Roadway Safety Data Program

NORTH CAROLINA'S STATE-SPECIFIC CMFs

ROADWAY SAFETY DATA AND ANALYSIS

CASE STUDY

FHWA-SA-16-107

Federal Highway Administration Office of Safety

Roadway Safety Data Program

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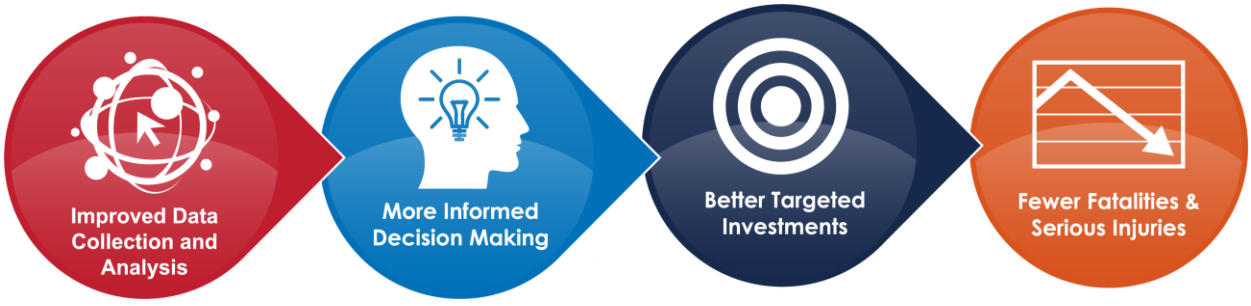

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U.S. Department of Transportation
Federal Highway Administration

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North Carolina is one of a small number of States that have actively pursued developing their own crash modification factor (CMF) "short list" for countermeasures that are deployed throughout the State. The North Carolina Department of Transportation (NCDOT) wanted to develop a list of CMFs to use in benefit cost analyses across the State. To develop the CMF list, NCDOT reviewed studies found online and later, they reviewed the available CMFs in the CMF Clearinghouse. The primary benefit that NCDOT has realized from conducting evaluations of countermeasures that previously had subjective CMF values is that the agency does not continue to implement countermeasures that have little to no quantifiable crash benefit. This is especially helpful with project selection processes and makes better use of safety dollars.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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ACRONYMS

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
CRFC	Crash Reduction Factor Committee
DOT	Department of Transportation
FDE	Fundamental Data Elements
FHWA	Federal Highway Administration
GIS	Geographic information system
GPS	Global positioning system
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSIS	Highway Safety Information System
HSM	Highway Safety Manual
KML	Keyhole Markup Language
LIDAR	Light detection and ranging
MIRE	Model Inventory of Roadway Elements
MIS	Management Information System
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
TMS	Traffic Monitoring System
XML	Extensive Markup Language

EXECUTIVE SUMMARY

North Carolina is one of a small number of States that have actively pursued developing their own crash modification factor (CMF) "short list" for countermeasures that are deployed throughout the State. It is important that all safety units across North Carolina use the same CMF value for a particular countermeasure in their benefit-cost analyses so that each safety unit has a level playing field when competing for safety dollars.

NCDOT wanted to develop a list of CMFs to use in benefit-cost analyses across the State. To develop the CMF list, NCDOT first reviewed studies found online. Later, they reviewed the available CMFs in the CMF Clearinghouse. The primary benefit that NCDOT has realized from conducting evaluations of countermeasures that previously had subjective CMF values is that the agency does not continue to implement countermeasures that have little to no quantifiable crash benefit. This is especially helpful with project selection processes and makes better use of safety dollars.

INTRODUCTION

North Carolina is one of a small number of States that have actively pursued developing their own crash modification factor (CMF) "short list" for countermeasures that are deployed throughout the State. It is important that all safety units across North Carolina use the same CMF value for a particular countermeasure in their benefit-cost analyses so that each safety unit has a level playing field when competing for safety dollars.

OBJECTIVE

NCDOT wanted to develop a list of CMFs to use in benefit-cost analyses across the State. To develop the CMF list, NCDOT first reviewed studies found online. Later, they reviewed the available CMFs in the CMF Clearinghouse. To summarize, update, and validate the information for use across the State, NCDOT created the Crash Reduction Factor Committee (CRFC) in 2002 responsible for monitoring, updating, and evaluating the applicability of CMFs selected for the North Carolina Project Development Crash Reduction Factor/CMF list.

AUDIENCE

The audience for this case study includes:

- State Departments of Transportation: Safety Engineering, Design, Planning, Maintenance, GIS, and Asset Management Units.
- Local and Regional: City and County Public Works/Engineering/Transportation Departments, Metropolitan Planning Organizations, and Regional Planning Commissions.
- Local Technical Assistance Programs.
- University and Research Academia
- Consultants and private industries involved with safety.

