Memorandum

To: Andrew Witter, PE, Publics Work Director
Sherburne County

From: Nick Semeja, PE
Matt Flanagan

Date: August 9, 2023

Subject: US Highway 169/CR 4 Rural Safety and Mobility Interchange Project – 2023 MPDG Grant Application Benefit-Cost Analysis Memorandum

Introduction

This memorandum summarizes the assumptions, methodology and results developed for the benefit-cost analysis of the No Build and Build Alternatives evaluated as part of the US 169 Rural Safety and Mobility Interchange Project – 2023 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 travel time, changes in vehicle operating costs, vehicle crashes, environmental impacts, capital costs and remaining capital value, and maintenance costs. The benefit-cost analysis can provide an indication of the economic desirability of an alternative, but decision-makers must weigh the results against other considerations, effects, and impacts of the project.

Project Overview

Sherburne County is requesting $24.7 million of 2023 Multimodal Project Discretionary Grant (MPDG) funds (US) 169 Rural Safety and Mobility Interchange Project. The project is in Sherburne County, Minnesota, within the city of Zimmerman. The Project's focus is to connect industrial centers, businesses, and people through sound multimodal transportation planning to provide for the safe and efficient movement of goods, services, and people in and around the City of Zimmerman, Sherburne County, and beyond. The project optimizes connectivity, improves safety, and provides regionwide economic impacts through several project improvements.

The US 169 and County Road (CR) 4 intersection is characterized by having a high rate of severe crashes and extensive mobility issues. Traffic delay at the signal is experienced for many hours of the day and during recreational time periods throughout the year, often resulting in mile-long queues on US 169 approaching the signal. The US 169 corridor is programmed to be converted to a freeway facility through the city of Elk River, located just south of the US 169 and CR 4 intersection. Once the freeway conversion takes place, the CR 4 intersection will be the last signalized intersection on US 169 in Central Minnesota, likely exacerbating the existing delay and safety issues.

The proposed project would construct a grade separated interchange in place of the at-grade signal at US 169 and CR 4. This project would connect the freeway facilities to the north and south and provide relief to the existing and future mobility and safety problems on the US 169 corridor. Additional project components are aimed at improving safety through intersection improvements, removing access points along US 169 and adding additional roadway connections to improve connectivity.

Description of Alternatives

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

No Build Alternative

The No Build Alternative included leaving the US 169 and CR 4 interchange in its current configuration of an at-grade signalized intersection. The No Build also condition assumes no construction of additional roadways or installation of alternative control types. Traffic impacts associated with programmed regional roadway improvements were included in the analysis. Figure 1 below shows the existing interchange configuration.

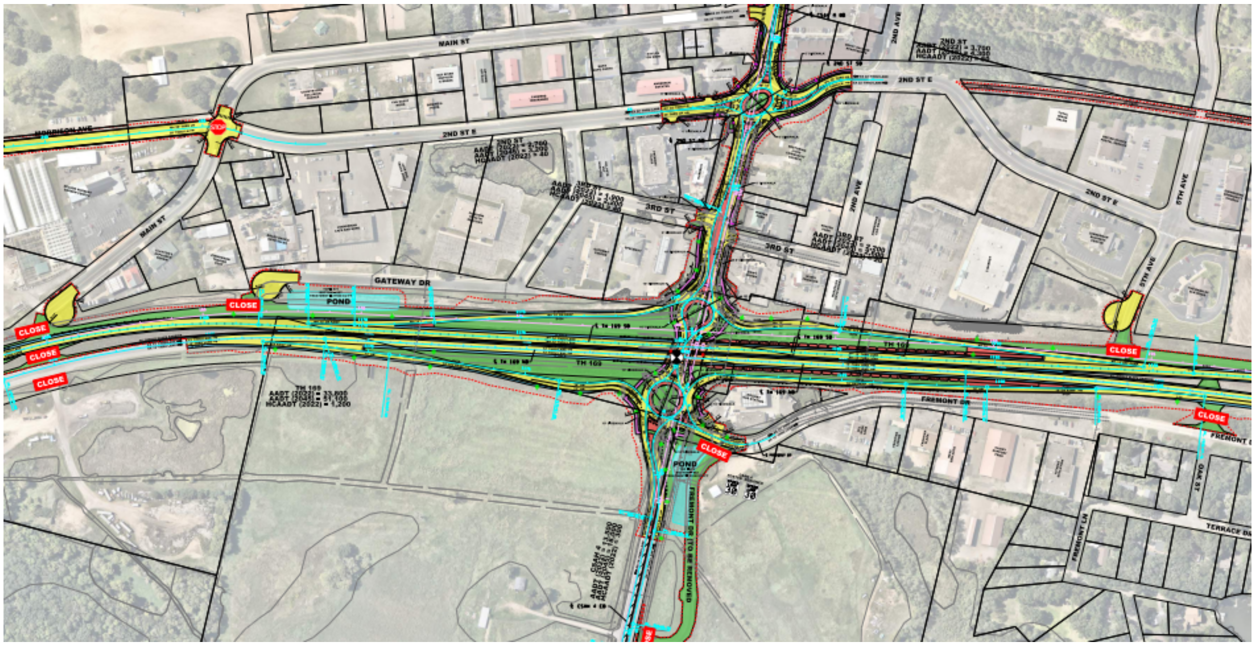
Figure 1. 169 and CR 4 Intersection Existing Conditions

Build Alternative

The proposed project will replace the existing signalized intersection with a full access interchange. The interchange will be configured as a peanut roundabout with US 169 going over CR 4. The interchange will also include a multimodal trail facility along the north side of CR 4. See Figure 2 for a concept of interchange improvements. This analysis also monetizes benefits associated with installation of a roundabout at US 169 and 255th Avenue and conversion of CR 4 and 2nd Street to an

R-CUT intersection. These modifications are anticipated to reduce delays and improve safety in the project area.

Figure 2. Build Interchange Concept



The BCA for the Build Alternative also assumed the same programmed improvements to the regional transportation system that were assumed in the No Build Alternative. Additional operations and maintenance costs associated with construction of new roadway were accounted for in this analysis.

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)
   - Vehicle operating costs
   - Crashes by severity
   - Environmental and air quality impacts
   - 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.
   - Operating and maintenance costs: These costs included annual inspection required for the new bridge and routine maintenance on the additional pavement associated with the interchange and other project improvements.

2. **Analysis Years**: This analysis assumed that construction would take place over a two-year period and be completed in 2026. Therefore, year 2027 was assumed to be the first full year that benefits will be accrued from the project. Since the project includes construction of a grade separated interchange and full reconstruction of the US 169 and CR 4 pavement adjacent to the new interchange, and at the intersection of the analysis focused on the estimated benefits for the thirty-year period from 2027 to 2056 based on anticipated service life of the improvements. The present value of all benefits and costs was calculated using 2021 as the year of current dollars.

