Memorandum

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

From: Nick Semeja, PE, Associate

Date: July 12, 2021

Subject: US Highway 169/CR 4 Rural Safety and Mobility Interchange Project – 2021 RAISE Program Application Benefit-Cost Analysis Memorandum

Introduction

This memorandum summarizes the assumptions, methodology and results developed for the benefit-cost analysis of the No Build and Build Alternatives evaluated as part of the US Highway 169/CR 4 Rural Safety and Mobility Interchange Project – 2021 RAISE Grant Program Application. The objective of a benefit-cost analysis (BCA) is to bring all the direct effects of a transportation investment into a common measure (dollars), and to 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.

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/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/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.

Description of Alternatives

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

No Build Alternative

The No Build Alternative included leaving the US 10 and CR 4 interchange in its current configuration of an at-grade signalized intersection. Traffic impacts associated with programmed regional roadway improvements were included in the analysis.

Build Alternative

The proposed project will replace the existing signalized intersection with a full access interchange and frontage road system. The interchange includes a tight ramp configuration west of US 169 and a loop in the southeast quadrant of the interchange. The CR 4 bridge over US 169 will also include a multimodal trail facility along the north side of CR 4.

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.

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)
   - Operating costs (vehicle miles traveled – VMT)
   - Crashes by severity
   - Environmental and air quality impacts
   - Initial capital costs: These costs were broken into distinct categories in accordance with service life (consistent with the recommendations of MnDOT Office of Transportation System Management, July 2020[1]) and were applied evenly over the duration of the construction period.
   - Remaining Capital Value: The remaining capital value (value of improvement beyond the analysis period) was considered a benefit and was added to other user benefits.
   - 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 frontage road system.
2. **Analysis Years**: This analysis assumed that construction would take place over a three-year period and be completed in 2025. Therefore, year 2026 was assumed to be the first full year that benefits will be accrued from the project. Since the project includes construction of an interchange and full reconstruction of the US 169 and CR 4 pavement adjacent to the new interchange, the analysis focused on the estimated benefits for the thirty-year period from 2026 to 2055. The present value of all benefits and costs was calculated using 2019 as the year of current dollars.

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[1] Table 5: http://www.dot.state.mn.us/planning/program/benefitcost.html

3. **Economic Assumptions**: 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 February 2021. Remaining capital value assumptions were consistent with rates from *Recommended remaining capital value factors for use in benefit-cost analysis in SFY 2021*[2], Minnesota Department of Transportation (MnDOT), Office of Transportation System Management, July 2020 (values were adjusted to reflect discount rate). 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 and differences in vehicle miles traveled in the US 169/CR 4 study area were captured using Synchro/SimTraffic microsimulation modeling. 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 turn 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[3]. 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.

   Changes in VMT between the No Build and Build Alternatives were primarily due to the realignment of US 169 and the addition of frontage roads to more efficiently service local trips. VMT for each modeling scenario was output from the microsimulation tool and factored to daily estimates by comparing the peak hour entering volumes and average annual daily traffic volumes obtained from the MnDOT Traffic Mapping Application[4].

   To capture travel time estimates in hours outside the morning, midday, and afternoon peak hours, volume-to-travel time relationships were developed and applied in the BCA. StreetLight[5] data for trips through the US 169/CR 4 intersection was used to identify 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 21 hours of the day outside the morning, midday, and afternoon peak hours (see Figure 1). 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 and VHT for the No Build and Build Alternatives in years 2019 and 2040. Benefits for years between existing year 2019 and

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[2] http://www.dot.state.mn.us/planning/program/appendix_a.html
[3] https://www.co.sherburne.mn.us/DocumentCenter/View/4535/Sherburne-County-Transportation-Plan---Complete
[4] https://www.dot.state.mn.us/traffic/data/tma.html
[5] StreetLight is a data analytics tool that processes annual vehicle probe data to determine detailed trip information. https://www.streetlightdata.com/

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 and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types.

