Recommended Procedure for Combining Crash Reduction Factors

J. Kevin Lacy, P.E. Research Engineer, Highway Safety Research Center
May 2, 2001

There are three situations that require combining crash reduction (1) application of more than one countermeasure at a particular intersection or roadway segment; (2) application of a countermeasure that affects both intersection and road segment crashes differently; and (3) a combination of one and two. While combining the crash reduction factors is not a strenuous mathematical exercise, it is not as straight forward as adding the reduction factors or their estimated effects. For instance, if one just adds the effects of different countermeasures, the total effect may be larger than the available crashes. If three countermeasures applied to an intersection has angle crash reduction factors of 50%, 30% and 25% reduction simply adding them produces a 105 percent reduction. This creates what may be called the Lazarus effect, not only will the treatment prevent future crashes, they will also prevent crashes that already occurred! This simple example shows the importance of applying a reasonable methodology to combine the effects of multiple treatments.

This document was prepared for the North Carolina Traffic Engineering and Safety Systems Branch. The NCDOT uses the term crash reduction factor (CRF) in the form of percent crashes reduced. Many research documents choose to use the term crash modification factor (CMF) or accident modification factor (AMF) and these terms are often expressed in the format of a multiplier theta (θ). The relation between the two formats is simply (100*(1-θ))=CRF.

Ideal World

In the ideal world, research provides crash reduction factors for the combined treatments in one value of chart. This approach more effectively accounts for the interaction between the different countermeasures. The cost to produce a comprehensive listing is a sizable hurdle that will not be overcome in the near future. This creates the need for a good method to combine the available reduction factors or modification factors.

Combining Crash Reduction Factors for a Single Entity

An entity is a single intersection, a single roadway segment or one of any other roadway feature like a bridge. For example, an intersection may include the actual area shared by the intersection routes and a Y-line of 150 feet. This intersection excludes crashes beyond 150 feet from the intersection. The following equation creates a single crash reduction factor for the multiple treatments applied at the single entity. [1]

$$CRF_{Ti} = 1 - \left[(1 - CRF_{1i}) * (1 - CRF_{2i}) * \ldots * (1 - CRF_{ni})\right] \qquad (1)$$

Where

- CRF_{Ti} = the total crash reduction factor for the crash type i (angle, left turn, etc) in decimal format (25% = 0.25)
- CRF_{1i} = the crash reduction factor for the first treatment for the given crash type in decimal format (25% = 0.25)
- CRF_{2i} = the crash reduction factor for the second treatment for the given crash type in decimal format
- CRF_{ni} = the crash reduction for the nth treatment for the given crash type in decimal format

Example 1

Lets use the same example that resulted in the Lazarus effect earlier, three treatments that reduces angle collisions 50%, 30%, and 25%. Plugging these crash reduction factors in equation one results as:

$$CRF_{Tandgle} = 1 - \left[(1 - CRF_{1i}) * (1 - CRF_{2i})* \ldots *(1 - CRF_{ni}) \right]$$
$$CRF_{Tandgle} = 1 - \left[(1 - 0.5) * (1 - 0.3) * (1 - .25) \right]$$
$$CRF_{Tandgle} = 1 - 0.2625$$
$$CRF_{Tandgle} = .7375 = 73.75\%$$

The resulting combined crash reduction factor for angle crashes for these three treatments is 73.75 percent reduction in angle collisions. So rather than traveling back in time and reducing previously occurring crashes, the estimated reduction for combined treatment is 74% rounded.

Example 2

At the same intersection in example 1, the recommended treatments also affect rear-end crashes as well. The individual crash reduction factors for rear-end crashes are 10%, 5% and -15% (actually increasing the frequency of rear-end crashes). Plugging these number into equation one for rear-end crashes result as:

$$CRF_{Trear-end} = 1 - \left[(1 - CRF_{1i}) * (1 - CRF_{2i})* \ldots *(1 - CRF_{ni}) \right]$$
$$CRF_{Trear-end} = 1 - \left[(1 - 0.1) * (1 - 0.05) * (1 - -0.15) \right]$$
$$CRF_{Trear-end} = 1 - 0.98325$$
$$CRF_{Trear-end} = 0.017 = 1.675\%$$

The resulting combined crash reduction factor for rear-end crashes for these three treatments is 2% rounded.