3. **Economic Assumptions**: Value of time, vehicle operating costs, emissions costs and quality of life benefits were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023. The analysis was completed using an assumed discount rate of seven percent.

4. **Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)**: Travel time changes associated with conversion of the existing US 169 and CR 4 signalized intersection to a standard diamond interchange with roundabout control were captured using Vissim (Version 10) microsimulation modeling software.

   No Build and Build models were developed for morning, midday, and afternoon peak hours, and analysis was performed for existing year 2019 and forecast year 2040. Year 2019 turning movement counts were used for the existing year analysis, and year 2040 forecast volumes were developed by applying a 20-year growth factor of 1.4 to reflect the overall traffic growth expected in Sherburne County, as stated on page 66 of the Sherburne County Transportation Plan[1]. A higher growth rate of three percent per year is also stated in the Plan. However, the BCA used the lower of the two potential expected growth rates to keep the estimate of benefits conservative. A summary of traffic operations analysis is provided in Attachment B - Summary of Vissim Operations Analysis.

   Changes in VMT equivalents between the No Build and Build Alternatives were estimated based on the change in vehicle idling. It was assumed that time vehicles spend idling would produce wear and tear on the vehicle similar to time moving. The change in intersection delay between No Build and Build conditions was obtained from microsimulation modeling and converted to equivalents of vehicle-miles traveled (VMT) by applying fuel consumption for idling vehicles to average miles per gallon for passenger cars.

   To capture travel time and idling estimates in hours outside the morning, midday, and afternoon peak hours, volume-to-travel time relationships were developed and applied in the BCA. StreetLight[2] data for trips through the US 169 and CR 4 intersection was used to identify

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[1] Sherburne County Transportation Plan: https://www.co.sherburne.mn.us/DocumentCenter/View/4535/Sherburne-County-Transportation-Plan---Complete

[2] StreetLight is a data analytics tool that processes annual vehicle probe data to determine detailed trip information. https://www.streetlightdata.com/

hour-of-day and month-of-year volume profiles for the entirety of year 2019. Travel time-to-volume curves were developed based on study network entering volume and travel time output from each of the microsimulation modeling scenarios (existing year and forecast year, no build and build). These curves were used to predict travel time for the remaining hours of the day outside the morning, midday, and afternoon peak hours (see Figure 3). Once daily travel time for each modeling scenario was established, monthly adjustment factors for study area traffic volumes were applied based on the annual volume profile obtained from the StreetLight data. These adjustment factors (see Table 1) reflect the number of vehicle trips through the study area relative to the analysis base month of March (i.e. month the turn movements counts were collected).

Outcomes from the analysis estimate full-year VMT equivalents and VHT for the No Build and Build Alternatives in years 2019 and 2040. Benefits for years between existing year 2019 and forecast year 2040 were interpolated based on an annual growth rate, and benefits for years beyond year 2040 were extrapolated using the same annual growth rate. Savings due to reduction of VMT equivalents and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types.

Figure 3. Hourly Travel Times by Scenario

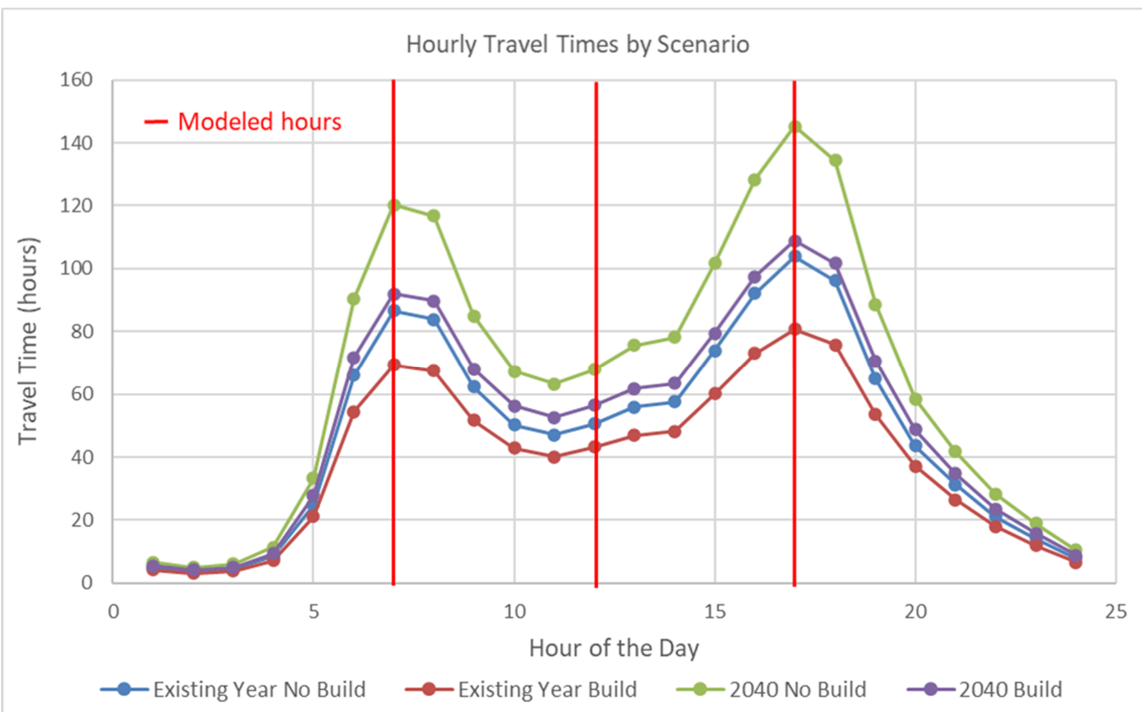

Table 1 – Monthly Traffic Volume Adjustment Factors

Month	Adjustment Factor
January	0.89
February	0.92
March	0.97
April	1.07
May	1.03
June	1.04
July	0.96
August	0.93
September	1.06
October	1.06
November	1.03
December	1.02

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 in the analysis was 8.3 percent and was based on year 2018 daily traffic and heavy truck counts provided in the MnDOT Traffic Mapping Application[3].
   - Vehicle occupancy that was used in the analysis is consistent with values provided by *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023. The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.
6. **Safety Analysis:** The Build Alternative improves safety in the project area by providing grade separation at the existing US 169 and CR 4 signal. This eliminates the high-speed at-grade crossing and reduces both congestion and conflicting volumes at intersections in the area. It

[3] MnDOT Traffic Mapping Application: https://mndot.maps.arcgis.com/apps/webappviewer/index.html?id=7b3be07daed84e7fa170a91059ce63bb

also involves two intersection safety improvements at Hwy 169 and 255th Ave (conversion to RAB intersection) and conversion of CR 4 and 2nd Street (conversion to R-CUT intersection).

