Calibrating Crash Modification Factors for Wyoming-Specific Conditions: Application of the Highway Safety Manual - Part D

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Introduction

Transportation Engineering is a relatively old branch of engineering whose importance has been stressed by the engineering community for some period of time. Traffic safety, however, is relatively a new field and its emphasis has been growing since epidemic nature of roadway fatalities has been discovered in the last decade. American Association of State Highway and Transportation Officials (AASHTO), after ten years of research have finally published their first edition of Highway Safety Manual (HSM) in 2010.The Highway Safety Manual (HSM) is a result of extensive work spearheaded by the Transportation Research Board (TRB) committee on Highway Safety Performance. This is a welcomed development as it bridges the gap between research and practice. The HSM is considered as the sole national resource for quantitative information about traffic accident analysis and evaluation with a main focus of reducing crash frequency and severity. Equally useful is the FHWA Guide to Developing Quality Crash Modification Factors (CMFs). Crash Modification Factors or Functions are defined as a measure of the safety effectiveness of a particular treatment or design element. There is a need to validate the CMFs in the HSM Part D to Wyoming. In other words, could the HSM Part D be implemented in Wyoming without any adjustments or calibration is needed? The answer could be somewhere in between. We would likely need to adjust some values, charts or Safety Performance Functions (SPFs), but we can use others. This research proposal is a first step toward the adaptation of the Highway Safety Manual to Wyoming conditions.

The HSM has been a hot research topic since its publication. Researchers are keen to work on the application of the HSM in different states. States like Florida (Ahmed et al., 2015; Ahmed and Abdel-Aty, 2015; Muamer et al., 2014; Abdel-Aty et al., 2014), Utah (Brimley et al., 2012), Kansas (Howard and Steven, 2012), Oregon (Zhou and Dixon, 2012) and etc., have already worked on calibrations and modifications of the safety performance functions in the HSM on their own roadways. Although other states have calibrated their own CMFs, it was clearly found that the HSM in its current format will not be suitable to adopt in Wyoming. The outcomes from this study will help in prioritizing and selecting the appropriate countermeasures for the situation.

Background

The future edition of the Highway Safety Manual (HSM) – Part D was discussed during the 2015 Transportation Research Board Annual Meeting. The Safety Performance Committee and its subcommittees discussed three options to propose to AASHTO; 1) keep and update Part D in the second edition of the HSM, 2) remove Part D and include a methodology section on how to calibrate state-specific Crash Modification Factors (CMFs), 3) remove Part D and maintain an updated CMFs on the CMF Clearinghouse website. From the committee discussion, it is more likely that the second option will be elected. Not having a CMFs chapter in the new HSM edition emphasize the need of calibrating State-Specific Crash Modification Factors/ Functions for Wyoming. Moreover, the unique roadway characteristics and weather conditions in Wyoming urges a full calibration of CMFs for treatments of interest. The main objectives of this study are 1) to quantify the safety effectiveness of different countermeasures on different roadway types, intersection, crash type, and severity level, and 2) to validate and apply Crash Modification Factors/ Functions to the State of Wyoming.

HSM Part D provides CMFs for roadway segments (e.g., roadside elements, alignment, signs, rumble strips, etc.), intersections (e.g., control), interchanges, special facilities (e.g., Hwy-rail crossings), and road networks. CMFs could be applied individually if a single treatment is proposed or multiplicative if multiple treatments are implemented. Other possibilities are to divide or interpolate CMFs. In this study, the Empirical Bayes (EB) approach to analysis before-after effects will be utilized. The EB method can overcome the limitations faced by simple before-after evaluation and Comparison Group (CG) methods by not only accounting for regression to the mean effects, but also accounting for traffic volume changes when identifying the crash modification factors. This will increase the reliability of the CMF and increase the likelihood of achieving the same change in crash frequency if the treatment is implemented elsewhere. Crash Modification Factors can therefore play a vital role as an important tool to enable practitioners in WYDOT to estimate the safety effects of various countermeasures (e.g. installing guard-rails, rumble strips, widening shoulders, variable speed limit during inclement weather, etc.), identify the most cost-effective strategies to reduce the number of crashes (or severe crashes) at problematic locations, and check the validity of assumptions in cost-benefit analyses.