Figure 1. Hourly Travel Times by Scenario

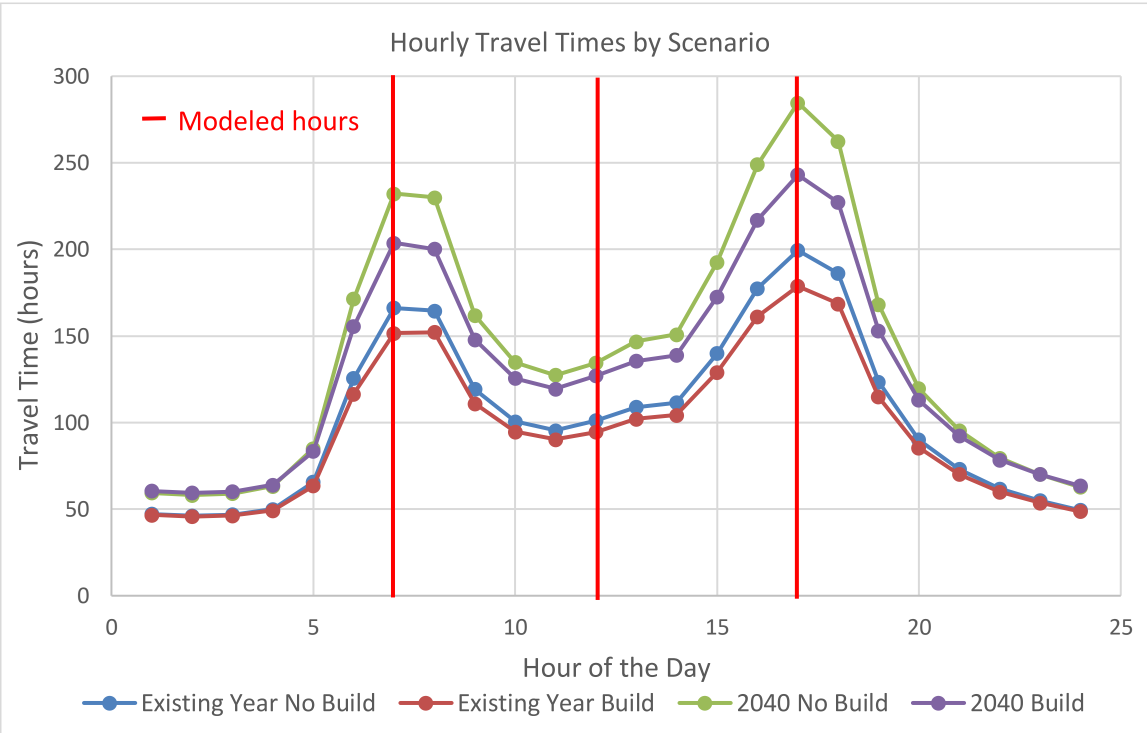

Table 1 – Monthly Traffic Volume Adjustment Factors

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.
- Vehicle occupancy that was used in the analysis is consistent with values provided by *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021. 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/CR 4 signal. This eliminates the high speed at-grade crossing and reduces both congestion and conflicting volumes at intersections in the area.

   Safety benefits were monetized using the Interactive Highway Safety Design Manual program (IHSDM-HSM Predictive Method - 2019 Release, v 15.0.0). IHSDM is a tool developed by the U.S. Department of Transportation – Federal Highway Administration (US DOT – 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, and site-specific crash distributions provided by MnDOT. This safety analysis predicted the total number of crashes in accordance with methods outlined in the Highway Safety Manual (HSM) for each year between 2026 to 2055 by severity on the KABCO scale. The safety benefit was then quantified for years 2026 to 2055 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 February 2021.

7. **Environmental and Air Quality Impacts:** Annual VMT is expected to be impacted by realignment of US 169 and construction of an interchange and frontage road system. The change in VMT between No Build and Build conditions was obtained from the microsimulation model (as discussed in development of VMT section) and applied to emission rates by vehicle type. Average emission rates per vehicle type were obtained from the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 3. Emission rates per vehicle type are provided in the attached BCA Workbook. Total change in emissions was valued in accordance with the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated February 2021.

8. **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 St. 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[6] was divided by the US population[7] to determine an average water pollution cost per person. This cost was then applied to the population of the City of Elk River[8], 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.

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.

9. **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 and frontage road pavement. 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.

