Developing a Methodology for Implementing Safety Improvements on Low-Volume Roads in Montana

Task VII Report: Assessing Benefits of Proposed Methodology

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1. INTRODUCTION

This report summarizes the results of task 7 for the project titled "Developing a Methodology for Implementing Safety Improvements on Low-Volume Roads in Montana." This task aims at assessing the potential benefits of the network screening methodology developed and proposed in task 6 of this project. To that end, an economic assessment was performed in the form of benefit-cost analysis where the estimated benefits and costs of implementing the new methodology were quantified and analyzed. This report discusses the analysis methodology used, analysis inputs and data used, the different benefit and cost elements and major analysis results.

2. METHODOLOGY

To assess the potential benefits of the network screening methodology proposed in task 6, an economic analysis was conducted. The economic analysis, in the form of the conventional benefit-cost ratio, using the present worth of costs and benefits was used in this assessment. Upon consultation with the panel, an analysis period of 10 years was selected. All the cost elements were discounted to their present worth and were then used to calculate the benefit-cost ratios. The discount rate is defined as "*the forgone rate of return if an investor chose to accept an amount in the future versus the same amount today*" (Murphy, 2020). The ten-year average of daily yield curve rate for treasury bonds with 20-year maturity (US Department of Treasury, n.d.) was used as the discount rate. **Equation 1** shows the formula for calculating the present worth.

$$Present\ Worth = Future\ Worth \times (1 + \frac{Discount\ Rate}{100})^{-n} \ldots \ldots \ldots (1)$$

Where n = number of years,

The following sections discuss the different inputs and assumptions that were used in this analysis, i.e. in the estimation of the potential benefits and the associated costs for developing and implementing the proposed screening method.

2.1. Approximations and Assumptions

For a quantitative benefit-cost analysis, a few approximations and/or assumptions were made to assess the potential benefits and costs of the proposed method. This section discusses these approximations and/or assumptions and how it was used in the analysis.

I. The crash reduction factors (CRFs) for relevant safety improvements were used in assessing the potential benefits of the new method. As it is not possible to predict which countermeasures would be applied to the LVR network during the analysis period, specific CRFs could not be used directly in the analysis. Therefore, instead of using specific CRFs, crash reduction for general countermeasure categories were found using the average CRFs for category-related countermeasures. For example, crash reduction for the "Signing and Delineation" category is found using the average of the CRFs for countermeasures like installing edgeline, centerline, and delineator.

II. Due to budget constraints, it is both expected and logical that safety countermeasures could not be applied across the whole LVR network during the analysis period.

However, it was necessary to estimate the proportion of the LVR network that would undergo any form of safety improvement during the analysis period. Using input from the project technical panel, it was assumed that 33 percent of the Montana LVR network would receive some sort of safety improvement during the 10-year analysis period.

III. The goal of any network screening method is to identify and rank at-risk sites that are expected to yield greater safety benefits upon implementing safety improvements. Therefore, the potential benefit from the implementation of the proposed network screening method would be a greater reduction in crashes on low-volume roads since the selection and prioritization process would be more robust. Therefore, it was assumed that the implementation of the proposed method would increase the average crash reduction of safety countermeasures by 5 percent.

IV. The most recent five-year crash numbers (2015-2019) for different severity levels on LVRs were used in the estimation of the potential benefits of the proposed method. In estimating the number of crashes over the analysis period (10 years), the average number of crashes per year using crash data for the years 2015-2019 inclusive was used in this estimation.

2.2. Benefits

Low-Volume Roads (LVRs) warrant the reduction of crashes based on the specific countermeasures implemented on the specific low-volume rural roads or locations. The main purpose of the proposed low-volume roads network screening methodology is to have an independent and justifiable approach for evaluating, nominating, and prioritizing low-volume road safety improvement projects based on the unique merits of low-volume roads. The primary expected benefit of developing and implementing the proposed methodology would be an increase in crash reduction on low-volume roads.

To obtain an estimate of crash reduction, common safety countermeasure categories applied to Montana's LVRs were estimated in consultation with the project technical panel. **Table 1** shows the common countermeasure categories and their respective percentages of projects on Montana's LVRs. It is important to note that the analysis used the top three categories of countermeasures shown in **Table 1** which primarily involve low-cost safety treatments that are commonly used on LVRs.

Table 1: Common Countermeasures for Montana Low-Volume Roads

Countermeasure Category	Percentage
Signing and Delineation (Curve)	40
Signing and Delineation (Non-curve)	27
Intersection Improvements	17
Other	16

Appropriate crash reduction factors (CRFs) for different countermeasures under each of these broad categories were identified using the Highway Safety Manual (HSM) (AASHTO, 2010) and the Crash Modification Factor (CMF) clearinghouse website (CMF Clearinghouse, n.d.). Then using those CRFs, an average crash reduction for each of the three countermeasure categories was calculated. Finally, the weighted average crash reduction was calculated using the average CRFs for each category and their respective weights based on the percentages shown in **Table 1**. **Table 2** shows the relative weight and average crash reduction for each countermeasure along with the weighted average crash reduction for all safety countermeasures on Montana's LVR network.