First phase of this study (year 1) will identify, collect Wyoming data, and calibrate Crash Modification Factors/ Functions for selected countermeasures in interest for the state, second phase (year 2) will compare the calibrated Wyoming-Specific CMFs to those calibrated in the HSM, provide recommendations for CMFs application in Wyoming, and integrate with results from Parts B and C.

Study Benefits

According to the Federal Highway Administration (FHWA) MAP-21, "Supports an Aggressive Safety Agenda" is one of the key points in the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA_LU) signed by the President in 2005. With over 35,000 fatalities occurring on the Nation's highways each year, roadway safety remains one of the most challenging issues facing the U.S. The primary goal of the recently issued Wyoming Strategic Highway Safety Plan (SHSP) is to reduce fatal and serious injury crashes. Validation and application of the Highway Safety Manual in Wyoming is a crucial step toward achieving such goal. Crash Modification Factors can therefore play a vital role as an important tool to enable practitioners in WYDOT to estimate the safety effects of various countermeasures, identify the most cost-effective strategies to reduce the number of crashes (or severe crashes) at problematic locations, and check the validity of assumptions in cost-benefit analyses.

The results from this research would be of great interest to the WYDOT design office since many CMFs are based on changes in design, e.g., adding a lane, roadside safety, intersection skew angle, signal timing, etc. WYDOT traffic operations office would also be interested in the CMFs pertaining to intersections, e.g., signalization of a stop controlled intersection, etc. All district safety offices as well as cities and counties have also a great interest to quantify the safety benefits of various countermeasures.

The findings, recommendations, and how to move forward to validate the Highway Safety Manual Part-D will be presented to the Safety Management System Committee, which will determine if a potential funding is available to continue the work. In addition, the research results will be disseminated through technical paper publications and presentations in academic venues and press releases using media outlets. The technology transfer activities in this project will benefit both the scientific community and authorities responsible for traffic safety and decision making, and will be a key to the implementation of the Highway Safety Manual in the state of Wyoming.

This research proposal was presented to WYDOT Safety Management System Committee which recommended forwarding the proposal to the RAC for potential funding.

Project Goals

HSM Part D provides CMFs for roadway segments (e.g., roadside elements, alignment, signs, rumble strips, etc.), intersections (e.g., control), interchanges, special facilities (e.g., Hwy-rail crossings), and road networks. CMFs could be applied individually if a single treatment is proposed or multiplicative if multiple treatments are implemented. Other possibilities are to divide or interpolate CMFs. In this study, the Empirical Bayes (EB) approach to analysis before-after effects will be utilized. The EB method can overcome the limitations faced by simple before-after evaluation and compare group methods by not only accounting for regression to the mean effects, but also accounting for traffic volume changes when identifying the crash modification factors. This will increase the reliability of the CMF and increase the likelihood of achieving the same change in crash frequency if the treatment is implemented elsewhere.

Crash Modification Factors can therefore play a vital role as an important tool to enable practitioners in WYDOT to estimate the safety effects of various countermeasures (e.g. installing guard-rails, rumble strips, widening shoulders, variable speed limit during inclement weather, etc.), identify the most cost-effective strategies to reduce the number of crashes (or severe crashes) at problematic locations, and check the validity of assumptions in cost-benefit analyses.

In order to validate and apply CMFs to Wyoming, the following tasks are proposed (prioritization of the analysis group (e.g. roadway segments, intersections, interchanges, etc., type of treatment, and crash type(s)) will be defined by WYDOT):

Phase 1:

1. Identify and collect Wyoming data for different locations where treatments have been adopted
2. Conduct a critical review of literature related to crash prediction models for the most important treatments in Wyoming.
3. Data Preparation
4. Exploratory Analysis
5. Proof of concept (conduct evaluations and calculate the CMFs).
6. Recommendations

Phase 2:

1. Compare the calibrated Wyoming based CMFs to those calculated for the same location type and treatment using the HSM procedure
2. Develop recommendations as to whether we can use the HSM Part D, or some applications/countermeasures need CMF re-calibration and validation and adjustments to use in Wyoming.
3. Provide an extension to the HSM based on WYDOT needs and Wyoming conditions.
4. Adjusted CMFs for Wyoming.
5. Integrate and coordinate with the results of Parts B and C in Wyoming.