10. **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 2019 dollars and were added to other project benefits in accordance with USDOT guidance. In determining remaining capital value of the initial capital cost, the costs of the Build Alternative were separated into the following categories:

    - Right of Way
    - Major Structures
    - Grading and Drainage
    - Sub-Base and Base
    - Surface
    - Miscellaneous Costs – Includes mobilization, removals, utility relocation, traffic control, and program delivery. These were assumed to be sunk costs and assigned zero remaining capital value.

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[6] https://www.sciencedaily.com/releases/2008/11/081112124418.htm
[7] Table 1 from https://www.census.gov/data/tables/2008/demo/age-and-sex/2008-age-sex-composition.html
[8] https://www.census.gov/quickfacts/fact/table/elkrivercityminnesota/IPE120219

Project components in each cost category were assumed a service life based on recommendations provided by MnDOT Office of Transportation System Management.

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:
    - Increased travel time reliability in the study area due to the increase in roadway capacity.
    - 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 US 169 and CR 4 being reconstructed as part of the realignment and interchange construction.
    - Benefits accrued in the second half of year 2025 after project opening. Accelerating the benefit-cost analysis period by a half-year is expected to produce approximately an additional $945 thousand in net present value.

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 1. See Attachment A for the complete benefit-cost analysis workbook.

Table 2 – Total Project Results

	Initial Capital Cost (2019 Dollars)	Project Benefits (2019 Dollars)	Benefit-Cost Ratio (7% Discount Rate)	Net Present Value (2019 Dollars)
No Build vs. Build	$31.1 million	$44.5 million	1.4	$13.4 million

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Appendix

IHSDM Predictive Crash Reports

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

June 3, 2021

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List of Tables

Report Overview

Report Generated: Jun 3, 2021 1:15 PM
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Evaluation Date: Thu May 27 08:20:47 CDT 2021
IHSDM Version: v15.0.0 (Oct 31, 2019)
Site Set Crash Prediction Module: v|ModuleInfo.moduleVersion| (|ModuleInfo.moduleDate|)

User Name: Matt Flanagan
Organization Name: SRF Consulting Group
Phone: 608.298.5400
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: v1

Evaluation Title: 2026-2055 - HSM Configurations
Evaluation Comment: Created Thu May 27 08:20:20 CDT 2021
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration
First Year of Analysis: 2026
Last Year of Analysis: 2055
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 AND 17-58

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.

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 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	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	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: 15790; 2052: 15965; 2053: 16141; 2054: 16316; 2055: 16492	

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	991.622	33.0541	11.2012	5.4159	21.8528	2.02	33.0541
		Total	Total	991.622	33.0541	11.2012	5.4159	21.8528	2.02	33.0541

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

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
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
Total	991.62	336.04	33.888	655.58	66.112
Average	33.05	11.20	33.888	21.85	66.112

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	Angle Collision	105.85	10.7	140.95	14.2	253.85	25.6
Intersection	Head-on Collision	27.89	2.8	22.29	2.2	53.55	5.4
Intersection	Other Collision	13.78	1.4	15.08	1.5	29.75	3.0
Intersection	Rear-end Collision	158.61	16.0	331.07	33.4	487.88	49.2
Intersection	Sideswipe	15.79	1.6	96.37	9.7	105.11	10.6
Intersection	Single	13.78	1.4	50.48	5.1	61.48	6.2
	Total Crashes	335.70	33.9	656.24	66.2	991.62	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

June 3, 2021

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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: US 169 Interchange - Build Conditions
Site Set Comment: Created Tue May 11 13:00:58 CDT 2021
Site Set Version: v1

Evaluation Title: 2026-2055 - HSM Configurations (2 of 2)
Evaluation Comment: Created Thu Jun 03 13:05:09 CDT 2021
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration
First Year of Analysis: 2026
Last Year of Analysis: 2055
Empirical-Bayes Analysis: None

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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.