Table 2: Crash Reduction for Countermeasure Categories and the Weighted Average Crash Reduction on Montana LVRs

Countermeasure Categories	Relative Weight	Average Crash Reduction
Signing and Delineation (Curve)	0.48	0.27
Signing and Delineation (Non-curve)	0.32	0.27
Intersections	0.20	0.30
Weighted Average Crash Reduction		**0.274**

The weighted average crash reduction was then multiplied by 0.33 to account for the assumption that 33 percent of the total LVR network would receive a form of safety improvement during the 10-year analysis period. Then, to estimate the potential benefit of applying the new method, it was assumed that the expected crash reduction for the network would increase by 5 percent once the proposed method is used for identifying the at-risk sites on Montana's LVR network. **Table 3** shows the expected crash reduction both before and after the implementation of the proposed screening method.

Table 3: Expected Crash Reduction before and after Implementing the Proposed Screening Method

Expected crash reduction before implementing the proposed method	0.0919
Expected crash reduction after implementing the proposed method	0.0965

Using the crash reductions in **Table 3** above and the number of crashes on Montana's LVRs, the potential benefits of implementing the proposed screening method can be estimated. **Table 4** shows the number of crashes by crash severity for the period 2015 to 2019, the average crash number per year for each severity level, and the estimated number of crashes for the 10-year analysis period. The crash numbers by severity for the period 2015-2019 inclusive were used as a basis for estimating the crash numbers for the 10-year analysis period.

Table 4: Number of Crashes by Severity and their Estimates for the Analysis Period

Crash Severity	Crash Numbers 2015-2019 Period	Average Crashes per year	Crash Numbers for the Analysis Period
Fatal (K)	301	60.2	602
Suspected Serious Injury (A)	1,158	231.6	2,316
Suspected Minor Injury (B)	3,540	708	7,080
Possible Injury (C)	3,486	697.2	6,972
No Apparent Injury (O)	29,158	5,831.6	58,316

The estimated crash numbers for the analysis period shown in **Table 4** and expected crash reductions shown in **Table 3** were used in estimating the number of crashes by severity that are reduced due to the implementation of the proposed method. The crashes reduced by severity were then converted to monetary terms using the estimated crash cost for each crash severity. The analysis used the Highway Safety Manual (AASHTO, 2010) crash costs that were adjusted for inflation using the consumer price indexes (CPI) to reflect the costs in January 2021 dollars. The CPI value for 2009 (crash costs in the HSM were in 2009 dollars) was obtained from a US Bureau of Labor Statistics (BLS) report (2010). The CPI value for January 2021 was obtained from the trading economics website (Trading Economics, n.d.). **Equation 2** shows the inflation adjustment equation used in the calculations and **Table 5** shows the inflation adjusted crash costs for each severity level.

$$Crash\ Cost(January\ 2021) = Crash\ Cost\ (December\ 2009) \times \frac{CPI\ for\ January\ 2021}{CPI\ for\ December\ 2009} \ldots\ldots (2)$$

Table 5: Inflation Adjusted Crash Costs for Different Crash Severities

Crash Severity	HSM Crash Costs (Dec. 2009 Dollars)	Inflation Adjusted Crash Costs (Jan. 2021 Dollars)
Fatal (K)	$ 4,008,900.00	$ 4,868,042.82
Suspected Serious Injury (A)	$ 216,000.00	$ 262,290.72
Suspected Minor Injury (B)	$ 79,000.00	$ 95,930.40
Possible Injury (C)	$ 44,900.00	$ 54,522.47
No Apparent Injury (O)	$ 7,400.00	$ 8,985.89

Finally, the expected benefits from implementing the proposed method were calculated using the number of crashes reduced by severity and the inflation-adjusted crash costs shown in **Table 5**. **Table 6** shows the expected economic benefits from the implementation of the proposed network screening method.

Table 6: Benefits Calculation for the Analysis Period

Crash Severity	Crash Numbers	Existing Reduction (Crashes)	New Reduction (Crashes)	Increase in Reduction (Crashes)	Benefits ($)
Fatal (K)	602	55.34	58.10	2.77	$ 13,468,822.68
Suspected Serious Injury (A)	2316	212.89	223.53	10.64	$ 2,791,902.37
Suspected Minor Injury (B)	7080	650.79	683.33	32.54	$ 3,121,535.44
Possible Injury (C)	6972	640.86	672.91	32.04	$ 1,747,075.37
No Apparent Injury (O)	58316	5360.39	5628.41	268.02	$ 2,408,393.07
Total Benefits					**$ 23,537,728.92**

2.3. Costs

For calculating the benefit-cost ratios, an estimate of the costs associated with developing and implementing the proposed methodology is required. **Table 7** shows the different cost elements and the total cost for the 10-year analysis period. As seen from the table, the estimated total costs for implementing the proposed method is around one million dollars.

The different cost elements that were considered in estimating the costs for the economic analysis are discussed in the following paragraphs.