Interchange Safety Benefits

Safety benefits were monetized using the Interactive Highway Safety Design Manual program (IHSDM-HSM Predictive Method - 2021 Release, v 17.0.0). IHSDM is a tool developed by the U.S. Department of Transportation – Federal Highway Administration (USDOT – FHWA) and is intended to help justify the need for proposed roadway designs and modifications by predicting crashes based on existing or proposed roadway geometry and traffic volumes. Results from the IHSDM Analysis are provided in the Appendix.

The data used in this analysis included existing and forecasted annual average daily traffic (AADT) projections, geometric and operational design elements. In the No Build, site-specific crash distributions provided by MnDOT were used to determine crash severity distributions. The build conditions crash distribution was based on "A Study of the Traffic Safety at Roundabouts in Minnesota (Revised September 15, 2021)[4]" . The crash severity distribution obtained from this study was used to calibrate results to local conditions. Note: If analysis was completed using non-localized factors (HSM default parameters in IHSDM V 17.0.0), crash savings would be greater than results presented in this analysis. A summary of this safety analysis is provided in Attachment C - Summary of Predictive Safety Analysis.

This safety analysis predicted the total number of crashes in accordance with methods outlined in the Highway Safety Manual (HSM) for each year between 2027 to 2056 by severity on the KABCO scale. The safety benefit was then quantified for years 2027 to 2056 using crash cost assumptions for the KABCO scale and are consistent with values and methodologies published in the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023.

Intersection Safety Benefits

Intersection safety benefits were also quantified for the conversion of Hwy 169 and 255th Avenue to a roundabout and for conversion of CR 4 and 2nd Street to an R-CUT intersection.

Crashes were gathered from these intersections using MnDOT's crash mapping analysis tool[5] for years 2015-2019 to exclude COVID-19 pandemic related drops in traffic volumes. No Build crashes by severity and crash cost were determined for existing year 2019 and forecast year 2040 using projected traffic growth rates.

The crash modification factor for the "convert intersection with minor-road stop control to modern roundabout[6]" was obtained from the Crash Modification Factors (CMF)

[4] A Study of Traffic Safety at Roundabouts in Minnesota (MnDOT, Published in 2017, Revised 2021): http://www.dot.state.mn.us/roundabouts/safety.html (Table 7 on Page 19)
[5] Minnesota Crash Mapping Analysis Tool (MnCMAT2): https://www.dot.state.mn.us/stateaid/mncmat2.html
[6] CMF ID#: 231 https://www.cmfclearinghouse.org/detail.cfm?facid=231#commentanchor

Clearinghouse database. The crash modification factor was applied to all crashes of all severity at this intersection.

The crash modification factor for the "convert intersection to restricted crossing U-turn (R-CUT) intersection[7]" was obtained from the CMF Clearinghouse database. The crash modification factor was applied to all crashes of all severity at this intersection.

Annual crash costs and crashes by severity for years 2027 to 2056 were calculated by multiplying the base year crashes by the percent change in AADT between the base year (year 2019 being the center of the crash analysis period) and forecast year 2040. The benefits for the years between 2041 and 2056 were extrapolated the same annual growth rate. Crash cost assumptions for the KABCO scale are consistent with values and methodologies published in the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023.

Environmental and Air Quality Impacts: Changes in emissions are expected to be impacted by the time vehicles spend idling at each of the project intersections. The change in intersection delay between No Build and Build conditions was obtained from travel time analysis and converted to equivalents of vehicle-miles traveled (VMT) by applying fuel consumption for idling vehicles to average miles per gallon for passenger cars. The change in VMT equivalents was then applied to emission rates by vehicle type. Average emission rates per vehicle type were obtained from the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 3. Emission rates per vehicle type are provided in the attached BCA Workbook. Total change in emissions was valued in accordance with the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023.

7. **Water Quality Impacts:** Currently, nutrient runoff in the project area feeds downstream to the Tibbets Brook, which is listed by the Minesota Pollution Control Agency (MPCA) to hold excessive levels of E.coli bacteria and phosphorus levels. The project will incorporate sedimentation, filtration, plant uptake, and groundwater recharge methods to control nutrient runoff.

   Benefits from addressing nutrient runoff into the Mississippi River Street. Cloud Watershed were derived by determining pollution costs per person and applying the rates to number of people impacted. National annual cost of water pollution from nutrients[8] was divided by the US population[9] to determine an average water pollution cost per person. This cost was then applied to the population of the City of Elk River[10], which is directly downstream from the runoff coming from the US 169 and CSAH 4 project area, to determine an estimate of potential water quality cost savings if nutrient runoff is to be mitigated.

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[7] CMF ID#: 10383 - https://www.cmfclearinghouse.org/detail.cfm?facid=10383
[8] Freshwater Pollution Cost Study (Kansas State, 2008),https://www.sciencedaily.com/releases/2008/11/081112124418.htm
[9] United States Census Bureau: https://www.census.gov/data/tables/2008/demo/age-and-sex/2008-age-sex-composition.html
[10]United States Census Bureau: https://www.census.gov/quickfacts/fact/table/elkrivercityminnesota/IPE11

It is likely that additional individuals will be impacted by the reduction in nutrient runoff from the project area, as the Tibbet Brook flows into the drinking water intake for the Twin Cities, which contains more than 3 million residents. However, the water quality will likely be somewhat diluted from other sources by the time it reaches the Twin Cities. Thus, benefits to users outside of the City of Elk River were not monetized as part of the BCA but are likely to be realized. It was also assumed that these additional unquantified benefits may be offset from residual amounts of nutrient runoff possibly remaining after the project improvements are incorporated, rather than a full elimination of nutrient pollution in the Tibbets Brook and subsequently, the City of Elk River.

8. **Operating and Maintenance Costs**: Routine annual roadway maintenance costs associated with maintaining the additional roadway infrastructure under the Build Alternative were considered in the BCA. An annual maintenance cost of $8,100 per lane mile, which derived from maintenance reports for similar facility types within the Twin Cities metro area, was applied to the length of the new interchange pavement and roadway along 255th, Morrison Avenue, 2nd Street and 269th Avenue. This maintenance cost included costs associated with striping, snow plowing, minor repairs, and shoulder maintenance. An annual cost of $2,000 was also assumed for inspections of the new bridge in the Build Alternative based on recommendations from the MnDOT Bridge Office.

9. **Calculation of Remaining Capital Value**: Because many components of the initial capital costs have service lives well beyond the 30-year analysis period, the remaining capital value was calculated for the Build Alternative. These values were expressed in terms of 2021 dollars and were added to other project benefits in accordance with USDOT guidance. The assumed service life used in this analysis is 65 years and is based on recommendations provided by MnDOT Office of Transportation System Management.

