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REVISED MEDIAN BARRIER WARRANTS FOR CROSS MEDIAN CRASHES

INTRODUCTION

Cross median crashes (CMC) in which a vehicle leaves a divided highway to the left and crosses completely through the median into oncoming roadway, are one of the most severe types of crashes due to high speeds and risk of collision with an opposing vehicle. Sideswipe collisions, overcorrecting after leaving the roadway to the right, and adverse roadway conditions are typical occurrences that initiate the loss of control and contribute to CMCs. Vehicles crossing the median commonly roll over, hit guardrails or other fixed objects, or collide with oncoming vehicles.

Till recently, Wisconsin Department of Transportation classified CMC as one of two types; namely multi- and single-vehicle cross median crashes. CMC where the crossing vehicle collides with a vehicle in the opposing lanes are classified as multi-vehicle CMC. The severities of these crashes are typically high due to the high rates of speed and head-on or opposing sideswipe crash types. Additionally, as more vehicles are involved in a crash, more injuries and fatalities often result.

In a vast majority of CMC observed in Wisconsin, the crossing vehicle entered or crossed the opposing travel lanes without colliding with an oncoming vehicle (*1*). These crashes, were referred to as single-vehicle CMCs, are typically less severe and have fewer injuries than multi-vehicle crashes, but can still be severe as they often involve rollovers or collisions with roadside objects. Single-vehicle CMCs are expected to have contributing factors and crash dynamics that are similar to multiple-vehicle CMCs and would thus have similar treatments. Additionally, single-vehicle CMC incidents have the potential to become the more severe multi-vehicle crashes, but the crossing vehicle found a gap in the opposing traffic stream. Single-vehicle CMC frequency is an important factor in predicting safety performance on divided highways as they act as an indicator to highlight potential problem areas. Therefore, Wisconsin DOT recently revised their definition of CMC to include both single-vehicle and multi-vehicle CMC.

Due to the catastrophic nature of multi-vehicle CMC, most agencies have made them the primary focus of safety improvements mitigating CMC. In 1978, California Department of Transportation (Caltrans) adopted the crash rate warrants of 0.50 CMC (only multi-vehicle) per mile per year and 0.12 fatal CMC per mile per year, with at least three CMC over a five year period, to determine sites that warrant additional analysis on the basis of crash history. The crash rate warrants were reviewed in 1991 by Seamons and Smith and again in 1997 by Nystrom et al. (*2, 3*). Seamons and Smith concluded that the median width/traffic volume warrant and the crash rate warrants

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(identified above) be retained as guidelines for identifying sites requiring additional analysis (*2*). Sites meeting the warrant with three to four crashes over a five year period "frequently lost their warrants before construction" due to the random nature of crashes. Although one of the suggestions was that the warrant be increased to require five rather than three crashes observed in a five year period, the crash frequency requirement was not changed so as not to "preclude valid projects from being identified and constructed." In 1997, Nystrom et al. concluded that the crash rate warrant was appropriate (*3*). This crash-rate warrant and CMC definition have been adopted as guidelines by Wisconsin Department of Transportation (WisDOT).

The TOPS Lab developed predictive and retrofit warrants using Wisconsin data (*1*). Towards this goal data from a diverse array of sources was assembled and transformed to be utilized by the modeling effort. Crash data was queried and manually filtered to assemble single- and multi-vehicle cross median crash (CMC) and median barrier crash (MBC) datasets. A software method was pioneered to visually inventory roadway characteristic data from the Photolog. The spatial mismatch between the Photolog-collected data and STN was addressed to integrate the crash and roadway data for use in the modeling process. Crash prediction models were formulated to describe the cross median and barrier crash frequencies and severities. Since limited cable barrier crash data were available at the time, concrete barrier crashes were used. Using the crash frequency models developed for CMCs and MBCs and WisDOT costs for crashes and barrier installation and maintenance, predictive median barrier warrant was developed (shown in Figure 1). None of the highway segments showed benefit/cost ratio greater than one. The data used to develop frequency models for CMC is mostly from rural Wisconsin (with lower ADT) while the data for MBC model is mostly from Greater Milwaukee area (with higher ADT). This disparity in datasets skews the comparison and reduces the calculated benefits drastically, which in turn, reduces the benefit/cost ratios. It was recommended that as new MBC data becomes available, the predictive warrant may be revised to better capture the effect of installing median barrier on crash occurrence and severity.