DEVELOPING STATE-SPECIFIC CMFS

PRACTICES IN PLACE FOR USING THE CMF CLEARINGHOUSE

In North Carolina, all potential spot safety projects are required to have a benefit-cost analysis (B/C) submitted with a project proposal. There are four main components in a B/C calculation:

- Cost of the target crashes prevented
- Service life of the countermeasure

- Cost of the countermeasure
- Estimated CMF of the countermeasure

In order to level the competition for safety funds between the eight different regions in North Carolina, NCDOT developed a list of countermeasures with a standard CMF for use across the State. NCDOT staff review and add new countermeasures to the list as necessary and then redistribute the list to appropriate parties.

NCDOT established the CRFC in 2002. The committee members are a NCDOT safety engineer and five regional engineers. The CRFC developed the first list of 28 recommended CMFs in their first year. Most of the CMF values came from research reports found online. The CRFC repeated this process approximately every six months to identify new CMFs to add to the list. The CRFC formally revised the list in 2007, and committee responsibilities increased as the list continued to grow. When the CMF Clearinghouse debuted in 2009, the CRFC downloaded and reviewed the CMFs of countermeasures that are used in North Carolina. Since 2009, the Committee's update period has varied from as little as 3 months to as long as 18 months. The timing depends on the volume of material to be reviewed and the workload of the committee members.

It is important to note that NCDOT uses both "CRF" and "CMF" terminology. NCDOT used "CRF" terminology when the CRFC was established in 2002; however, the current practice in the traffic safety field is for all references to countermeasure effectiveness be expressed as CMFs to be consistent with the *Highway Safety Manual*, which was published in 2010. The main difference between CRF and CMF is that CRF provides an estimate of the percentage reduction in crashes, while CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given improvement. For example, a 0.70 CMF corresponds to a 30 percent reduction in crashes (CRF of 30) and a 1.2 CMF corresponds to a 20 percent increase in crashes (CRF of -20).

Part of the purpose of the CRFC is to determine which CMF for a particular countermeasure from the CMF Clearinghouse should be included in the NCDOT list. Generally speaking, when there are multiple CMFs for a particular countermeasure, the committee selects the CMF from the Clearinghouse with the highest star rating and lowest standard error. There are no requirements for minimum star rating. When needed, the committee determines which CMF value to use by vote. In situations where a vote is necessary, a member of the CRFC pulls all potentially relevant information from the CMF Clearinghouse for reference and context. The CRFC divides the workload so that one member may review the information and present recommendations for which CMFs should or should not be adopted to the full Committee. The CRFC then votes on the recommendations from the committee member.

NCDOT also uses countermeasures that are not yet represented in the CMF Clearinghouse. For these, the CRFC has a separate procedure in place for determining what CMF value to use. In these cases, the CRFC searches online for recent research. If they find a published CMF for the countermeasure of interest, they use it. In cases where no information can be found, the CRFC uses subjective data (agreed upon by the committee members) until empirical data can be gathered. The subjective data comes from experience and opinions of the CRFC members as well as small samples of internal NCDOT simple before/after analyses. These values are based on NCDOT's own effectiveness evaluations after a specific treatment has been implemented. In many cases, the method does not control for regression to the mean; however, the estimated CMF values are considered preliminary and are used only until new research provides a more rigorously obtained value.

As of 2016, there are approximately 166 countermeasures in the NCDOT list. About 42 percent of the CMF values for these come from the CMF Clearinghouse. The rest are either based on prior published research or NCDOT's before/after studies. The full listing is available here: North Carolina Project Development Crash Reduction Factor Information.

EVALUATION OF SPECIFIC CMFS

The CRFC recognizes the need to evaluate, when possible, the CMFs selected using subjective data to ensure that the CMF chosen is appropriate to use based on empirical data. As an example, NCDOT has completed an analysis for the original countermeasure called "Upgrade Overhead Warning Flasher – Actuated Vehicles Entering" and they are currently evaluating the countermeasure called "Widen or Improve Shoulder".

Evaluation of "Upgrade Warning Flasher Actuated Vehicles Entering" Countermeasure

The "Upgrade Warning Flasher Actuated Vehicles Entering" was evaluated by comparing crash frequency before and after NCDOT installed "Vehicle Entering When Flashing" systems at over 70 sites in North Carolina. These systems alert an approaching vehicle to other vehicles entering the intersection from other approaches.

