ATTACHMENT E

Slope CMFs for $CMF_{ROADSIDE}$

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INTRODUCTION

The roadside crash modification function, $CMF_{ROADSIDE}$, is assumed to have the following form:

$$CMF_{ROADSIDE} = \left[\beta_{SHLD} \cdot X_{SHLD} \cdot \prod_{j=1}^{m1} CMF_j\right] + \left[\beta_{UNSHLD} \cdot X_{UNSHLD} \cdot \prod_{k=1}^{m2} CMF_k\right]$$

Where:

X_{SHLD} =	Proportion of the segment edge where longitudinal barriers are installed where $0 \leq X_{SHLD} \leq 1$.
X_{UNSHLD} =	Proportion of the segment edge where there are unshielded ditches or roadside slopes and other unshielded fixed objects where $0 \leq X_{UNSHLD} \leq 1$.
Condition that:	$1 = X_{SHLD} + X_{UNSHLD}$ (100% of the segment edge is accounted for).
β_{SHLD} =	A regression coefficient associated with the segment edges where longitudinal barriers are installed.
β_{UNSHLD} =	A regression coefficient associated with the segment edges where there are unshielded ditches, roadside slopes or fixed objects like trees, tree lines, utility poles, bridge piers, etc.
CMF_j =	Crash modification factors associated with roadside feature j that modify the ROR crashes associated with longitudinal barriers. These CMFs would account for characteristics like barrier type, barrier terminals, barrier transitions, barrier offset, etc.
CMF_k =	Crash modification factors associated with roadside feature k that modify the ROR crashes associated with unshielded roadsides. These CMFs would account for characteristics like the presence of ditches, the density of narrow fixed objects, and other unshielded objects.

Crash type definitions were developed for the different ROR crash types to accompany $CMF_{ROADSIDE}$. These same definitions are used here. Recall that any vehicle that runs off the road in any sequence of events is included in the dataset used to develop the SPFs. The modeling of $CMF_{ROADSIDE}$ required knowledge of longitudinal barrier crashes. A longitudinal barrier crash was defined as any crash where the longitudinal barrier is the first object struck off the road. In other words, if a vehicle runs of the road to the left and hits a w-beam, it is a longitudinal barrier crash. If a vehicle side-swipes another vehicle then runs off the road to the right and hits a longitudinal barrier, it is a longitudinal barrier crash. On the other hand, if a vehicle runs of the road to the right and hits a tree then a longitudinal barrier, it is a fixed object crash.

The development of $CMF_{ROADSIDE}$ was documented in Attachment C16. Throughout the derivation of β_{SHLD} and β_{UNSHLD}, CMF_j and CMF_k are taken to be unity since the modelling at that point was based on the mean roadside condition of the base segments. β_{SHLD} and β_{UNSHLD} were tabulated for each severity discussed in Attachment C16. The documentation of the roadside base conditions where CMF_j and CMF_k, are equal to unity is provided in Attachment D16.

This attachment documents the collection of data to improve the understanding of the influence of roadside slopes on rollover crashes.

DATA COLLECTION

Two different data sources will be used in this analysis: (1) simulated trajectories generated under previous research for different slopes and encroachment angles; and (2) data collected are crashes were the vehicle ran off the road in an unprotected section of the roadway and either rollover or did not rollover. Each of these data sources are described below.

SIMULATED TRAJECTORY DATA

The objective of NCHRP 22-22(02) is to produce comprehensive recommendations for placement of barriers on roadside and median slopes. Toward accomplishing this objective, the Bligh *et al*. simulated encroachment trajectories on a variety of slopes.[Bligh16] Bligh *et al*. has graciously provided these simulated trajectories for use in this effort. These simulated trajectories will be used to develop a crash modification factor for slopes. The CMF developed using the simulated trajectory data will be validated by the CMF generated using the crash data.