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:

    - Increased travel time reliability in the study area due to the increase in roadway capacity.
    - Health, safety and quality of life benefits associated with connecting future trails on the east and west sides of US 169.
    - Savings on future rehabilitation costs required under a No Build scenario on the portions of the project area being reconstructed as part of the realignment and interchange construction.
    - Safety benefits:
        - Removing seven at grade access driveways to US 169 and improving the access points at 255th Avenue and 269th Avenue to provide left turn lanes and only allow right turns onto US 169, reducing traffic crossing US 169.
        - Reconstructing the roadway with wider shoulders and rumble strips, which will help to reduce single vehicle run off the road crashes.
        - Building a multimodal trail crossing under US 169 on both sides of CR 4 that provides separated walk/bike facilities with limited pedestrian and vehicle conflict points connecting Zimmerman to east of US 169.

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 (2021 Dollars)	Project Benefits (2021 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2021 Dollars)
No Build vs. Build	$36.17 million	$54.43 million	1.50	$18.25 million

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Attachment A

Benefit-Cost Analysis Workbook

Attachment B

Summary of Vissim Operations Analysis

Summary of Traffic Operations Analysis
Vissim (Version 10)

Metric		Units	*Existing Volumes*						*Year 2040 Volumes*					
			No Build			Build			No Build			Build		
			AM	Midday	PM	AM	Midday	PM	AM	Midday	PM	AM	Midday	PM
Total Vehicles		veh	2,626	1,696	3,101	2,614	1,693	3,090	3,448	2,218	4,048	3,431	2,207	4,022
Average Vehicle Delay		sec	29.1	21.2	35.1	3.0	2.0	3.7	36.9	24.7	44.3	4.6	2.6	7.2
Average Speed		mph	42.7	45.9	40.9	52.8	53.4	52.5	39.6	44.1	37.7	51.5	52.6	50.1
Total Distance		mi	3,578	2,323	4,247	3,564	2,307	4,245	4,624	2,986	5,468	4,614	2,971	5,459
Total Travel Time		hrs	83.8	50.6	104.0	67.5	43.2	80.8	116.7	67.8	145.3	89.7	56.5	108.9
Total Network Delay		hrs	21.2	10.0	30.3	2.2	0.9	3.2	35.4	15.2	49.8	4.3	1.6	8.0
Intersection Delay	**West Ramps**	sec	26.6	19.2	32.6	1.9	1.0	1.6	33.7	22.5	41.2	2.7	1.3	2.5
	East Ramps	sec				2.5	1.8	4.0				4.4	2.5	9.9
	Fremont	sec	3.3	2.3	2.7				5.2	2.6	4.2			

Note: The table above summarizes the results of traffic operations analysis conducted using Vissim (version 10). These values are used in analysis presented in Attachment A - BCA Workbook. Additional analysis used to extrapolate this data to an annual total are described in the BCA Memorandum and are shown in the BCA Workbook. The value of time, vehicle operating costs, emissions costs, and cost of crashes were obtained from the Benefit Cost Analysis Guidance for Discretionary Grant Programs, dated January 2023.

Attachment C

Summary of Predictive Safety Analysis

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

February 13, 2023

Disclaimer

The Interactive Highway Design Model (IHSDM) software is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its content or use thereof. This document does not constitute a standard, specification, or regulation.

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Report Overview

Report Generated: Feb 13, 2023 7:24 PM
Report Template: System: Multi-Page, 508 Compliant [System] (sscpm4, Oct 7, 2021 8:13 AM)

Evaluation Date: Mon Feb 13 19:23:52 CST 2023
IHSDM Version: v17.0.0 (Sep 22, 2021)
Site Set Crash Prediction Module: v|ModuleInfo.moduleVersion| (|ModuleInfo.moduleDate|)

User Name: Matt Flanagan
Organization Name: SRF Consulting
Phone:
E-Mail: mflanagan@srfconsulting.com

Project Title: RAISE Grants
Project Comment: Created Mon May 10 16:54:52 CDT 2021
Project Unit System: U.S. Customary

Site Set: US 169 & CSAH 4 - Existing Conditions
Site Set Comment: Created Tue May 11 10:01:12 CDT 2021
Site Set Version: v3

Evaluation Title: Existing Conditions (1 of 1) - 2025-2060
Evaluation Comment: Created Mon Feb 13 19:20:49 CST 2023
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration

First Year of Analysis: 2025
Last Year of Analysis: 2060
Empirical-Bayes Analysis: None

Disclaimer Regarding Crash Prediction Method

IMPORTANT NOTICE ABOUT COMPARING RESULTS FROM HIGHWAY SAFETY MANUAL FIRST EDITION (2010) MODELS TO RESULTS FROM NEW MODELS DEVELOPED UNDER NCHRP PROJECTS 17-70, 17-58, AND 17-68

Since the publication of the Highway Safety Manual - First Edition (HSM-1), in 2010 by the American Association of State Highway and Transportation Officials (AASHTO), multiple research efforts have been undertaken through the National

Cooperative Highway Research Program (NCHRP) to develop safety performance models for road segment and intersection facility types that were not initially reflected in the HSM-1, in order to expand the breadth and depth of the HSM in the future.

The IHSDM Crash Prediction Module (CPM) is intended as a faithful implementation of HSM Part C predictive methods. As NCHRP projects to develop new predictive methods for the HSM are completed, FHWA works to incorporate the new methods into IHSDM, sometimes in advance of publication in the HSM. The following new crash predictive methods have been accepted by NCHRP project panels and incorporated into IHSDM, while pending AASHTO's approval for incorporation into a future edition of the HSM:

- Roundabouts: completed in 2018 under NCHRP Project 17-70, the new methods will provide improved outcomes for the safety analysis of roundabouts.
- 6+ lane and one-way urban/suburban arterials (including models for segments and intersections): completed under NCHRP Project 17-58.
- Intersection crash prediction methods for some intersection configurations and traffic control types not currently addressed in the HSM (e.g., all-way stop; rural 3-leg signalized; 3-leg stop-controlled where the major leg turns; urban 5-leg signalized; urban high-speed intersections): completed in 2021 under NCHRP Project 17-68.

However, in the absence of local calibration factors (see HSM-1 Part C, Appendix A for guidance on calibration of the predictive models), it is neither appropriate nor advisable to directly compare the results from new models (from NCHRP Projects 17-58, 17-68, and 17-70) to results from HSM-1 models, as the models were not calibrated to the same base state data sets, and consequently can produce unexpected results. If local calibration factors are available and applied to both new models and HSM-1 models, then it may be appropriate to directly compare the results.*[Note: Work being performed under NCHRP Project 17-72 (Update of Crash Modification Factors for the Highway Safety Manual) is expected to re-calibrate many of the old (HSM-1) and new (e.g., NCHRP 17-70) models to data from a single (or small number of) states, that would allow results from all models to be directly compared.]*

The models produced for NCHRP Project 17-70 have independent value in terms of informing the design of a roundabout and assessing the effects of different design characteristics on the expected safety performance of a roundabout.

