Safety Evaluation of Sinusoidal Centerline Rumble Strips

Task 4: Compile “before” period data

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INTRODUCTION

The Montana Department of Transportation (MDT) installed sinusoidal centerline rumble strips (SCLRS) on over 600 miles of rural roadway during 2021. The purpose of this research project is to evaluate the safety effectiveness of the installed sinusoidal centerline rumble strips using an observational before-after study. Specifically, the safety performance of SCLRS will be compared to the safety performance of conventional centerline rumble strips. The results will help MDT select the most appropriate countermeasure (conventional vs. sinusoidal rumble strips) for a given situation, improving the overall safety management process for two-lane rural highways.

The objective of Task 4 was to compile electric crash and roadway inventory data for treatment and reference group sites in the time period before SCLRS were implemented on MDT roadways. This task report documents the processes that were followed and a summary of these data.

The remainder of this document is organized into four sections. The first provides a summary of the data sources and data structures that were used. The second section describes the data preparation and quality control that was performed to clean the data for use in this project. The next summarizes the data that were finally compiled into an analysis database. Finally, the last section provides a summary of next steps to be performed in order to complete the data collection process for the project.

DATA SOURCES

This task focused entirely on electronic data that were already available and provided by MDT for use in this project. These data included:

- Roadway inventory data
- Crash data

Roadway inventory data

Roadway data were provided in Geographic Information Systems (GIS) format from MDT and consisted of information on all state owned/maintained roadway segments within the state of Montana. Several unique files were obtained, as described below:

- **AADT data** – These files contained information on traffic volumes on individual roadway segments, defined by corridor ID and beginning/ending milepost. A unique file was available for each year between 2016 to 2022, inclusive.

- **Route data** – These files contained information on route name/number, system, functional classification, route category, maintenance section, surface type, surface width, number of lanes, speed limit, divisor information (yes/no), one-way (yes/no), urban area (yes/no), and maintenance division, among other information. Individual segments were identified based on corridor ID and beginning/ending milepost. Unique files were provided for the years 2016 to 2023, inclusive.
- **Rumble strip data** – These files contained information on the installation of shoulder rumble strips on the roadway network. Each location with shoulder rumble strips installed was identified based on the corridor ID and beginning/ending milepost number. Unique files were available for the years 2017, 2019, 2020, 2021 and 2022.

Crash data

Electronic crash records from the MDT Crash Database were provided as an Excel spreadsheet file from MDT. This consisted of all reported crashes that occurred on state-owned roadways within Montana between 2016 and 2020, inclusive. Each crash record contained the following information:

- Crash ID
- Crash location, indicated by corridor ID and reference location along the corridor
- City name, if applicable
- County name
- Date and time
- Crash type
- Location type
- Injury severity
- Relationship to roadway
- Weather conditions
- Road surface conditions
- Lightning conditions
- Description of first harmful event
- Contributing circumstances
- Flags for specific crash types (e.g., involving pedestrians, bicyclists, trains, impaired drivers, commercial vehicle, or wild animals; occurring in a school zone, work zone or railway junction)
- Site specific features of the crash location, such as traffic volume, roadway type, number of lanes, shoulder width, etc.

DATA PREPARATION

Roadway and crash data were originally provided to the research team in August 2022. However, a review of the data revealed several issues that needed to be addressed. These included:

- Multiple overlapping segments with contradictory information in some of the GIS files
- Crash data only included portions of corridors on the roadway network and was not comprehensive.

The research team met with MDT staff to discuss these data issues in July 2023. MDT provided revised GIS datafiles and more comprehensive crash data in July 2023.

The research team reviewed these revised data and began to prepare analysis datafiles for the before period as a part of this task. Several issues remained; these are described below and addressed as follows:

- For some years (except 2020), AADT data files contained overlapping segments with different AADT values. In many cases, the differences were small and not likely to significantly influence the safety analysis results. However, in several cases, these differences were significant. To address this, when duplicate segments with different AADT values were provided for the same roadway segment, the research team compared AADT values for the same segment for the year 2020 (for which no duplicate values existed) and selected the values closest to the AADT observed in this year. In a handful of cases, it was not possible to compare to 2020 values. Instead, the research team compared AADT values to adjacent segments and selected the value that seemed the most reasonable.
- Urban area information was not available for the years 2016 to 2019. This information was derived from the 2020 dataset, under the assumption that urban and rural areas remained unchanged during this period. Similarly, speed limit information was not available for 2016 and 2017 and this information was derived from the 2018 dataset, presuming no changes occurred in speed limit restrictions during this period.
- Individual segments definitions were not consistent across individual datafile types (AADT, Route, and Rumble Strip) or across individual years; specifically, the corridor ID and beginning/ending milepost locations that defined the roadway segment. To address this, the research team split individual segments into smaller sections so that information from the provided roadway files could be maintained, but segments could be more easily merged across data files. An illustrative example of this is provided in Figure 1 using AADT information as an example; however, this was done across datafile type and across years of information provided. After this segmentation was performed, extremely short