Expected Crash Reduction

The number of crashes reduced by crash type is determined by multiplying the before crashes by the crash modification factor. One must consider the crash history at the location to determine a number that is representative of average annual crashes. Ideally, there are several years of data available to determine the average number of crashes. IF there are major fluctuations, the investigation should attempt to determine the cause of the fluctuations. The number of crashes reduced needs correcting by the project growth in traffic. This is also where several years of historical data can help make a more reasonable estimate. Equation 2 calculates the number of crashes reduced by a treatment.

$$N_R = \sum_i \left[\frac{ADT_P}{ADT_B} * N_{B_i} * CRF_i \right] \qquad (2)$$

Where

N_R = the total number of crashes reduced at the treatment site
ADT_P = the projected ADT for the location
ADT_B = the ADT for the analysis period
N_{Bi} = the number of crashes in the crash type i during the analysis period
CFR_i = the crash reduction factor for crash type i (may be a combined crash reduction factor
i = the different crash patterns that the various treatments affect at the treated location.

Combining Crash Reduction Factors Affecting More than One Entity

In some situation, application of a single countermeasure affects more than one entity such as an intersection and a roadway segment. An example of this is adding a continuous center turn lane thorough several intersections. The continuous left-turn lane crash reduction factor includes crashes along the segment where the left-turn crash reduction occurs at driveways and minor intersections. However, if the turn-lane extends through one or more intersections, the engineer must decide if the intersection is more than a minor low volume intersection. If the intersection carries a significant amount of traffic and has a higher number of left-turn crashes than the other driveways and minor intersections, then the treatment in the intersection is considered a separate treatment. When determining the predicted crash reductions of the project, it is divided into two portions, (1) the intersection improvement, adding turn lanes, and (2) roadway section improvement adding continuous left turn lane. The number of crashes reduced is calculated independently and added together. It is important to make the decision if the single treatment will have greater or less effect on different entities, this is where on engineer applies good reasoning and judgment. Equation 3 calculates the total number of crashes reduced by one treatment across multiple entities.

$$N_R = \sum_j \left[\sum_i \left[\frac{ADT_P}{ADT_B} * N_{B_i} * CRF_i \right] \right] \tag{3}$$

Where

N_R = the total number of crashes reduced at the treatment site
ADT_P = the projected ADT for the location
ADT_B = the ADT for the analysis period
N_{Bi} = the number of crashes in the crash type i during the analysis period
CFR_i = the crash reduction factor for crash type i (may be a combined crash reduction factor
i = the different crash patterns that the various treatments affect at the treated location.
j = the different entities within the treatment area

Example

Installation of a half mile long continuous left turn lane in Utown cross one major intersection. The ADT is expected to remain constant over the next 5 years. The influence area of the intersection is 150 feet on either side of the intersection along the treated route. There were 100 left-turn same road crashes annually along the entire project length with 20 occurring at the intersection. Determine the number of left-turn same road crashes reduced by this treatment.

The number of left-turn same road crashes along the segment is 80 crashes. The CRF for left-turn same road crashes for continuous left-turn lanes is 30%. *Crashes reduced $_{TWLTL}$ = Number of Crashes * CRF = 80*.3) = 24 crashes.* The number of left-turn same road crashes at the intersection is 20. The CRF left-turn same road crashes for left-turn lane at an intersection is 50%. *Crashes reduced $_{Left\text{-}Turn}$ Lane = Number of Crashes * CRF = 20*.5) = 10 crashes.* Placing this in the format of equation 3 gives:

$$N_R = \sum_j \left[\sum_i \left[\frac{ADT_P}{ADT_B} * N_{B_i} * CRF_i \right] \right] = (1*80*0.3) + (1*20*0.5)$$

$$N_R = 24 + 10$$

$$N_R = 34$$

The total number of left-turn same road crashes reduced is 34 per year rather than 30 that results when applying the continuous left turn lane CRF throughout the project. It is important to determine if it is reasonable to expect that the treatment will perform differently at the particular intersection than the remaining portion of the road. One way to help make that decision in this case is how do you expect the pavement marking to appear at the intersection. Will the pavement marking show left-turn bays at the more important intersections or will the pavement marking remain the same throughout the entire project length?

Determining the Crash Reduction for a Project

Many larger projects contain several mini projects, where the mini projects may include adding left-turn lanes at several different intersections along a corridor and widening the paved shoulder along the entire project limits. Determining the number of crashes reduced in these cases is very similar to the method used in the previous section. However, you will need to complete the analyses for each entity and treatment. The total number of crashes reduced on a project is the sum of the crashes reduced, or increased, based upon all the treatments applied in the project. Equation 3 applies to this process as well where i indicates the different crash patterns and j represents the different entities.

References

1. D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt. "Prediction of The Expected Safety Performance of Rural Two-Lane Highways." Federal Highway Administration. Washington, D.C. December 2000