The HSM-1 interim method previously included in IHSDM for evaluating roundabouts on urban/suburban arterials (i.e., evaluating an existing intersection and then applying a Crash Modification Factor for replacing the existing intersection with a roundabout) has been deactivated in IHSDM, to minimize any confusion with the new roundabout methodology.

Section Types

Rural MultiLane Site Set CPM Evaluation

Site Type

Type: 4SG
Calibration Factor: 1

Table 1. Evaluation and Crash Data (CSD) (if applicable) Intersection Sites

Site No.	Type	Highway	Site Description	Major AADT	Minor AADT	Presence of Lighting
1	4SG	US 169 & CSAH 4	Rural-Multi Lane; Four-Legged Signalized Intersection	2025: 26209; 2026: 26510; 2027: 26812; 2028: 27113; 2029: 27415; 2030: 27716; 2031: 28017; 2032: 28319; 2033: 28620; 2034: 28921; 2035: 29223; 2036: 29524; 2037: 29825; 2038: 30127; 2039: 30428; 2040: 30730; 2041: 31031; 2042: 31332; 2043: 31634; 2044: 31935; 2045: 32236; 2046: 32538; 2047: 32839; 2048: 33140; 2049: 33442; 2050: 33743; 2051: 34044; 2052: 34346; 2053: 34647; 2054: 34948; 2055: 35250; 2056: 35551; 2057: 35852; 2058: 36154; 2059: 36455; 2060: 36757	2025: 11228; 2026: 11403; 2027: 11579; 2028: 11754; 2029: 11930; 2030: 12105; 2031: 12280; 2032: 12456; 2033: 12631; 2034: 12807; 2035: 12982; 2036: 13158; 2037: 13333; 2038: 13509; 2039: 13684; 2040: 13860; 2041: 14035; 2042: 14210; 2043: 14386; 2044: 14561; 2045: 14737; 2046: 14912; 2047: 15088; 2048: 15263; 2049: 15439; 2050: 15614; 2051: 15789; 2052: 15965; 2053: 16140; 2054: 16316; 2055: 16491; 2056: 16667; 2057: 16842; 2058: 17018; 2059: 17193; 2060: 17369	

Table 2. Predicted Crash Frequencies and Rates by Site

Site No.	Type	Highway	Site Description	Total Predicted Crashes for Evaluation Period	Predicted Total Crash Frequency (crashes/yr)	Predicted FI Crash Frequency (crashes/yr)	Predicted FI no/C Crash Frequency (crashes/yr)	Predicted PDO Crash Frequency (crashes/yr)	Predicted Intersection Travel Crash Rate (crashes/million veh)	Intersection Crash Rate (crashes/yr)
1	4SG	US 169 & CSAH 4	Rural-Multi Lane; Four-Legged Signalized Intersection	1,216.909	33.8030	11.4035	5.5669	22.3995	2.02	33.8030
		Total	Total	1,216.909	33.8030	11.4035	5.5669	22.3995	2.02	33.8030

Table 3. Predicted Crash Frequencies by Year (4SG)

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
2025	27.29	9.60	35.174	17.69	64.826
2026	27.66	9.70	35.084	17.95	64.916
2027	28.03	9.81	34.994	18.22	65.006
2028	28.40	9.91	34.906	18.49	65.094
2029	28.77	10.02	34.819	18.75	65.181
2030	29.14	10.12	34.734	19.02	65.266
2031	29.51	10.23	34.651	19.29	65.350
2032	29.88	10.33	34.568	19.55	65.432
2033	30.25	10.43	34.486	19.82	65.514
2034	30.63	10.54	34.406	20.09	65.594
2035	31.00	10.64	34.327	20.36	65.673
2036	31.37	10.74	34.249	20.63	65.751
2037	31.74	10.85	34.172	20.89	65.828
2038	32.12	10.95	34.097	21.17	65.903
2039	32.49	11.05	34.022	21.43	65.978
2040	32.86	11.16	33.948	21.71	66.052
2041	33.23	11.26	33.876	21.98	66.124
2042	33.61	11.36	33.804	22.25	66.196
2043	33.98	11.46	33.733	22.52	66.266
2044	34.35	11.56	33.664	22.79	66.336
2045	34.73	11.67	33.595	23.06	66.405
2046	35.10	11.77	33.527	23.33	66.473
2047	35.48	11.87	33.460	23.61	66.540
2048	35.85	11.97	33.394	23.88	66.606
2049	36.22	12.07	33.328	24.15	66.672
2050	36.60	12.17	33.264	24.42	66.736
2051	36.97	12.28	33.200	24.70	66.800
2052	37.35	12.38	33.137	24.97	66.863
2053	37.72	12.48	33.075	25.25	66.925
2054	38.10	12.58	33.013	25.52	66.987
2055	38.47	12.68	32.952	25.80	67.048
2056	38.85	12.78	32.892	26.07	67.108
2057	39.22	12.88	32.833	26.35	67.167
2058	39.60	12.98	32.774	26.62	67.226
2059	39.98	13.08	32.716	26.90	67.284
2060	40.35	13.18	32.658	27.17	67.342
Total	1,216.91	410.53	33.735	806.38	66.265
Average	33.80	11.40	33.735	22.40	66.265

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

Table 4. Predicted 4SG Crash Type Distribution

Element Type	Crash Type	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)	Total Crashes	Percent Total (%)
Intersection	Single	16.83	1.4	62.09	5.1	75.45	6.2
Intersection	Total Single Vehicle Crashes	16.83	1.4	62.09	5.1	75.45	6.2
Intersection	Angle Collision	129.32	10.6	173.37	14.2	311.53	25.6
Intersection	Head-on Collision	34.07	2.8	27.42	2.3	65.71	5.4
Intersection	Rear-end Collision	193.77	15.9	407.22	33.5	598.72	49.2
Intersection	Sideswipe	19.30	1.6	118.54	9.7	128.99	10.6
Intersection	Total Multiple Vehicle Crashes	376.45	30.9	726.55	59.7	1,104.95	90.8
Intersection	Total Intersection Crashes	410.12	33.7	807.19	66.3	1,216.91	100.0
Intersection	Other Collision	16.83	1.4	18.55	1.5	36.51	3.0
	Total Crashes	410.12	33.7	807.19	66.3	1,216.91	100.0

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

February 13, 2023

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Report Template: System: Multi-Page, 508 Compliant [System] (sscpm4, Oct 7, 2021 8:13 AM)