segments (<0.01 mi) were removed and joined with the most appropriate adjacent segment. Finally, shorter segments with identical information were also merged.

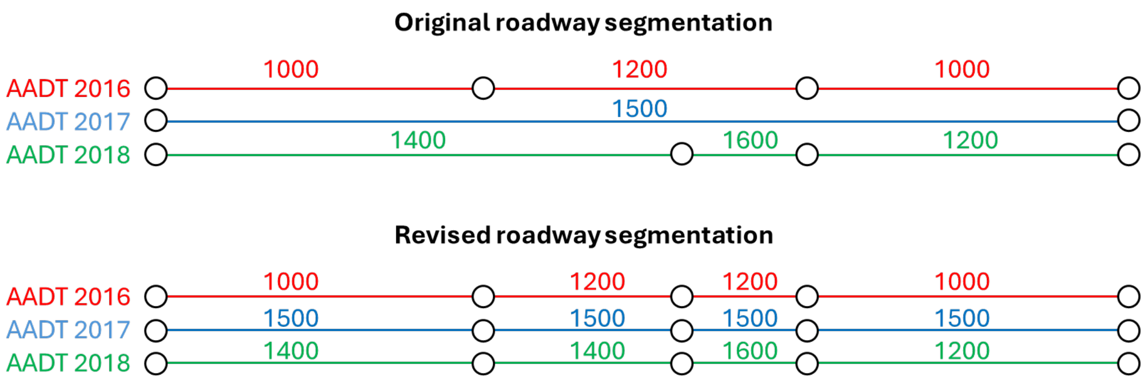

Figure 1. Illustrative example of revised roadway data segmentation

Finally, crash data were merged into the roadway data files to identify the total number of crashes of each target type that occurred within each roadway segment for each year of available crash data (2016 to 2020, inclusive). The set of target crashes – and the specific way they were identified in the data provided – are described below:

- **Total crashes** – all crashes with non-blank or non-NA crash ID
- **All fatal + injury crashes for all crash types** – all crashes with the following crash severities:
  - Fatal crash
  - Suspected serious injury
  - Suspected minor injury
  - Possible injury crash
- **Total and fatal + injury crashes of the following "target" crash types**: the following crash types were obtained for both the set of total crashes and fatal + injury crashes.
  - **Head-on** – crashes with collision type equal to:
    - Head on
  - **Opposite direction sideswipe crashes** – crashes with collision type equal to:
    - Sideswipe, opposite direction
  - **Off road left** – crashes with the following properties:
    - Number of vehicles = 1
    - Relation to the traffic way equal to:
      - Roadside left

    - Excluding any crashes with first harmful event detail equal to[1]:
        - Animal domestic
        - Animal wild
        - Bridge overhead structure
        - Cargo/equipment loss or shift
        - Fell/jumped from motor vehicle
        - Fire/explosion
        - Pedestrian
        - Pedalcycle
        - Railway vehicle (train engine)
        - Work zone / maintenance equipment
        - Other non-collision
        - Struck by falling shifting cargo
        - Thrown or falling object
        - Blanks
- **Single vehicle run-off the road** – crashes with the following properties:
    - Number of vehicles = 1
    - Relation to the traffic way equal to either:
        - Separator
        - Roadside right
        - Outside right-of-way (trafficway)
        - Off roadway location unknown
        - Roadside left
    - Excluding any crashes with first harmful event detail equal to[2]:
        - Animal domestic
        - Animal wild
        - Bridge overhead structure
        - Cargo/equipment loss or shift
        - Fell/jumped from motor vehicle
        - Fire/explosion
        - Pedestrian
        - Pedalcycle
        - Railway vehicle (train engine)
        - Work zone / maintenance equipment
        - Other non-collision
        - Struck by falling shifting cargo

[1] These crashes were excluded as they are likely not impacted by rumble strip installation.

[2] These crashes were excluded as they are likely not impacted by rumble strip installation.