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 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

Freeway Ramp Terminal Site Set CPM Evaluation

Site Type

Type: Ramp Terminal

Calibration Factor: RT_ST_FI=1.0, RT_ST_PDO=1.0, RT_SG_FI=1.0, RT_SG_PDO=1.0

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

Site No.	Type	Ramp Terminal	Area Type	Traffic Control	AADT
1	D4 - Four-Leg with Diagonal Ramps	SB Ramp Terminal	Urban	Signalized	Inside: 2026: 12358; 2027: 12558; 2028: 12759; 2029: 12959; 2030: 13159; 2031: 13360; 2032: 13560; 2033: 13760; 2034: 13961; 2035: 14161; 2036: 14361; 2037: 14562; 2038: 14762; 2039: 14962; 2040: 15163; 2041: 15363; 2042: 15563; 2043: 15764; 2044: 15964; 2045: 16164; 2046: 16365; 2047: 16565; 2048: 16765; 2049: 16966; 2050: 17166; 2051: 17366; 2052: 17567; 2053: 17767; 2054: 17967; 2055: 18168; Outside: 2026: 14280; 2027: 14506; 2028: 14732; 2029: 14957; 2030: 15183; 2031: 15409; 2032: 15634; 2033: 15860; 2034: 16086; 2035: 16311; 2036: 16537; 2037: 16763; 2038: 16988; 2039: 17214; 2040: 17440; 2041: 17665; 2042: 17891; 2043: 18117; 2044: 18342; 2045: 18568; 2046: 18794; 2047: 19020; 2048: 19245; 2049: 19471; 2050: 19697; 2051: 19923; 2052: 20148; 2053: 20374; 2054: 20600; 2055: 20826 :: Entrance: 2026: 5435; 2027: 5525; 2028: 5614; 2029: 5704; 2030: 5794; 2031: 5884; 2032: 5973; 2033: 6063; 2034: 6153; 2035: 6243; 2036: 6332; 2037: 6422; 2038: 6512; 2039: 6602; 2040: 6692; 2041: 6781; 2042: 6871; 2043: 6961; 2044: 7050; 2045: 7140; 2046: 7230; 2047: 7320; 2048: 7409; 2049: 7499; 2050: 7589; 2051: 7679; 2052: 7768; 2053: 7858; 2054: 7948; 2055: 8038; Exit: 2026: 2254; 2027: 2280; 2028: 2306; 2029: 2332; 2030: 2357; 2031: 2383; 2032: 2409; 2033: 2435; 2034: 2461; 2035: 2486; 2036: 2512; 2037: 2538; 2038: 2564; 2039: 2590; 2040: 2616; 2041: 2641; 2042: 2667; 2043: 2693; 2044: 2719; 2045: 2745; 2046: 2770; 2047: 2796; 2048: 2822; 2049: 2848; 2050: 2874; 2051: 2899; 2052: 2925; 2053: 2951; 2054: 2977; 2055: 3003
2	B2 - Three-Leg at Two-Quadrant Parclo B	NB Ramp Terminal	Urban	Signalized	Inside: 2026: 12358; 2027: 12558; 2028: 12759; 2029: 12959; 2030: 13159; 2031: 13360; 2032: 13560; 2033: 13760; 2034: 13961; 2035: 14161; 2036: 14361; 2037: 14562; 2038: 14762; 2039: 14962; 2040: 15163; 2041: 15363; 2042: 15563; 2043: 15764; 2044: 15964; 2045: 16164; 2046: 16365; 2047: 16565; 2048: 16765; 2049: 16966; 2050: 17166; 2051: 17366; 2052: 17567; 2053: 17767; 2054: 17967; 2055: 18168; Outside: 2026: 8680; 2027: 8825; 2028: 8970; 2029: 9115; 2030: 9260; 2031: 9405; 2032: 9550; 2033: 9695; 2034: 9840; 2035: 9985; 2036: 10130; 2037: 10275; 2038: 10420; 2039: 10565; 2040: 10710; 2041: 10854; 2042: 10999; 2043: 11144; 2044: 11289; 2045: 11434; 2046: 11579; 2047: 11724; 2048: 11869; 2049: 12014; 2050: 12159; 2051: 12304; 2052: 12449; 2053: 12594; 2054: 12739; 2055: 12884 :: Entrance: 2026: 1889; 2027: 1910; 2028: 1931; 2029: 1952; 2030: 1972; 2031: 1993; 2032: 2014; 2033: 2035; 2034: 2056; 2035: 2076; 2036: 2097; 2037: 2118; 2038: 2139; 2039: 2160; 2040: 2181; 2041: 2201; 2042: 2222; 2043: 2243; 2044: 2263; 2045: 2284; 2046: 2305; 2047: 2326; 2048: 2346; 2049: 2367; 2050: 2388; 2051: 2409; 2052: 2429; 2053: 2450; 2054: 2471; 2055: 2492; Exit: 2026: 4157; 2027: 4227; 2028: 4298; 2029: 4368; 2030: 4439; 2031: 4509; 2032: 4580; 2033: 4651; 2034: 4721; 2035: 4792; 2036: 4862; 2037: 4933; 2038: 5003; 2039: 5074; 2040: 5145; 2041: 5215; 2042: 5286; 2043: 5356; 2044: 5427; 2045: 5497; 2046: 5568; 2047: 5638; 2048: 5709; 2049: 5779; 2050: 5850; 2051: 5920; 2052: 5991; 2053: 6061; 2054: 6132; 2055: 6203