Project Tasks

The expected *Tasks* for completing this research study are:

Phase-1:

1. *Literature Review*

   Conduct a critical review of literature related to crash prediction models for the most important treatments in Wyoming.
2. *Prioritizing Countermeasures for Phase-1*

   Based on information received from WYDOT about recent safety and improvement projects in Wyoming, the PI has identified a list of candidate countermeasures shown in Table 1-3 for different roadway facilities. With help from WYDOT SMS committee, a set of countermeasures will be selected to quantify their safety benefits.

Table 1: Countermeasures Candidate List for Roadway Segments

Countermeasure	Roadway Classification	Methodology	Notes
Passing Lanes	• Rural 2-lane highways • Urban 2-lane highways	Empirical Bayes (EB)	Preliminary Analysis on a 26-mile on WY59
Climbing Lanes	• Rural 2-lane highways • Urban 2-lane highways • Freeways • Multilane Highways	EB & CS	
Adding Lane(s) and Divide	• Rural 2-lane highways • Urban 2-lane highways • Multilane Highways	EB & CS	
Adding Lane(s) undivided	• Rural 2-lane highways • Urban 2-lane highways	EB & CS	
Shoulder Rumble Strips	• Rural 2-lane highways • Urban 2-lane highways • Freeways • Multilane Highways	EB & CS	Ongoing study on ML34B US WY26
Centerline Rumble Strips	• Rural 2-lane highways • Urban 2-lane highways • Multilane Undivided Highways	EB & CS	
Combined Shoulder & Centerline Rumble Strips	• Rural 2-lane highways • Urban 2-lane highways • Multilane Undivided Highways	EB & CS	
Access Management (TWLTL)	• Arterial Multilane Undivided Highways	EB & CS	
Roadway Diet	• Arterial Multilane Undivided Highways • Arterial Multilane Divided Highways	EB & CS	
Headlight Signs	• Rural 2-lane highways	Cross-Sectional	Ongoing study on 4 locations
Widening and Overlay	• 2-lane highways • Multilane highways	EB & CS	
Restoration & Rehabilitation	• 2-lane highways • Multilane highways • Freeways	EB & CS	
Cable Median Barriers	• Freeways	EB & CS	
Resurfacing	• Rural 2-lane highways • Urban 2-lane highways • Freeways • Multilane Highways	EB & CS	

EB (Empirical Bayes), CS (Cross-Sectional)

Table 2: Countermeasures Candidate List for Intersections

Countermeasure	Intersection Types	Methodology	Notes
Signalization	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Adding a Stop Sign	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Flashing Yellow Arrow	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Flashing Red	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Roundabout	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Adding Left-turn Lanes	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	
Adding Right-turn Lanes	• 4-leg (# of lanes) • 3-leg (# of lanes)	EB & CS	

Table 3: Countermeasures Candidate List for ITS and Special Facilities

Countermeasure	Intersection Types	Methodology	Notes
Variable Speed Limits (VSL)	• Freeways	EB	
ITS – Roadway Info. "DMS"	• Freeways	EB & CS	
Weigh-in-motion	• Freeways	EB & CS	
Wild-life Crossing	• Two-lane highways	EB	
Snow Fence	• Freeways	CS	
Diverging Diamond Interchange (DDI)	• Freeways	EB & CS	

3. *Collect Wyoming data for different CMFs*

This task requires identification of different sites in Wyoming that had one or more treatments. This could be an extensive data collection effort. For each site, before and after data would be needed to evaluate the effect of the treatment(s). Various sources of data will be used; these sources may include the as-built plans, video logs, and the TRANSVIEW aerial mapping system. Moreover, crash data will be collected from WDOT Crash database CARE. Traffic volumes will be collected for time periods of before and after treatment(s).