NCDOT began implementing this countermeasure in 1999 but there was no known CMF available at the time. Based on their own discussions, the CRFC assumed a 25 percent reduction in total crashes and set the preliminary, subjective CMF at 0.75. They also began collecting simple before/after data on each site where the system was installed in order to eventually validate the subjective CMF value chosen.

After many years of using the subjective CMF value and collecting simple before/after data, the CRFC conducted a basic benefit-cost analysis of 74 sites to see if the crash pattern changed

after implementation of the countermeasure. The empirical data showed the crash pattern was not changing and thus a more detailed analysis was warranted. A detailed investigation revealed that there were four types of "Vehicles Entering When Flashing" scenarios and each needed to be evaluated separately.

After doing a detailed analysis (before/after empirical Bayes) on the four types of scenarios, the CRFC found that scenarios one and two had a minimal effect on crash reduction and scenarios three and four had a larger effect on crash reduction. Therefore, the results of the study changed the NCDOT CMF list as noted in Figure 1.

October 2010 (value from original CMF list)					November 2012 (results from NCDOT study)				
Countermeasure Name	***Countermeasure Scenario***	***Crash Type***	***CRF***	***CMF***	***Countermeasure Name***	***Countermeasure Scenario***	***Crash Type***	***CRF***	***CMF***
2.2 Upgrade Overhead Warning Flasher Actuated Vehicles Entering	N/A	Total Crashes	25%	0.75	2.2 Actuated Vehicle Entering When Flashing	Overhead signs and flashers on major, loop on minor (2-lane at 2-lane intersections)	Total Crashes	-5%	1.05
						Overhead signs and flashers on minor, loop on major (2-lane at 2-lane intersections)	Total Crashes	5%	0.95
						Post mounted signs and flashers on major, loop on minor (2-lane at 2-lane intersections)	Total Crashes	32%	0.68
						Combination of signs and flashers on major/minor, loop on major/minor (combination of countermeasure scenarios above)	Total Crashes	25%	0.75
						All potential countermeasure scenarios (4-lane at 2-lane intersections)	Total Crashes	-7%	1.07

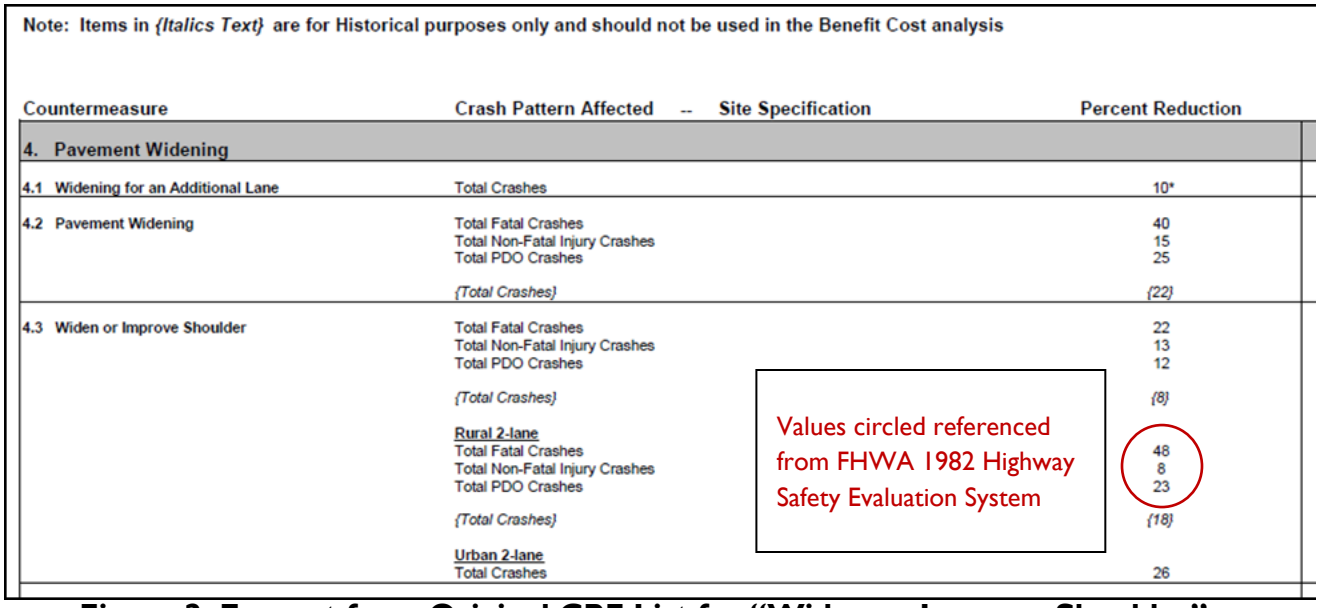
Figure 1. Revised CRFs and CMFs for "Vehicles Entering When Flashing" Scenarios

