0	0	1	0	3
Wet	2	29%	0	0	0	2	0
Ice / Snow	1	14%	0	0	0	0	1
Other	0	0%	0	0	0	0	0
	7	100%	0	0	1	2	4

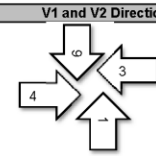
Lighting Conditions			K	A	B	C	O
			Breakdown by Severity				
Dawn/Dusk	0	0%	0	0	0	0	0
Daylight	7	100%	0	0	1	2	4
Dark	0	0%	0	0	0	0	0
Dark (lighted)	0	0%	0	0	0	0	0
Unknown	0	0%	0	0	0	0	0
	7	100%	0	0	1	2	4

V1 and V2 Configuration*

Passenger Car =	6
PU / Van / Utility =	7
Truck =	1
Bus / Motorhome =	0
Motorcycle + Moped =	0
Ped or Bike =	0

These are only the most popular choices.

V1 and V2 Directions



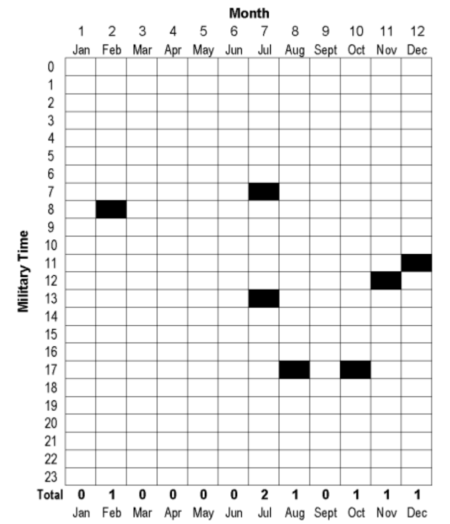
NB = 1
SB = 6
EB = 4
WB = 3

D1 and D2 Alcohol / Drugs*

Yes (alcohol or drugs present) = 0

D1 and D2 Age/Sex

Age	M	F	Total
0-17	0	0	0
18-20	0	0	0
21-24	0	0	0
25-34	3	1	4
35-44	1	0	1
45-54	2	2	4
55-64	0	0	0
65-74	2	0	2
75+	3	0	3
	11	3	14



Year	Start Date	End Date	Angle NB+EB	Angle NB+WB	Angle SB+EB	Angle SB+WB	Angle Subtotal	Rear End NB	Rear End SB	Rear End EB	Rear End WB	Rear End Subtotal	Left Turn NB to WB	Left Turn SB to EB	Left Turn EB to NB	Left Turn WB to SB	Left Turn Subtotal	Sideswipe Same Dir. NB	Sideswipe Same Dir. SB	Sideswipe Same Dir. EB	Sideswipe Same Dir. WB	Sideswipe Same Dir. Subtotal	Backing	Ped/Bike	Single Veh.	Head-on/other	Total	K	A	B	C	O	Dry	Wet	Ice/Snow	Construction?
1	1/1/14	12/31/14																									0									
2	1/1/15	12/31/15			1		**1**			1		**1**															2					2	2			
3	1/1/16	12/31/16																									0									
4	1/1/17	12/31/17																									0									
5	1/1/18	12/31/18				1	**1**																				1				1			1		
6	1/1/19	12/31/19																									0									
7	1/1/20	12/31/20																									0									
8	1/1/21	12/31/21		1	1	1	**3**																				3			1	1	1	1	1	1	1
9	1/1/22	12/31/22																	1			**1**					1					1	1			
10	1/1/23	12/31/23																									0									
				1	2	2	5			1		1							1			1					7			1	2	4	4	2	1	1