4. *Data Preparation*

   There are some data related issues that will need to be taken care of before merging datasets together. As per HSM Part D, CMFs can be developed for 5 main categories; 1) Roadway Segments, 2) Intersections, 3) Interchanges, 4) Special Facilities and 5) Road Networks. Among these categories, most of the roadway segments are expected to have zero crashes, a criterion of minimum 100 segments may be adopted as a cutoff point for a sufficient sample size for regression analysis. There is a possibility of having a small sample size because of rare crash type or rare treatment type, and lack of suitable treatment locations. Crash data will then be screened and assigned on each of above mentioned categories.

5. *Exploratory Analysis*

   Exploratory data analysis will be conducted for the geometric characteristics, crash severity, and crash rates for the above mentioned categories.

6. *Proof of Concept*

   This task will illustrate a preliminary proof of concept and will highlight the need for additional funding to continue the work. This effort will involve conducting an evaluation of the chosen sites for specific treatment(s) and calculating the CMFs using the Empirical Bayes method to account for the regression-to-the-mean effect. This would be done for each type of locations following the HSM categorization, i.e., road segments, intersections, etc. and the treatments considered by the HSM, e.g., rumble strips, alignment, cable barriers, etc. This task could be enormous, and WYDOT prioritization would be sought, as to what would be investigated in this first phase of the project. At this stage the research team does not want to limit the locations and treatments, as this would be determined by the data availability.

7. *Recommendations and Proposal for Phase-2*

   This task will provide recommendations and proposal for Phase-2. The preliminary tasks thought in Phase-2 are listed in the below section.

8. *Implementation and Technology Transfer*

The final findings, and recommendations will be presented to the Safety Management System Committee, which will help in identifying the most cost effective countermeasures for selected roadway facilities. The calibrated CMFs will be also shared with local governments around the state. In addition, the research results will be disseminated through technical paper publications and presentations in academic venues and press releases using media outlets. The technology transfer activities in this project will benefit both the scientific community and authorities responsible for traffic safety and decision making, and will be a key to the implementation of the Highway Safety Manual process of calibrating Crash Modification Factors.

Phase 2:

1. *Compare Wyoming based CMFs to those calculated for the same location type and treatment using the HSM procedure*

The HSM procedure will be applied for the treated sites in Wyoming and the expected crash frequencies will be identified. Then the CMFs from the HSM and those relevant CMFs from task 4 above will be compared. Also the expected values from the HSM procedure will be compared to the actual observed values after the treatments.

2. *Develop recommendations as to whether we can use the HSM Part D, or some applications/countermeasures need validation and adjustments to use in WY*

Based on Phase 1- task 5, we will identify those parts in the HSM part D that could be used without any modifications and those that need adjustments to Wyoming conditions. For example if the actual values of crashes are within 10% of the expected, and the standard error in the HSM is within the same range, then we can use the same values as the HSM. If the difference is larger, we would need to adjust the tables, charts or SPFs accordingly. This task will investigate the rules that would be used to accept or adjust values from the HSM.

3. *Provide an extension to the HSM based on WYDOT needs and Wyoming conditions*

Not all applications are provided in the HSM. While total crash frequency and in many cases severity are addressed in the different chapters and sections of Part D, others might not be available due to limitations in similar studies in the literature or non-conclusive results. For example, in Wyoming we experience high frequency of lane departure crashes and adverse weather related crashes (roll-over crashes because of strong wind). With consultation with the WYDOT Project Manager, we might need to provide additional CMFs for these types of crashes, etc.

4. Document the adjusted HSM for WY

The final objective of this research would be to reach specific conclusions about how to implement the HSM Part D in Wyoming. The deliverable might be an adjusted Part D or at least the adjusted sections and values. WYDOT might choose to account for other resources such as the "A Guide to Developing Quality Crash Modification Factors", FHWA, 2010, or other.

5. Integrate and coordinate with the results of Parts B and C in WY

Although there is no substantial redundancy between the different HSM parts, we intend to integrate this effort with other efforts in the state for HSM parts B and C. Part D of the HSM is related to Part B in diagnosing crash frequency, selecting countermeasures and conducting economic evaluation. Some of the CMFs are used in the form of Safety performance functions (SPFs) which is the main objective of part C (although CMF equations seem to be simpler by using AADT or fewer parameters). If needed, and with consultation of WYDOT's project manager and availability of the results from other projects in the state addressing Parts B and C, we intend to investigate the relevance of some of the other Parts of the HSM and if needed provide a way for integration between the different parts of the WY HSM.