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Benefits / Costs		Directional AADT (vehicle/day)					
		5,000	10,000	20,000	30,000	40,000	50,000
Median width (ft)	10	-0.434	-0.434	-0.296	-0.100	0.118	0.345
	20	-0.443	-0.449	-0.322	-0.135	0.075	0.294
	30	-0.452	-0.465	-0.349	-0.170	0.032	0.244
	40	-0.462	-0.480	-0.374	-0.204	-0.010	0.195
	50	-0.385	-0.496	-0.400	-0.238	-0.052	0.146
	60	-0.480	-0.511	-0.425	-0.272	-0.093	0.097
	70	-0.488	-0.526	-0.450	-0.306	-0.134	0.050
	80	-0.497	-0.541	-0.479	-0.339	-0.175	0.002
	90	-0.506	-0.555	-0.499	-0.371	-0.215	-0.045
	100	-0.515	-0.570	-0.523	-0.403	-0.255	-0.091

Figure 1. Predictive Median Barrier Warrant. (*1*)

TOPS Lab also developed a retrofit warrant for cross median crashes with the data used for developing predictive warrant. The benefit-cost framework formulated by the research team for developing predictive median barrier warrants was utilized for retrofit warrant development as well. While the benefit-cost formulation is the same for both predictive and retrofit warrants, there is a fundamental difference between them. In the “Predictive” warrant, the number of CMC (multi or all) one can expect to see on the average in a year (given the influence of bridges, ramps, curves etc.) are predicted. In retrofit warrants the observed crashes (or crash rates) are used. The CMC rate threshold of 0.48 CMC per mile per year was adopted by WisDOT. This corresponded to a benefit-cost ratio of 10 and was expected to be conservative, since the expected median barrier crashes were overestimated, as explained above. The objective of this effort was to revisit the predictive and retrofit warrants based on an updated cable barrier crash frequency model developed using Wisconsin data.

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REVISION OF WARRANTS

Since the development of the two warrants, second phase of cable barrier evaluation was completed by the TOPS Lab (*4*). In the second phase of cable barrier evaluation, 10 high-tension systems at 16 study sites were evaluated. At least one system produced by each of five predominant cable barrier manufacturers was evaluated. The 16 sites evaluated in this study are spread over 14 Wisconsin counties and when combined, account for a total of 82.06 miles of cable barrier installations. Up to three years of after crash data was used resulting in 436 median barrier related crashes. These crashes were used to develop a cable barrier frequency model based on Wisconsin data. Negative binomial modeling was used as recommended by the Highway Safety Manual (*5*). The negative binomial model outputs a coefficient estimate for each significant variable. The regression coefficients can be applied to the following form of regression equation which only include AADT as the predictor variable:

$$\mu = \exp(\beta_0)\, L\, AADT exp(\beta_1 \log(\text{AADT})) \quad (1)$$

Where:

μ = Predicted number of CMCs per year;

β_0, β_1 = Regression coefficients;

L = Length of segment;

AADT = Directional daily traffic volume; and,

The resultant relationship between cable barrier frequency and AADT is shown in equation 2.

Expected CMC per year = 0.0000265* (AADT^0.91) (2)

Predictive warrant was revised using this cable barrier frequency model and is shown in Figure 2. WisDOT adopted the 0.48 CMC/mi/yr threshold for retrofit warrants corresponding to a B/C ratio of 10, based on the previous research. Therefore, this cable barrier frequency model was used to compute the benefit cost ratio that would result from using 0.48 CMC/mi/yr for the retrofit warrant. Analysis shows that 0.48 CMC/mi/yr corresponds to a B/C ratio of 13.