Table 2. Predicted Crash Frequencies and Rates by Site

Site No.	Type	Ramp Terminal	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	D4 - Four-Leg with Diagonal Ramps	SB Ramp Terminal		127.291	4.2430	1.4999	2.7431	0.55	4.2430
2	B2 - Three-Leg at Two-Quadrant Parclo B	NB Ramp Terminal		173.082	5.7694	2.7436	3.0258	0.95	5.7694
		Total	Total	300.372	10.0124	4.2435	5.7689	0.73	10.0124

Table 3. Predicted Crash Frequencies by Year (Ramp Terminal)

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
2026	8.23	3.55	43.138	4.68	56.862
2027	8.36	3.60	43.038	4.76	56.962
2028	8.50	3.65	42.943	4.85	57.057
2029	8.63	3.70	42.851	4.93	57.149
2030	8.76	3.75	42.763	5.01	57.237
2031	8.89	3.80	42.677	5.10	57.323
2032	9.03	3.85	42.596	5.18	57.404
2033	9.16	3.90	42.517	5.27	57.483
2034	9.29	3.94	42.440	5.35	57.560
2035	9.41	3.99	42.401	5.42	57.599
2036	9.53	4.04	42.372	5.49	57.628
2037	9.64	4.08	42.345	5.56	57.655
2038	9.76	4.13	42.321	5.63	57.679
2039	9.88	4.18	42.299	5.70	57.701
2040	9.99	4.22	42.279	5.77	57.721
2041	10.10	4.27	42.263	5.83	57.737
2042	10.22	4.32	42.248	5.90	57.752
2043	10.33	4.36	42.234	5.97	57.766
2044	10.44	4.41	42.224	6.03	57.776
2045	10.55	4.46	42.214	6.10	57.786
2046	10.67	4.50	42.207	6.17	57.793
2047	10.78	4.55	42.201	6.23	57.799
2048	10.89	4.59	42.199	6.29	57.801
2049	11.00	4.64	42.197	6.36	57.803
2050	11.11	4.69	42.197	6.42	57.803
2051	11.22	4.74	42.198	6.49	57.802
2052	11.33	4.78	42.202	6.55	57.798
2053	11.44	4.83	42.206	6.61	57.794
2054	11.55	4.88	42.213	6.68	57.787
2055	11.66	4.92	42.221	6.74	57.779
Total	300.37	127.31	42.382	173.07	57.618
Average	10.01	4.24	42.382	5.77	57.618

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 Ramp Terminal 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	0.0413	1.0315	6.7619	37.1626	82.2934
2	0.0969	2.4199	14.4254	65.3652	90.7740
Total	0.1382	3.4514	21.1873	102.5278	173.0674