6. Implementation and Technology Transfer

The final findings, and recommendations will be presented to the Safety Management System Committee, which will help in identifying the most cost effective countermeasures for various roadway facilities. The calibrated CMFs will be also shared with local governments around the state. In addition, the research results will be disseminated through technical paper publications and presentations in academic venues and press releases using media outlets. The technology transfer activities in this project will benefit both the scientific community and authorities responsible for traffic safety and decision making, and will be a key to the implementation of the Highway Safety Manual process of calibrating Crash Modification Factors.

Deliverables

Quarterly progress report will be submitted. In addition, any major achievement, i.e., the completion of tasks will be reported to the project managers. Calibrated Crash Modification Factors, draft final report and a final report incorporating the project managers' comments and corrections would be submitted at the end of the project.

Project Kickoff Meeting

A kick-off meeting shall be scheduled to occur within the first 30 days of execution by the university. The preferred method for the kick-off meeting is via teleconference or video conference. As a minimum, the project manager and the principal investigator will attend. The Research Center staff must be advised of the meeting and given the option to attend. Other parties may be invited, as appropriate. The subject of the meeting will be to review and discuss the project's tasks, schedule, milestones, deliverables, reporting requirements, and deployment plan. A summary of the kick-off meeting shall be included in the first progress report.

Progress Reports

The university will submit quarterly progress reports to the Research Center. The first report will cover the activity that occurred in the 90 days following the issuance of the task work order.

Draft Final Report

The Draft Final Report is due 90 days prior to the end date of the task work order. The draft final report will be submitted to the WYDOT Research Center. It should be edited for technical accuracy, grammar, clarity, organization, and format prior to submission to the Department for technical approval.

Final Report

Once the draft final report has been approved, the university shall prepare the final report. The university will deliver a CD or DVD containing the final report in PDF as well as MS Word format.

Project Closeout Presentations

The findings of this study will be presented to the SMS committee as well the WYDOT RAC at the conclusion of the project.

Timeline

It is envisioned that total time required for Phase-1 including the submission of the final report would be 16 months beginning January 1st, 2016. The review of the literature will be carried out over the first 12 months to insure up-to-date information.

Table 4: Work Plan Schedule

	Month															
Research Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Task 1																
Literature Review																
Task 2																
Prioritizing Countermeasures for Phase-1																
Task 3																
Data Collection for selected Countermeasures																
Task 4																
Data Preparation																
Task 5																
Exploratory Analysis																
Task 6																
Proof of concept																
Task 7																
Recommendations & Proposal for 2nd Phase																
Task 8																
Technology Transfer																
Documentation and Deliverables Schedule																

Quarter Reports   Draft Final Report   Final Report

Budget

As shown in Table 2, the total cost of the project is $79,234. That cost will cover all data collection and analysis activities as well as technology transfer. In addition, it will cover the salaries of one graduate student, and one faculty member.

Table 5: Project Budget

Budget Year: 2016-2017			
Mohamed Ahmed - University of Wyoming			
CATEGORY	Budgeted Amount from WYDOT	Budgeted Matching Funds - MPC	Explanatory Notes
Center Director Salary			
Faculty Salaries	$18,581	$7,000	
Administrative Staff Salaries	$0	$0	
Other Staff Salaries	$0	$0	
Student Salaries	$23,500	$20,500	
Staff Benefits	$9,722	$4,245	
Total Salaries and Benefits	**$51,803**	**$31,745**	
Student Support Other Than Salaries	$8,970	$5,463	Tuition/No indirects
Permanent Equipment	$1,500	$1,200	No indirects
Expendable Property, Supplies, and Services	$500	$500	
Domestic Travel	$2,000	$2,000	
Foreign Travel	$3,000	$0	
Other Direct Costs (specify)	$0	$6,000	
Total Other Direct Costs	**$15,970**	**$15,163**	
F&A (Indirect) Costs	$11,461	$8,049	
TOTAL COSTS	**$79,234**	**$54,957**	

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