CRASH DATA

The CMF for slopes developed from crash data will use a case-control study. A case-control study is a study in which existing groups with differing outcomes are identified and compared on the basis of some supposed causal attribute. The WHO says "…the choice of controls and cases must not be influenced by exposure status, which should be determined in the same manner for both."[Bonita06] Lewallen and Courtright (1998) offer additional advice on selecting controls, stating "[c]ontrols should be chosen who are similar in many ways to the cases." "The selected control group must be at similar risk of developing the outcome.…" The WHO suggestion for the design of a case-control study is shown graphically in Figure 1.

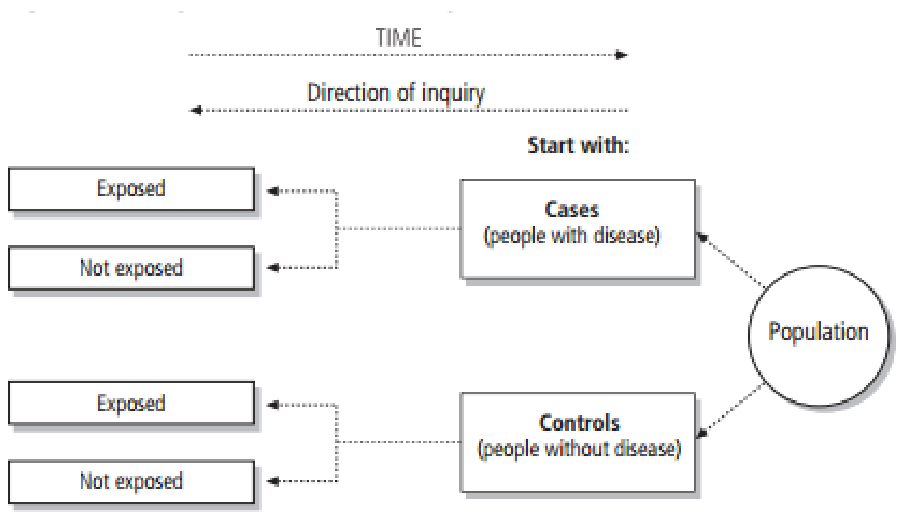

Figure 1. WHO Suggested Design of a Case-Control Study. [Bonita06]

Gross, Persaud, and Lyon (2010), with respect to highway safety studies specifically, indicate "[c]ase-control studies are based on cross-sectional data." Sites and controls are identified by outcome (e.g., crash or no crash; A+K crash or BCO crash). The treatment at each site is then determined. The WHO suggestion for the design of a case-control study shown in Figure 1 has been adapted for a study of slopes where the investigator wishes to study the Odds (or relative risk) of a rollover crash on slope A to a non-rollover crash on slope A. This is shown in Figure 1a. Notice that first the cases and controls are identified and then the slope is collected. This process of identifying cases and controls first then collecting the slope data agrees with the methodology outlines by Gross, Persaud, and Lyon. It also ensures that the cases and controls were determined using the same method and that the identification of controls was not influenced by the slope, as the WHO warns against.