Evaluation Date: Mon Feb 13 19:27:29 CST 2023
IHSDM Version: v17.0.0 (Sep 22, 2021)
Site Set Crash Prediction Module: v|ModuleInfo.moduleVersion| (|ModuleInfo.moduleDate|)

User Name: Matt Flanagan
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Project Title: RAISE Grants
Project Comment: Created Mon May 10 16:54:52 CDT 2021
Project Unit System: U.S. Customary

Site Set: Node 10 - Build RAB
Site Set Comment: Created Thu Jan 26 11:55:48 CST 2023
Site Set Version: v5

Evaluation Title: Node 10 - Build RAB (2025-2060)
Evaluation Comment: Created Mon Feb 13 19:27:16 CST 2023
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration

First Year of Analysis: 2025
Last Year of Analysis: 2060
Empirical-Bayes Analysis: None

Disclaimer Regarding Crash Prediction Method

IMPORTANT NOTICE ABOUT COMPARING RESULTS FROM HIGHWAY SAFETY MANUAL FIRST EDITION (2010) MODELS TO RESULTS FROM NEW MODELS DEVELOPED UNDER NCHRP PROJECTS 17-70, 17-58, AND 17-68

Since the publication of the Highway Safety Manual - First Edition (HSM-1), in 2010 by the American Association of State Highway and Transportation Officials (AASHTO), multiple research efforts have been undertaken through the National

Cooperative Highway Research Program (NCHRP) to develop safety performance models for road segment and intersection facility types that were not initially reflected in the HSM-1, in order to expand the breadth and depth of the HSM in the future.

The IHSDM Crash Prediction Module (CPM) is intended as a faithful implementation of HSM Part C predictive methods. As NCHRP projects to develop new predictive methods for the HSM are completed, FHWA works to incorporate the new methods into IHSDM, sometimes in advance of publication in the HSM. The following new crash predictive methods have been accepted by NCHRP project panels and incorporated into IHSDM, while pending AASHTO's approval for incorporation into a future edition of the HSM:

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- Intersection crash prediction methods for some intersection configurations and traffic control types not currently addressed in the HSM (e.g., all-way stop; rural 3-leg signalized; 3-leg stop-controlled where the major leg turns; urban 5-leg signalized; urban high-speed intersections): completed in 2021 under NCHRP Project 17-68.

However, in the absence of local calibration factors (see HSM-1 Part C, Appendix A for guidance on calibration of the predictive models), it is neither appropriate nor advisable to directly compare the results from new models (from NCHRP Projects 17-58, 17-68, and 17-70) to results from HSM-1 models, as the models were not calibrated to the same base state data sets, and consequently can produce unexpected results. If local calibration factors are available and applied to both new models and HSM-1 models, then it may be appropriate to directly compare the results.*[Note: Work being performed under NCHRP Project 17-72 (Update of Crash Modification Factors for the Highway Safety Manual) is expected to re-calibrate many of the old (HSM-1) and new (e.g., NCHRP 17-70) models to data from a single (or small number of) states, that would allow results from all models to be directly compared.]*

The models produced for NCHRP Project 17-70 have independent value in terms of informing the design of a roundabout and assessing the effects of different design characteristics on the expected safety performance of a roundabout.

The HSM-1 interim method previously included in IHSDM for evaluating roundabouts on urban/suburban arterials (i.e., evaluating an existing intersection and then applying a Crash Modification Factor for replacing the existing intersection with a roundabout) has been deactivated in IHSDM, to minimize any confusion with the new roundabout methodology.

Section Types

Roundabout Site Set CPM Evaluation

Site Type

Type: Roundabout RML 41R

Calibration Factor: RML 41R = 1.0

Table 1. Evaluation and Crash Data (CSD) (if applicable) Roundabout - Homogeneous Sites

Site No.	Type	Roundabout	Site Description	Area Type	Entering AADT
1	41R - Roundabout with 4 legs and a single circulating lane	Node 10	RAB	Rural	Leg 1:2025: 2226; 2026: 2252; 2027: 2278; 2028: 2304; 2029: 2330; 2030: 2356; 2031: 2382; 2032: 2408; 2033: 2434; 2034: 2460; 2035: 2486; 2036: 2512; 2037: 2538; 2038: 2564; 2039: 2590; 2040: 2616; 2041: 2642; 2042: 2668; 2043: 2694; 2044: 2720; 2045: 2746; 2046: 2772; 2047: 2798; 2048: 2824; 2049: 2850; 2050: 2876; 2051: 2902; 2052: 2928; 2053: 2954; 2054: 2980; 2055: 3006; 2056: 3032; 2057: 3058; 2058: 3084; 2059: 3110; 2060: 3136; Leg 2:2025: 8136; 2026: 8276; 2027: 8417; 2028: 8558; 2029: 8698; 2030: 8839; 2031: 8980; 2032: 9120; 2033: 9261; 2034: 9402; 2035: 9542; 2036: 9683; 2037: 9824; 2038: 9964; 2039: 10105; 2040: 10246; 2041: 10391; 2042: 10536; 2043: 10681; 2044: 10826; 2045: 10971; 2046: 11116; 2047: 11262; 2048: 11407; 2049: 11552; 2050: 11697; 2051: 11842; 2052: 11987; 2053: 12132; 2054: 12278; 2055: 12423; 2056: 12568; 2057: 12713; 2058: 12858; 2059: 13003; 2060: 13149; Leg 3:2025-2060: 0; Leg 4:2025: 6611; 2026: 6717; 2027: 6822; 2028: 6928; 2029: 7034; 2030: 7139; 2031: 7245; 2032: 7351; 2033: 7457; 2034: 7562; 2035: 7668; 2036: 7774; 2037: 7879; 2038: 7985; 2039: 8091; 2040: 8197; 2041: 8163; 2042: 8130; 2043: 8096; 2044: 8063; 2045: 8029; 2046: 7996; 2047: 7962; 2048: 7929; 2049: 7895; 2050: 7862; 2051: 7828; 2052: 7795; 2053: 7761; 2054: 7728; 2055: 7694; 2056: 7661; 2057: 7627; 2058: 7594; 2059: 7560; 2060: 7527

Table 2. Predicted Crash Frequencies and Rates by Site

Site No.	Type	Roundabout	Site Description	Total Predicted Crashes for Evaluation Period	Predicted Total Crash Frequency (crashes/yr)	Predicted FI Crash Frequency (crashes/yr)	Predicted PDO Crash Frequency (crashes/yr)	Predicted Intersection Travel Crash Rate (crashes/million veh)	Intersection Crash Rate (crashes/yr)
1	41R - Roundabout with 4 legs and a single circulating lane	Node 10	RAB	88.536	2.4593	0.1713	2.2881	0.64	2.4593
		Total	Total	88.536	2.4593	0.1713	2.2881	0.64	2.4593