- Thrown or falling object
- Blanks

DATA SUMMARY

Table 1 provides a summary of total roadway segment mileage and total number of roadway segments – by year – that were available in the roadway inventory files. Please note that the total mileage for the years 2020 and 2021 is much smaller than other years as fewer route IDs were included in the data provided by MDT. As the project proceeds, the research team will either obtain these additional data from MDT to update our "before" database or use the 2019 and 2022 data as a starting point and interpolate/update information as needed during the manual data collection process.

Table 1. Summary of all roadway inventory data available

Year	Total number of segments	Total mileage
2016	8060	11034.1
2017	8493	11316.98
2018	10020	12172.8
2019	10422	12164.17
2020	8365	10422.7
2021	8614	10467.03
2022	9261	12001.76

Of particular interest in this project are two-lane rural roads, which are the primary roadway type that the SCLRS were installed. Table 2 provides a summary of the available data for just this roadway type in the roadway inventory database. As shown, two-lane rural roads make up the majority (approximately 80%) of the total mileage of state roads in Montana. Further, the mileage of two-lane rural roads is consistent across years even though the total mileage in Table 1 has significant differences in 2020 and 2021.

Table 2. Summary of two-lane rural roads data available

Year	Total number of segments		Total mileage
	Before segmentation	After segmentation	
2016	5991	10471	9663.77
2017	6351	10559	9876.35
2018	7283	10564	9887.25
2019	7566	10591	9900.72
2020	6016	10371	9645.63
2021	6236	10430	9686.63
2022	6387	10468	9711.94

Table 3 provides summary statistics for reported annual crash frequencies of all target crash types that will be considered in this project to illustrate the magnitude of safety issues. Note these data are only summarized for two-lane rural roads segmented using the method described in the 'Data Preparation' section. The summary statistics suggest that fatal + injury crashes make up approximately 20% of the total crashes that are reported. Head on crashes make up less than 1% of crashes on average but tend to involve a fatality or injury. The same is true of opposite direction sideswipe crashes; this crash type makes up less than 1% of all crashes but tend to involve a fatality or injury. Off-road crashes are more common and less likely to result in fatalities or serious injuries; specifically, off-road left crashes make up 11% of the total crashes and single-vehicle off road crashes make up 31% of all crashes.

Table 3. Summary of reported crash frequencies per target crash type

Year	Mean	Standard Deviation	Min	Max
Total Crash Frequency				
2016	0.604	1.87	0	45
2017	0.693	2.235	0	61
2018	0.684	2.145	0	63
2019	0.662	2.133	0	50
2020	0.681	2.14	0	52
Fatal and Injury Crash Frequency				
2016	0.153	0.58	0	14
2017	0.153	0.57	0	12
2018	0.147	0.572	0	14
2019	0.152	0.597	0	11
2020	0.151	0.548	0	10
Head On Crash, Total Frequency				
2016	0.005	0.074	0	2
2017	0.007	0.083	0	2
2018	0.006	0.079	0	2
2019	0.006	0.079	0	2
2020	0.007	0.082	0	1
Head On Crash, Fatal and Injury Frequency				
2016	0.004	0.062	0	1
2017	0.005	0.072	0	2
2018	0.004	0.068	0	2
2019	0.004	0.068	0	2
2020	0.005	0.072	0	1
Opposite Direction Sideswipe, Total Frequency				
2016	0.009	0.095	0	2
2017	0.009	0.095	0	2
2018	0.008	0.091	0	2
2019	0.008	0.093	0	2
2020	0.008	0.097	0	3
Opposite Direction Sideswipe, Fatal and Injury Frequency				
2016	0.005	0.069	0	2
2017	0.003	0.054	0	1
2018	0.003	0.057	0	2
2019	0.004	0.06	0	1
2020	0.002	0.047	0	1

Year	Mean	Standard Deviation	Min	Max
Off Road Left, Total Frequency				
2016	0.059	0.296	0	6
2017	0.081	0.392	0	8
2018	0.073	0.356	0	8
2019	0.076	0.374	0	7
2020	0.074	0.345	0	7
Off Road Left, Fatal and Injury Frequency				
2016	0.024	0.166	0	3
2017	0.029	0.185	0	3
2018	0.021	0.152	0	2
2019	0.026	0.178	0	4
2020	0.026	0.175	0	3
Single Vehicle Run Off Road, Total Frequency				
2016	0.167	0.664	0	15
2017	0.223	0.895	0	17
2018	0.217	0.84	0	22
2019	0.211	0.838	0	19
2020	0.21	0.791	0	19
Single Vehicle Run Off Road, Fatal and Injury Frequency				
2016	0.064	0.312	0	5
2017	0.069	0.318	0	5
2018	0.064	0.322	0	8
2019	0.068	0.329	0	6
2020	0.072	0.326	0	5