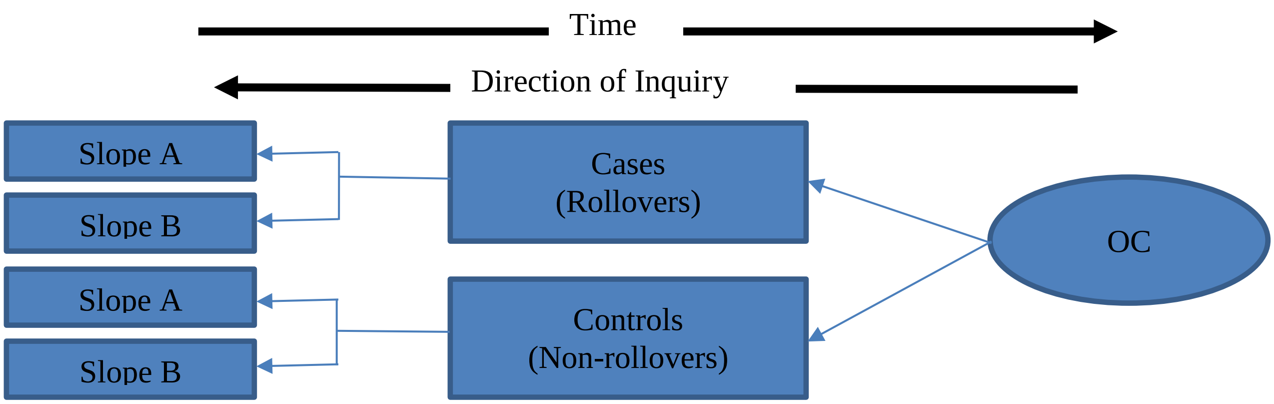

Figure 1a. WHO Suggest Design of Case-Control Study Applied to Slopes.

Gross, Persaud, and Lyon (2010) provide a table to capture both the cases and controls. This table is reproduced here as Table 1. This table is accompanied by an equation to determine the odds ratio which references the table, as shown here:

Odds Ratio (OR)=CMF=$\frac{A/B}{C/D} = \frac{AD}{BC}$

Table 1. Tabulation for Simple Case-Control Analysis. [Gross10]

	Number of Cases	Number of Controls
With Treatment	A	B
Without Treatment	C	D

For the reasons discussed above, first the cases and controls should be identified and then the treatment (i.e., slope) is identified to ensure that the cases and controls are determined using the same method and that the identification of controls was not influenced by the slope.

Identification of Data Population

It is assumed that divided roadways generally provide a clear zone which would allow the vehicle an opportunity to interact with a slope prior to encountering fixed objects, therefore, consideration was only given to crashes on divided roadways for this analysis. Furthermore, only right existing vehicles were considered (i.e., median slopes were not considered in the analysis).

Crashes with longitudinal barriers were eliminated from consideration, as the slopes were not exposed. Using the definitions for longitudinal barrier crashes (LB) and other crashes (OC), only OC were carried forward. The population is, therefore, OC which occurred on the right edge of divided highways. Data was collected for this entire population.

Data Collection

Google Earth Pro was used to determine the slope for each crash in the identified population. The crash data did not originally contain the latitude and longitude; which are required for navigation using Google Earth Pro. These data were found using the route and milepost available in the crash database in conjunction with an online photo log of Ohio roadways called PathWeb. The route and milepost were entered into PathWeb for each case to obtain the corresponding latitude and longitude.

Using the latitude and longitude, each crash location was viewed on Google Earth Pro. The measuring tool was used to collect five data points that make up the slope data used for slope analysis. These five data points are defined here:

- Edge line elevation (ELE) is the elevation at the edge line. It is the painted line at the edge of the travel way the vehicle exited.
- Break point elevation (BPE) is the elevation at the break point. It is defined as the first point from the edge line where the elevation has a measurable change.
- End of slope elevation (ESE) is the elevation at the end of the slope. It is defined as the point where the elevation change can be observed (visually on the elevation graph) changing direction from that indicated by the break point elevation or at a maximum of 60 feet.
- Edge to end distance (EED) is defined as the horizontal distance between the edge line and the end of the slope.
- Break point distance (BPD) is defined as the horizontal distance between the edge line and the break point.

It was not the objective to collect detailed data for complex slopes (e.g., grading around culverts, bridges, intersections, etc.) because this type of detailed slope data would not be applicable to long roadway stretches. Complex slopes, however, were captures in the data collection effort as complex slopes. A complex slope is defined as any slope which is within 400’ in advance of an intersection, bridge, or a culvert as well as a slope at a location that is within the limits of an on/off ramp. It is possible, with enough data points, that the effect of complete slopes can be compared to traversable slopes through a CMF.

While data collection was limited to OC (i.e., non-longitudinal barrier crashes) to provide events where only unprotected roadside slopes were present, some locations presented longitudinal barriers. When the presence of longitudinal barrier was recorded at a location, this location was removed from the data population.

SUMMARY

The research team will use these two different data sources (i.e., crash data and simulated trajectory data to analyze the effect of various slopes on crash frequency and ultimately develop CMFs for roadside slopes. The data collection effort for the crash data will continue this quarter.

REFERENCES

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