Table 5. Predicted Ramp Terminal Crash Type Distribution

Element Type	Crash Type	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)	Total Crashes	Percent Total (%)
Ramp Terminal	Collision with Animal	0.00	0.0	0.00	0.0	0.00	0.0
Ramp Terminal	Collision with Fixed Object	4.20	1.4	8.65	2.9	12.85	4.3
Ramp Terminal	Collision with Other Object	0.13	0.0	0.35	0.1	0.47	0.2
Ramp Terminal	Other Single-vehicle Collision	2.29	0.8	1.21	0.4	3.50	1.2
Ramp Terminal	Collision with Parked Vehicle	0.13	0.0	0.35	0.1	0.47	0.2
Ramp Terminal	Total Single Vehicle Crashes	6.75	2.2	10.56	3.5	17.30	5.8
Ramp Terminal	Right-Angle Collision	33.10	11.0	38.08	12.7	71.17	23.7
Ramp Terminal	Head-on Collision	1.40	0.5	1.21	0.4	2.61	0.9
Ramp Terminal	Other Multi-vehicle Collision	1.15	0.4	3.46	1.2	4.61	1.5
Ramp Terminal	Rear-end Collision	79.56	26.5	93.98	31.3	173.54	57.8
Ramp Terminal	Sideswipe, Same Direction Collision	5.35	1.8	25.79	8.6	31.13	10.4
Ramp Terminal	Total Multiple Vehicle Crashes	120.56	40.1	162.51	54.1	283.07	94.2
Ramp Terminal	Total Ramp Terminal Crashes	127.31	42.4	173.07	57.6	300.37	100.0
	Total Crashes	127.31	42.4	173.07	57.6	300.37	100.0

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Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

June 3, 2021

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Report Overview

Report Generated: Jun 3, 2021 1:20 PM
Report Template: System: Multi-Page, 508 Compliant [System] (sscpm4, Jun 13, 2020 7:55 AM)

Evaluation Date: Thu Jun 03 13:06:36 CDT 2021
IHSDM Version: v15.0.0 (Oct 31, 2019)
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: Old 169 & CSAH 4 - Build Conditions
Site Set Comment: Created Fri May 21 09:03:39 CDT 2021
Site Set Version: v1

Evaluation Title: 2026-2055 - HSM Configurations (1 of 2)
Evaluation Comment: Created Thu Jun 03 13:06:21 CDT 2021
Policy for Superelevation: AASHTO 2011 U.S. Customary
Calibration: HSM Configuration
Crash Distribution: HSM Configuration
Model/CMF: HSM Configuration
First Year of Analysis: 2026
Last Year of Analysis: 2055
Empirical-Bayes Analysis: None

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Section Types

Urban Arterial 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	Number of Approaches with Left-Turn Lanes	Number of Approaches with Right-Turn Lanes	Presence of Lighting	Number of Approaches with Permissive Left-Turn Phasing	Number of Approaches with Permissive/Protected or Protected/Permissive Left-Turn Phasing	Number of Approaches with Protected Left-Turn Phasing	Number of Approaches on which Right Turn on Red is Prohibited	Presence of Red-Light Cameras	Pedestrian Volumes Crossing all Intersection Legs (crossings/day)	Max. Number of Lanes Crossed by Pedestrians	Number of Bus Stops within 1000 ft of Intersection	Number of Schools within 1000 ft of Intersection	Number of Alcohol Sales Establishments within 1000 ft of Intersection
1	4SG2x2le5	Old 169 & CSAH 4		2026: 13261; 2027: 13471; 2028: 13681; 2029: 13891; 2030: 14101; 2031: 14311; 2032: 14521; 2033: 14732; 2034: 14942; 2035: 15152; 2036: 15362; 2037: 15572; 2038: 15782; 2039: 15992; 2040: 16203; 2041: 16413; 2042: 16623; 2043: 16833; 2044: 17043; 2045: 17253; 2046: 17463; 2047: 17673; 2048: 17884; 2049: 18094; 2050: 18304; 2051: 18514; 2052: 18724; 2053: 18934; 2054: 19144; 2055: 19355	2026: 2133; 2027: 2162; 2028: 2192; 2029: 2221; 2030: 2250; 2031: 2279; 2032: 2309; 2033: 2338; 2034: 2367; 2035: 2396; 2036: 2426; 2037: 2455; 2038: 2484; 2039: 2513; 2040: 2543; 2041: 2572; 2042: 2601; 2043: 2630; 2044: 2660; 2045: 2689; 2046: 2718; 2047: 2747; 2048: 2777; 2049: 2806; 2050: 2835; 2051: 2864; 2052: 2894; 2053: 2923; 2054: 2952; 2055: 2982	4	4	yes	2	2	0	0	no	50	4	0	0	0