Table 4 provides a summary of key continuous variables that were included in the analysis database, by year. Table 5 includes a summary of key categorical variables; for brevity, this is provided just for the last year (2022). Note these data are only summarized for two-lane rural roads segmented using the method described earlier. These descriptive statistics are provided only to describe the range of values that are observed in the database.

Table 4. Summary of continuous variables in the roadway inventory database

Description	Year	Mean	Standard Deviation	Min	Max
Average Annual Daily Traffic (AADT)	2016	2316.218	2833.905	10	29017
	2017	2316.573	2901.307	8	30978
	2018	2325.736	2892.751	8	31412
	2019	2357.783	2936.829	7	30509
	2020	2218.265	2674.195	1	29590
	2021	2485.515	3072.483	1	32312
	2022	2447.193	3043.013	1	30201
Surface Width, feet	2016	32.014	7.996	16	80
	2017	32.124	8.042	16	79
	2018	32.158	8.045	16	79
	2019	32.182	8.09	16	79
	2020	32.327	8.046	18	79
	2021	32.339	8.046	18	79
	2022	32.357	8.057	18	79
Segment Length, miles	2016	0.923	1.737	0.01	19.43
	2017	0.935	1.754	0.01	19.43
	2018	0.936	1.755	0.01	19.44
	2019	0.935	1.755	0.01	19.44
	2020	0.93	1.736	0.01	19.43
	2021	0.929	1.735	0.01	19.43
	2022	0.927	1.734	0.01	19.43

Table 5. Summary of categorical variables in the roadway inventory database (year 2022)

Category	Mileage	Percentage
Functional classification		
1 - Interstate	1094.66	11.28
3 - Principal Arterial - Other	2522.98	25.99
4 - Minor Arterial	2765.82	28.49
5 - Major Collector	3030.73	31.22
6 - Minor Collector	70.99	0.73
7 - Local	223.21	2.3
Surface type		
Asphalt	9685.23	99.72
Concrete	23.16	0.24
Shoulder rumble strips		
No Rumble Strip	6249.94	64.38
Shoulder RS	3458.45	35.62
Posted speed limit		
15	1.48	0.02
25	87.77	0.9
30	11.83	0.12
35	84.77	0.87
40	22.92	0.24
45	201.1	2.07
50	95.43	0.98
55	355.35	3.66
60	339.25	3.49
65	357.56	3.68
70	6620.41	68.19
75	99.91	1.03
80	980.66	10.1
NA	449.95	4.63

NEXT STEPS

After completing this data compilation activity, several data collection steps remain:

- The research team will obtain the latest roadway inventory data (2023 and beyond) to create a database of "after" period information. These datafiles will be prepared in a similar method as described in this document.

- The research team will obtain the latest crash data (2021 and beyond) from MDT and assign these to the roadway inventory data using the same methods as described here.
- The research team will manually collect additional data elements to append to the current analysis datafiles. These data will include:
  - Shoulder type and width: the research team will estimate shoulder type and width using imagery provided in the Pathweb/Pathview system and Google Maps.
  - Horizontal alignment: the research team will identify the presence of horizontal curves on individual segments using imagery in the Pathweb system and estimate the radius and length of these curves to include in the analysis database.
  - Presence of other safety influencing features: the research team will review Pathweb/Pathview imagery to identify the presence of other safety-influencing features, such as shoulder rumble strips, traffic control devices (e.g., horizontal curve warning signs, stop or signal ahead signs), presence of turn lanes along roadway segments, etc.
  - Driveways: conversations with MDT revealed that driveway information in the existing GIS database may not be accurate. Thus, the team will use this as a starting point to verify the number of driveways on individual roadway segments to ensure accuracy in the database.
  - Roadside hazard rating: the research team will use Pathweb/Pathview imagery to estimate the roadside hazard rating using the scale developed in Zegeer et al. (1991). In this system, a seven-point categorical scale is used to describe the potential hazards, ranging from 1 (least hazardous) to 7 (most hazardous). A detailed description of roadside design features that "map" to each of the seven RHR categories can be found in Torbic et al. (2009).

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