## Combining Crash Reduction Factors for Multiple Countermeasures

**Case 1**: when multiple CRFs can be applied to the same crash type, severity, and area type, the following equation can be used to calculate the Combined Crash Reduction Factors (CCRF) to determine the combined effect for a maximum of three countermeasures:

$CCRF_i = 1 - [(1-CRF1_i)*(1-CRF2_i)*(1-CRF3_i)]$

Where

$CCRF_i$ = the total crash reduction factor for the crash type i in decimal format

$CRF1_i$ = the crash reduction factor for the first countermeasure for the crash type i in decimal format

$CRF2_i$ = the crash reduction factor for the second countermeasure for the crash type i in decimal format

$CRF3_i$ = the crash reduction factor for the second countermeasure for the crash type i in decimal format

**Illustration:** This example illustrates the combination of CRFs for two treatments on a two-lane road segment. Treatment 1 is shoulder widening and treatment 2 is installing shoulder rumble strips. CRFs were identified from the CMF Clearinghouse for the two individual treatments. Total number of baseline crashes on this segment is 10 and both CRFs apply to total crashes.

Shoulder widening CRF1 (total crashes) = 0.14

Install shoulder rumble strips CRF2 (total crashes) = 0.15

The estimated combined CRF from this method is:

Combined CRF = 1 – [(1-CRF1)*(1-CRF2)] = 1-[0.86*0.85] = 0.27

**Case 2** when multiple CRFs can be applied to different crash types or severities, there can be a scenario **where each crash can only be used once for a countermeasure to be applied**.

In this scenario, the following equation can be used to calculate the Combined Crash Reduction Factors (CCRF) to determine the combined effect for a maximum of three countermeasures:

CCRF = [CRF1 *(no of crashes for countermeasure/total number of crashes)] + [CRF2*(no of crashes for countermeasure/total number of crashes)] + [CRF3*(no of crashes for countermeasure/total number of crashes)]

Where

CCRF = the total crash reduction factor

CRF1 = the crash reduction factor for the countermeasure for crash type 1

CRF2 = the crash reduction factor for the countermeasure for crash type 2

CRF3 = the crash reduction factor for the countermeasure for crash type 3

**Illustration:** This example illustrates the combination of CRFs for two treatments on a multi-lane road segment. Treatment 1 is installing shoulder rumble strips and treatment 2 is installing cable median barrier. CRFs were identified from the CMF Clearinghouse for the two individual treatment. Total number of baseline crashes on this segment is 10 of which 4 are run-off-road crashes and 6 are head-on crashes. CRF for treatment 1 applies to mitigate run-off road crashes whereas CRF for treatment 2 applies to mitigate head-on crashes.

Install shoulder rumble strips CRF1 (run-off-road crashes) = 0.15

Install cable median barrier CRF2 (head-on crashes) = 0.44

The estimated combined CRF from this method is:

Combined CRF = [0.15*(4/10)] + [0.44*(6/10)] = 0.32

**Case 3, scenario 1** when multiple CRFs can be applied to different crash types or severities, there can be a scenario **where a crash can be used for multiple countermeasure to be applied**. But one has to consider if the multiple countermeasures are **independent or not**. Two countermeasures are said to be dependent if the implementation of one would have an effect on the safety effectiveness of the other. For example, improving delineation along a curve and increasing the radius of the horizontal curve are countermeasures which both address run-off-road crashes; it is likely that the implementation of one of these two countermeasures would have effect on the safety effectiveness of the others. Engineering judgment is necessary to assess the interrelationships and independence of multiple treatments.

If the countermeasures are **independent,** the same equation mentioned in **Case 2** can be used to determine combined effect of multiple countermeasures.

**Illustration (for independent countermeasures):** This example illustrates the combination of CRFSs for two treatments that are independent at a signalized intersection. Treatment 1 is improving left turn offset to create a positive offset and treatment 2 is adding a three inch yellow retroreflective sheeting to signal backplates. CRFs were identified from the CMF Clearinghouse for the two individual treatment. Total number of baseline crashes at this intersection is 12 of which 5 are left turn crashes and 7 are angle crashes. CRF for treatment 1 applies to mitigate left turn crashes whereas CRF for treatment 2 applies to mitigate both left turn and angle crashes.

Improve left turn offset to create a positive offset CRF1 (left turn crashes) = 0.38

Add a three inch yellow retroreflective sheeting to signal backplates CRF2 (total crashes) = 0.15

The estimated combined CRF from this method is:

Combined CRF = [0.38*(5/12)] + [0.15*(12/12)] = 0.31

**Case 3, scenario 2** when multiple CRFs can be applied to different crash types or severities, there can be a scenario **where a crash can be used for multiple countermeasure to be applied but the countermeasures are not independent of each other.**

If the countermeasures are **not independent,** the following equation can be used to calculate the Combined Crash Reduction Factors (CCRF) to determine the combined effect for multiple countermeasures

$$CCRF = 1 - \frac{[(N - CRF1 * \text{no of crashes for countermeasure}) * (1 - CRF2)]}{N}$$

Where

CCRF = the total crash reduction factor

CRF1 = the crash reduction factor for the countermeasure for crash type 1

CRF2 = the crash reduction factor for the countermeasure for total crashes

N = total number of crashes

**Illustration (for not independent countermeasures):** This example illustrates the combination of CRFs for two treatments on a two-lane road segment. Treatment 1 is installing shoulder rumble strips and treatment 2 is widening shoulder. CRFs were

identified from the CMF Clearinghouse for the two individual treatments. Total number of baseline crashes on this segment is 10 of which 4 crashes are run-off road crashes. CRF for treatment 1 applies to run-off road crashes only and CRF for treatment 2 applies to all crashes.

Install shoulder rumble strips CRF1 (run-off-road crashes) = 0.26

Shoulder widening CRF2 (total crashes) = 0.14

Total number of crashes, N =10

The estimated combined CRF from this method is:

$$\text{Combined CRF} = \text{CCRF} = 1 - \frac{[(10-0.26*4)*(1-0.14)]}{10}$$

$$= 1 - \frac{[(10-1.04)*(1-0.14)]}{10}$$

$$= 0.23$$

If you have any questions on how to apply this guidance, contact Mohammad Shaheed via e-mail at MShaheed@azmag.gov or by phone at (602) 254-6300.