Evaluation of "Widen or Improve Shoulder" Countermeasure

NCDOT recently conducted a similar evaluation for the countermeasure for "Paved Shoulders" that focused on developing new CMFs for installing one- to two-foot paved shoulders on rural two-lane roads. Their original CMF list used the values circled in red in Figure 2 (in terms of crash reductions) for rural 2-lane total fatal crashes, total non-fatal injury crashes, and total PDO crashes (48-percent, 8-percent, and 23-percent reduction in crashes, respectively). These values came from an older national study (FHWA 1982 Highway Safety Evaluation System) that was available when the original CMF list was created in 2002.

The recent NCDOT study evaluated 35 safety projects where shoulders were paved on both sides of the roadway. Again they used the empirical Bayes before/after methodology and found that total crashes were reduced by 16 percent (CMF of 0.84) and lane departure crashes were reduced by only 7 percent (CMF of 0.93). As a result, the values circled in red in Figure 2 will be adjusted to a CMF of 0.93 for lane departure crashes.

Results of the analysis indicate crash reductions are not as great as the older national CMF value indicates. These types of projects are very expensive and if NCDOT is not getting the expected reduction in crashes for these projects, there is a potential that the projects may not rank as high on funding lists compared to other projects that have a better B/C ratio.



Note: Items in *{Italics Text}* are for Historical purposes only and should not be used in the Benefit Cost analysis

Countermeasure	Crash Pattern Affected -- Site Specification	Percent Reduction
4. Pavement Widening		
4.1 Widening for an Additional Lane	Total Crashes	10*
4.2 Pavement Widening	Total Fatal Crashes	40
	Total Non-Fatal Injury Crashes	15
	Total PDO Crashes	25
	{Total Crashes}	*{22}*
4.3 Widen or Improve Shoulder	Total Fatal Crashes	22
	Total Non-Fatal Injury Crashes	13
	Total PDO Crashes	12
	{Total Crashes}	*{8}*
	Rural 2-lane	
	Total Fatal Crashes	48
	Total Non-Fatal Injury Crashes	8
	Total PDO Crashes	23
	{Total Crashes}	*{18}*
	Urban 2-lane	
	Total Crashes	26

Figure 2. Excerpt from Original CRF List for "Widen or Improve Shoulder"

RESULTS

FUNDING

There are no specific funds set aside to staff the CRFC and maintain the CMF list or conduct safety evaluations for validating CMFs. In 1999, NCDOT formed the Safety Evaluation Group (SEG) in order to assess whether or not the countermeasures installed by NCDOT are working as intended. The CRFC is comprised of regional engineers and are not a part of the SEG. The SEG, which is a section within the Traffic Safety Unit of NCDOT, is responsible for maintaining the CMF list and validating new CMFs. They also evaluate all safety projects from NCDOT's Spot Safety and Hazard Safety Programs with simple before and after evaluations. With these evaluations, they try to answer some simple questions:

- Did the pattern of crashes change from the before to the after period?; and

- Did the countermeasure improve the situation? If not, these evaluations give the field engineers a second chance to mitigate the situation or problem.

BENEFITS

The primary benefit that NCDOT has realized from conducting evaluations of countermeasures that previously had subjective CMF values is that the agency does not continue to implement countermeasures that have little to no quantifiable crash benefit. This is especially helpful with project selection processes and makes better use of safety dollars. The goal is to gradually eliminate the subjective CMFs by developing estimated crash reductions based on actual data.

BARRIERS AND HOW THEY WERE OVERCOME

Perhaps the biggest barrier for the State to overcome is the selection of the correct CMF to use from the CMF Clearinghouse and ensuring that NCDOT staff use the CMF list appropriately. Another barrier to overcome is making sure the decisions of the CRFC get shared with and are understood by all CMF list users

LESSONS LEARNED

NCDOT believes it is imperative to have a single CMF list for a State's project development team to use. Prior to having their own list, NCDOT staff could use any CMF value that was available. Now the Safety Evaluation Group makes sure that everyone in the Department uses the same CMF across the State. This work is especially important now that the CMF Clearinghouse is accessible. NCDOT promotes use of selected countermeasures and committee-selected CMF values and discourages engineers from simply picking their most favored values from what is available in the CMF Clearinghouse. This levels the approach among districts and supports uniformity in B/C calculations.

NEXT STEPS

NCDOT and the CRFC and SEG will continue to monitor and update the North Carolina Project Development CMF list. They will also continue to study installations of countermeasures to ensure the CMF values assigned to these countermeasures are appropriate.

REFERENCES

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