Table 3. Predicted Crash Frequencies by Year (Roundabout RML 41R)

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
2025	2.11	0.14	6.506	1.98	93.494
2026	2.14	0.14	6.530	2.00	93.470
2027	2.16	0.14	6.554	2.02	93.446
2028	2.19	0.14	6.578	2.04	93.422
2029	2.21	0.15	6.601	2.06	93.399
2030	2.23	0.15	6.624	2.08	93.376
2031	2.26	0.15	6.647	2.11	93.353
2032	2.28	0.15	6.669	2.13	93.331
2033	2.30	0.15	6.691	2.15	93.309
2034	2.33	0.16	6.713	2.17	93.287
2035	2.35	0.16	6.734	2.19	93.266
2036	2.38	0.16	6.755	2.21	93.245
2037	2.40	0.16	6.776	2.23	93.224
2038	2.42	0.17	6.797	2.26	93.203
2039	2.44	0.17	6.817	2.28	93.183
2040	2.47	0.17	6.837	2.30	93.163
2041	2.48	0.17	6.870	2.31	93.130
2042	2.49	0.17	6.902	2.32	93.098
2043	2.50	0.17	6.934	2.33	93.066
2044	2.52	0.17	6.966	2.34	93.034
2045	2.53	0.18	6.997	2.35	93.003
2046	2.54	0.18	7.028	2.36	92.972
2047	2.55	0.18	7.059	2.37	92.941
2048	2.56	0.18	7.090	2.38	92.910
2049	2.58	0.18	7.120	2.39	92.880
2050	2.59	0.18	7.150	2.40	92.850
2051	2.60	0.19	7.180	2.41	92.820
2052	2.61	0.19	7.209	2.42	92.791
2053	2.62	0.19	7.238	2.43	92.762
2054	2.64	0.19	7.267	2.44	92.733
2055	2.65	0.19	7.296	2.45	92.704
2056	2.66	0.20	7.324	2.46	92.676
2057	2.67	0.20	7.353	2.48	92.647
2058	2.68	0.20	7.380	2.48	92.620
2059	2.69	0.20	7.408	2.50	92.592
2060	2.71	0.20	7.436	2.50	92.564
Total	88.54	6.17	6.965	82.37	93.035
Average	2.46	0.17	6.965	2.29	93.035

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

Table 4. Predicted Roundabout RML 41R Crash Severity

Site No.	Fatal (K) Crashes (crashes)	Incapacitating Injury (A) Crashes (crashes)	Non-Incapacitating Injury (B) Crashes (crashes)	Possible Injury (C) Crashes (crashes)	No Injury (O) Crashes (crashes)
1	0.0340	0.3379	2.1738	3.6207	82.3701
Total	0.0340	0.3379	2.1738	3.6207	82.3701

Table 5. Predicted Roundabout RML 41R Crash Type Distribution

Element Type	Crash Type	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)	Total Crashes	Percent Total (%)
Intersection	Collision with Animal	0.00	0.0	1.15	1.3	1.15	1.3
Intersection	Collision with Fixed Object	1.33	1.5	21.50	24.3	22.83	25.8
Intersection	Collision with Other Object	0.00	0.0	0.00	0.0	0.00	0.0
Intersection	Other Single-vehicle Collision	1.29	1.5	9.55	10.8	10.84	12.2
Intersection	Collision with Parked Vehicle	0.01	0.0	0.25	0.3	0.26	0.3
Intersection	Total Single Vehicle Crashes	2.63	3.0	32.45	36.6	35.09	39.6
Intersection	Angle Collision	0.71	0.8	12.27	13.8	12.98	14.7
Intersection	Head-on Collision	0.07	0.1	0.33	0.4	0.40	0.4
Intersection	Other Multiple-vehicle Collision	0.44	0.5	5.77	6.5	6.20	7.0
Intersection	Rear-end Collision	1.84	2.1	20.43	23.1	22.27	25.1
Intersection	Sideswipe	0.48	0.5	11.20	12.6	11.68	13.2
Intersection	Total Multiple Vehicle Crashes	3.53	4.0	50.00	56.4	53.53	60.4
Intersection	Total Intersection Crashes	6.17	7.0	82.45	93.0	88.62	100.0
	Total Crashes	6.17	7.0	82.45	93.0	88.62	100.0

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

February 13, 2023

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Report Overview

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Evaluation Date: Mon Feb 13 19:30:48 CST 2023
IHSDM Version: v17.0.0 (Sep 22, 2021)
Site Set Crash Prediction Module: v|ModuleInfo.moduleVersion| (|ModuleInfo.moduleDate|)

User Name: Matt Flanagan
Organization Name: SRF Consulting
Phone:
E-Mail: mflanagan@srfconsulting.com

Project Title: RAISE Grants
Project Comment: Created Mon May 10 16:54:52 CDT 2021
Project Unit System: U.S. Customary

Site Set: Node 20 - Build RAB
Site Set Comment: Created Thu Jan 26 12:10:27 CST 2023
Site Set Version: v7

Evaluation Title: Node 20 - Build RAB (2025-2060)
Evaluation Comment: Created Mon Feb 13 19:30:34 CST 2023
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration

First Year of Analysis: 2025
Last Year of Analysis: 2060
Empirical-Bayes Analysis: None

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Section Types

Roundabout Site Set CPM Evaluation

Site Type

Type: Roundabout RML 41R

Calibration Factor: RML 41R = 1.0

Table 1. Evaluation and Crash Data (CSD) (if applicable) Roundabout - Homogeneous Sites