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 PDO Crash Frequency (crashes/yr)	Predicted Intersection Travel Crash Rate (crashes/million veh)	Intersection Crash Rate (crashes/yr)
1	4SG	Old 169 & CSAH 4		54.277	1.8092	0.6130	1.1962	0.26	1.8092
		Total	Total	54.277	1.8092	0.6130	1.1962	0.26	1.8092

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

Year	Total Crashes	FI Crashes	Percent FI (%)	PDO Crashes	Percent PDO (%)
2026	1.40	0.47	33.449	0.93	66.551
2027	1.42	0.48	33.479	0.95	66.521
2028	1.45	0.49	33.508	0.96	66.492
2029	1.48	0.50	33.537	0.98	66.463
2030	1.51	0.51	33.566	1.00	66.434
2031	1.53	0.52	33.594	1.02	66.406
2032	1.56	0.53	33.622	1.04	66.378
2033	1.59	0.54	33.651	1.06	66.349
2034	1.62	0.55	33.679	1.07	66.321
2035	1.65	0.56	33.707	1.09	66.293
2036	1.68	0.56	33.734	1.11	66.266
2037	1.71	0.58	33.762	1.13	66.238
2038	1.73	0.59	33.789	1.15	66.211
2039	1.76	0.60	33.816	1.17	66.184
2040	1.79	0.61	33.843	1.19	66.157
2041	1.82	0.62	33.870	1.20	66.130
2042	1.85	0.63	33.897	1.22	66.103
2043	1.88	0.64	33.923	1.24	66.077
2044	1.91	0.65	33.949	1.26	66.051
2045	1.94	0.66	33.975	1.28	66.025
2046	1.97	0.67	34.001	1.30	65.999
2047	2.00	0.68	34.027	1.32	65.973
2048	2.02	0.69	34.053	1.34	65.948
2049	2.06	0.70	34.078	1.35	65.922
2050	2.08	0.71	34.103	1.37	65.897
2051	2.12	0.72	34.128	1.39	65.872
2052	2.15	0.73	34.153	1.41	65.847
2053	2.17	0.74	34.178	1.43	65.822
2054	2.21	0.75	34.202	1.45	65.798
2055	2.23	0.77	34.227	1.47	65.773
Total	54.28	18.39	33.882	35.89	66.118
Average	1.81	0.61	33.882	1.20	66.118

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	Collision with Animal	0.00	0.0	0.01	0.0	0.01	0.0
Intersection	Collision with Bicycle	0.80	1.5	0.00	0.0	0.80	1.5
Intersection	Collision with Fixed Object	0.68	1.2	2.14	3.9	2.81	5.2
Intersection	Non-Collision	0.13	0.2	0.08	0.2	0.21	0.4
Intersection	Collision with Other Object	0.07	0.1	0.17	0.3	0.24	0.4
Intersection	Other Single-vehicle Collision	0.04	0.1	0.06	0.1	0.09	0.2
Intersection	Collision with Parked Vehicle	0.00	0.0	0.00	0.0	0.00	0.0
Intersection	Collision with Pedestrian	0.47	0.9	0.00	0.0	0.47	0.9
Intersection	Total Intersection Single Vehicle Crashes	2.18	4.0	2.46	4.5	4.63	8.5
Intersection	Angle Collision	5.63	10.4	8.16	15.0	13.78	25.4
Intersection	Head-on Collision	0.79	1.5	1.00	1.8	1.80	3.3
Intersection	Other Multi-vehicle Collision	0.89	1.6	7.05	13.0	7.95	14.6
Intersection	Rear-end Collision	7.30	13.4	16.15	29.8	23.44	43.2
Intersection	Sideswipe	1.60	3.0	1.07	2.0	2.67	4.9
Intersection	Total Intersection Multiple Vehicle Crashes	16.21	29.9	33.43	61.6	49.65	91.5
Intersection	Total Intersection Crashes	18.39	33.9	35.89	66.1	54.28	100.0
	Total Crashes	18.39	33.9	35.89	66.1	54.28	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.