Method Development Cost: This cost element encompasses the cost expended by the MDT on this research project. The exact amount of this cost element is $63,501 per the project contract documents.

Training Costs: This element covers all costs that would be involved in providing training to the MDT and local agency staff on implementing the new proposed method. This element has three components: training materials development, training session, and online content development. The three cost value components were estimated in consultation with the Montana Local Technical Assistance Program (LTAP) Director (M. Ulberg, personal communication, July 9, 2020).

The training material development cost is a one-time cost and it was estimated to be $10,000. The online materials development cost is also a one-time cost that would be required to develop the online training contents (website, documents, videos, etc.). The online training content would provide the MDT and local agency staff with the necessary resources required for understanding and applying the proposed methodology.

The training session costs are annually recurring costs. These sessions, to be conducted by MDT staff or an external contractor, are estimated to have an average cost of $1,000 per session. It is assumed that the first three years would require a larger number of training sessions to promote the use of the method to all incorporated local agencies in Montana. For the first three years, it is assumed that 12 training sessions will be required each year. For the following years, only two sessions per year are considered in the analysis. These sessions would accommodate staff turnovers and/or staff that have missed the training in the first three years.

Table 7: Development and Implementation Costs for the 10-Year Analysis Period

Item	Years										Totals
	1	2	3	4	5	6	7	8	9	10	
Method Development Project Cost	63,501										$ 63,501
Training Material Development Costs	10,000										$ 10,000
Training Sessions	12,000	11,329	11,007	1,783	1,732	1,683	1,635	1,589	1,544	1,500	$ 45,800
Online Training Contents Development	30,000										$ 30,000
FTE Time	78,654	80,227	81,832	83,468	85,138	86,840	88,577	90,349	92,156	93,999	$ 861,239
Total Costs											**$ 1,010,540**

Additional Staff Costs: While implementing the new methodology should not be different from implementing any other methodology in terms of MDT staff requirements, it was decided to include it in the cost elements to be conservative in our approach. The assumption that is made in this economic analysis is that the proposed methodology would require an additional time of a safety professional that is equivalent to 0.8 FTE (full-time employee).

The median wage for a civil engineer in Montana was used for estimating the additional staff cost. The median hourly wage was collected from the Montana Department of Labor and Industry (2020) report. Further, a 30% benefits rate was added to the median wage in estimating the cost of additional staff. This analysis also incorporated a two percent annual raise to the staff salary in calculating the annual cost of additional staff time.

3. RESULTS AND DISCUSSION

This section discusses the results of the economic assessment associated with developing and implementing the proposed network screening method. Specifically, this section provides the estimates of the benefit-cost ratios using the benefits and costs discussed in the previous sections.

Table 8 shows the estimated benefit-cost ratios for the proposed method using three different inputs in estimating the benefits: 1) all crash severities, 2) fatal and suspected serious injury crashes only, and 3) fatal and all injury crashes (suspected serious injury, suspected minor injury, and possible injury). As shown in the table, all the benefit-cost ratios for the three different analysis inputs are notably higher than 1, making a strong case for the cost effectiveness of the proposed screening method.

Table 8: Benefit Cost Ratios for Different Analysis Inputs

Scenarios	Benefit-Cost Ratios
All Crashes (KABCO)	23.29:1
Fatal and Serious Injury Crashes Only (K & A Only)	16.09:1
All crashes except no apparent injury crashes (KABC)	20.91:1

The first benefit-cost ratio is for a scenario where the crash reduction for all crash types was used in estimating the benefits. As shown in **Table 8**, the benefit of implementing the proposed method outweighs the costs by almost 23 times.

The second scenario is when only fatal and suspected serious injury crashes are considered in estimating the benefits. In this case, the benefits of the proposed method are estimated to outweigh the costs of developing and implementing the proposed method by almost 16 times, still indicating a very high rate of return on the expended safety funds. Finally, the benefit-cost estimate for the third scenario (all fatality, suspected serious injury, suspected minor injury, and possible injury crashes except property damage only (PDO) crashes) fell in between the ratios of the first two scenarios. In this scenario, the expected benefits outweigh the costs of the proposed method by around 21 times.

4. CONCLUDING REMARKS

This report presented the results of Task VII of the project titled "Developing a Methodology for Implementing Safety Improvements on Low-Volume Roads in Montana." This task aimed at assessing the benefits of the proposed network screening methodology. An economic assessment in the form of benefit-cost analysis was performed to estimate the economic feasibility of using the new proposed method. This report discussed the methodology used in the analysis, analysis inputs and assumptions, and the economic analysis results.

The results of the analysis clearly showed that the expected safety benefits of the proposed screening method significantly outweigh all the costs associated with developing and implementing the proposed methodology. This finding was applicable to the three different severity scenarios investigated in this assessment. Specifically, the benefit-cost ratio for the three scenarios varied between 15 and 23 which makes a strong case for the cost effectiveness of using the new network screening method in identifying candidate safety improvement sites on Montana's LVRs.

5. REFERENCES

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