Site No.	Type	Roundabout	Site Description	Area Type	Entering AADT
1	41R - Roundabout with 4 legs and a single circulating lane	Node 20	RAB	Rural	Leg 1:2025: 1561; 2026: 1568; 2027: 1575; 2028: 1583; 2029: 1590; 2030: 1597; 2031: 1605; 2032: 1612; 2033: 1619; 2034: 1627; 2035: 1634; 2036: 1641; 2037: 1649; 2038: 1656; 2039: 1663; 2040: 1671; 2041: 1675; 2042: 1679; 2043: 1683; 2044: 1687; 2045: 1691; 2046: 1695; 2047: 1699; 2048: 1703; 2049: 1707; 2050: 1711; 2051: 1715; 2052: 1719; 2053: 1723; 2054: 1727; 2055: 1731; 2056: 1735; 2057: 1739; 2058: 1743; 2059: 1747; 2060: 1751; Leg 2:2025: 5194; 2026: 5283; 2027: 5372; 2028: 5461; 2029: 5550; 2030: 5640; 2031: 5729; 2032: 5818; 2033: 5907; 2034: 5996; 2035: 6085; 2036: 6174; 2037: 6263; 2038: 6352; 2039: 6441; 2040: 6531; 2041: 6616; 2042: 6702; 2043: 6788; 2044: 6873; 2045: 6959; 2046: 7045; 2047: 7130; 2048: 7216; 2049: 7302; 2050: 7388; 2051: 7473; 2052: 7559; 2053: 7645; 2054: 7730; 2055: 7816; 2056: 7902; 2057: 7987; 2058: 8073; 2059: 8159; 2060: 8245; Leg 3:2025: 4081; 2026: 4152; 2027: 4223; 2028: 4294; 2029: 4365; 2030: 4435; 2031: 4506; 2032: 4577; 2033: 4648; 2034: 4719; 2035: 4790; 2036: 4861; 2037: 4932; 2038: 5003; 2039: 5074; 2040: 5145; 2041: 5215; 2042: 5286; 2043: 5357; 2044: 5428; 2045: 5499; 2046: 5570; 2047: 5641; 2048: 5712; 2049: 5783; 2050: 5854; 2051: 5924; 2052: 5995; 2053: 6066; 2054: 6137; 2055: 6208; 2056: 6279; 2057: 6350; 2058: 6421; 2059: 6492; 2060: 6563; Leg 4:2025: 4124; 2026: 4186; 2027: 4247; 2028: 4309; 2029: 4370; 2030: 4432; 2031: 4493; 2032: 4555; 2033: 4616; 2034: 4678; 2035: 4739; 2036: 4801; 2037: 4862; 2038: 4924; 2039: 4985; 2040: 5047; 2041: 5104; 2042: 5161; 2043: 5218; 2044: 5275; 2045: 5332; 2046: 5389; 2047: 5446; 2048: 5503; 2049: 5560; 2050: 5617; 2051: 5674; 2052: 5731; 2053: 5788; 2054: 5845; 2055: 5902; 2056: 5959; 2057: 6016; 2058: 6073; 2059: 6130; 2060: 6187

Table 2. Predicted Crash Frequencies and Rates by Site

Site No.	Type	Roundabout	Site Description	Total Predicted Crashes for Evaluation Period	Predicted Total Crash Frequency (crashes/yr)	Predicted FI Crash Frequency (crashes/yr)	Predicted PDO Crash Frequency (crashes/yr)	Predicted Intersection Travel Crash Rate (crashes/million veh)	Intersection Crash Rate (crashes/yr)
1	41R - Roundabout with 4 legs and a single circulating lane	Node 20	RAB	84.918	2.3588	0.2319	2.1270	0.68	2.3588
		Total	Total	84.918	2.3588	0.2319	2.1270	0.68	2.3588

Table 3. Predicted Crash Frequencies by Year (Roundabout RML 41R)

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
2025	2.00	0.19	9.389	1.81	90.611
2026	2.02	0.19	9.416	1.83	90.584
2027	2.04	0.19	9.443	1.85	90.557
2028	2.06	0.20	9.470	1.87	90.530
2029	2.08	0.20	9.497	1.89	90.503
2030	2.10	0.20	9.523	1.90	90.477
2031	2.13	0.20	9.549	1.92	90.451
2032	2.15	0.21	9.575	1.94	90.425
2033	2.17	0.21	9.600	1.96	90.400
2034	2.19	0.21	9.625	1.98	90.375
2035	2.21	0.21	9.650	2.00	90.350
2036	2.23	0.22	9.674	2.02	90.326
2037	2.25	0.22	9.699	2.04	90.301
2038	2.27	0.22	9.723	2.05	90.277
2039	2.29	0.22	9.746	2.07	90.254
2040	2.32	0.23	9.770	2.09	90.230
2041	2.34	0.23	9.792	2.11	90.208
2042	2.36	0.23	9.814	2.12	90.186
2043	2.38	0.23	9.835	2.14	90.165
2044	2.40	0.24	9.857	2.16	90.143
2045	2.42	0.24	9.878	2.18	90.122
2046	2.43	0.24	9.899	2.19	90.101
2047	2.45	0.24	9.920	2.21	90.080
2048	2.47	0.25	9.941	2.23	90.059
2049	2.49	0.25	9.961	2.24	90.038
2050	2.51	0.25	9.982	2.26	90.018
2051	2.53	0.25	10.002	2.28	89.998
2052	2.55	0.26	10.022	2.29	89.978
2053	2.57	0.26	10.042	2.31	89.958
2054	2.59	0.26	10.061	2.33	89.939
2055	2.61	0.26	10.081	2.34	89.919
2056	2.63	0.27	10.100	2.36	89.900
2057	2.65	0.27	10.119	2.38	89.881
2058	2.66	0.27	10.138	2.39	89.862
2059	2.68	0.27	10.157	2.41	89.843
2060	2.70	0.28	10.176	2.43	89.824
Total	84.92	8.35	9.830	76.57	90.170
Average	2.36	0.23	9.830	2.13	90.170

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

Table 4. Predicted Roundabout RML 41R Crash Severity

Site No.	Fatal (K) Crashes (crashes)	Incapacitating Injury (A) Crashes (crashes)	Non-Incapacitating Injury (B) Crashes (crashes)	Possible Injury (C) Crashes (crashes)	No Injury (O) Crashes (crashes)
1	0.0518	0.5149	3.3131	4.4674	76.5707
Total	0.0518	0.5149	3.3131	4.4674	76.5707

Table 5. Predicted Roundabout RML 41R Crash Type Distribution

Element Type	Crash Type	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)	Total Crashes	Percent Total (%)
Intersection	Collision with Animal	0.00	0.0	1.07	1.3	1.07	1.3
Intersection	Collision with Fixed Object	1.80	2.1	19.98	23.5	21.79	25.6
Intersection	Collision with Other Object	0.00	0.0	0.00	0.0	0.00	0.0
Intersection	Other Single-vehicle Collision	1.75	2.1	8.88	10.4	10.63	12.5
Intersection	Collision with Parked Vehicle	0.02	0.0	0.23	0.3	0.25	0.3
Intersection	Total Single Vehicle Crashes	3.56	4.2	30.17	35.5	33.73	39.7
Intersection	Angle Collision	0.96	1.1	11.41	13.4	12.37	14.6
Intersection	Head-on Collision	0.09	0.1	0.31	0.4	0.40	0.5
Intersection	Other Multiple-vehicle Collision	0.59	0.7	5.36	6.3	5.95	7.0
Intersection	Rear-end Collision	2.49	2.9	18.99	22.3	21.48	25.3
Intersection	Sideswipe	0.65	0.8	10.41	12.3	11.06	13.0
Intersection	Total Multiple Vehicle Crashes	4.78	5.6	46.48	54.7	51.26	60.3
Intersection	Total Intersection Crashes	8.35	9.8	76.65	90.2	84.99	100.0
	Total Crashes	8.35	9.8	76.65	90.2	84.99	100.0

Note: *Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.