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Benefits / Costs		Directional AADT (vehicle/day)					
		5,000	10,000	20,000	30,000	40,000	50,000
Median width (ft)	10	0.74	1.24	2.07	2.78	3.41	4.00
	20	0.73	1.22	2.04	2.74	3.37	3.94
	30	0.72	1.21	2.01	2.70	3.32	3.89
	40	0.71	1.19	1.98	2.66	3.27	3.83
	50	0.70	1.18	1.96	2.63	3.22	3.78
	60	0.69	1.16	1.93	2.59	3.18	3.72
	70	0.68	1.14	1.90	2.55	3.13	3.67
	80	0.67	1.13	1.88	2.51	3.09	3.61
	90	0.66	1.11	1.85	2.48	3.04	3.56
	100	0.66	1.10	1.82	2.44	3.00	3.51

Figure 2. Updated Predictive Median Barrier Warrant.

In developing the spreadsheet, costs for cable barrier installation, maintenance, crashes, discount rate etc. provided by WisDOT were used. However, all these values can be changed in the spreadsheet (snapshot is shown in Figure 3) developed in this research to reflect project-specific values if required. In developing the predictive warrant shown in Figures 1 and 2, only directional ADT was used to compute the expected CMC frequency. Influence of factors such as bridges, curves, and entrance and exit ramps on CMC was not considered to make the warrant generally applicable. Using the spreadsheet these factors can be accounted for in specific projects.

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Directional ADT (veh/day)											
	5000	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.66
	10000	1.24	1.22	1.21	1.19	1.18	1.16	1.14	1.13	1.11	1.10
	20000	2.07	2.04	2.01	1.98	1.96	1.93	1.90	1.88	1.85	1.82
	30000	2.78	2.74	2.70	2.66	2.63	2.59	2.55	2.51	2.48	2.44
	40000	3.41	3.37	3.32	3.27	3.22	3.18	3.13	3.09	3.04	3.00
	50000	4.00	3.94	3.89	3.83	3.78	3.72	3.67	3.61	3.56	3.51
		10	20	30	40	50	60	70	80	90	100
		Median Width (feet)									

Enter the values here

Multi CMC Cost	Single CMC Cost	MBC Cost	Cable barrier installation cost per mile	Cable barrier maintenance cost per hit		Discount rate (%)	Service life (years) 10 or 20?	SPW(Present Worth Factor)
945,193	176,696	28,669	100,000	1,000		3%	10	8.78610892

Figure 3. Spreadsheet tool for the Predictive Warrant

CONCLUSIONS

The previous research used concrete barrier crash data to develop predictive and retrofit warrants for CMC. The objective of this research was to develop a Wisconsin cable barrier crash frequency model, and use it to update the predictive median barrier warrant for CMC, and compute the B/C ratio corresponding to the retrofit warrant. The predictive warrant based on previous research showed negative B/C ratios for most conditions and for the few conditions with positive B/C ratios they were all less than 1. The updated predictive warrant using the cable barrier frequency model shows that B/C ratios are positive for all the combinations of median width and directional AADT. Once WisDOT determines a suitable B/C ratio, the updated predictive median barrier warrant can be incorporated in to the WisDOT Facilities Development Manual as median barrier warrant for new construction or major reconstruction projects. WisDOT adopted 0.48 CMC/mi/yr as the threshold for retrofit warrant for CMC based on previous research which used a B/C ratio of 10. Using the newly developed cable barrier frequency model the B/C ratio corresponding to 0.48 CMC/mi/yr was found to be 13. Therefore, the threshold of 0.48 CMC/mi/yr for retrofit warrant is satisfactory.

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