Estimating the Combined Effect of Multiple Countermeasures

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CRASH MODIFICATION FACTORS CLEARINGHOUSE

Questions

- What is the difference between crash modification factors (CMFs) and adjustment factors (AFs)?
- How can you estimate the combined effect of multiple countermeasures?
- What method should you use?
  - Additive, Multiplicative, Other?
- How many CMFs/AFs can you apply?

WHAT IS THE DIFFERENCE BETWEEN A CMF AND AF?

Difference between CMF and AF

Comparison	CMF	AF
Representation	Multiplier ≥ 0	Multiplier ≥ 0
Application	Adjust crash predictions to represent presence (or absence) of a feature compared to a base condition	Adjust crash predictions to represent presence (or absence) of a feature compared to a base condition
Applicability	All crash predictive methods	HSM Part C Predictive Method

HOW TO ESTIMATE COMBINED EFFECT OF MULTIPLE COUNTERMEASURES?

Ideally

Apply a CMF that represents combined effect

Examples of CMFs for Combined Countermeasures	CMF	Star Rating	CMF ID
Install shoulder rumble strips and widen shoulder	0.61	4-star	6665
Install centerline and shoulder rumble strips	0.80	5-star	6850
Install a traffic signal and left turn lanes	0.57	4-star	7967
Install raised median with marked crosswalk	0.54	3-star	175

In an Unideal World

Estimate the combined effect using CMFs that represent individual countermeasure effects

Countermeasure 1	CMF 1	CMF ID	Countermeasure 2	CMF 2	CMF ID	Combined Effect
Install left-turn lane	0.72	260	Improve intersection sight distance	0.63	1638	?
Install two-way-left-turn lane	0.80	2341	Reduce driveway density from 15 to 10 per mile	0.89	2248	?
Install high-visibility crosswalk	0.60	4123	Implement leading pedestrian interval	0.87	9918	?

WHAT METHOD TO USE?

Potential Methods

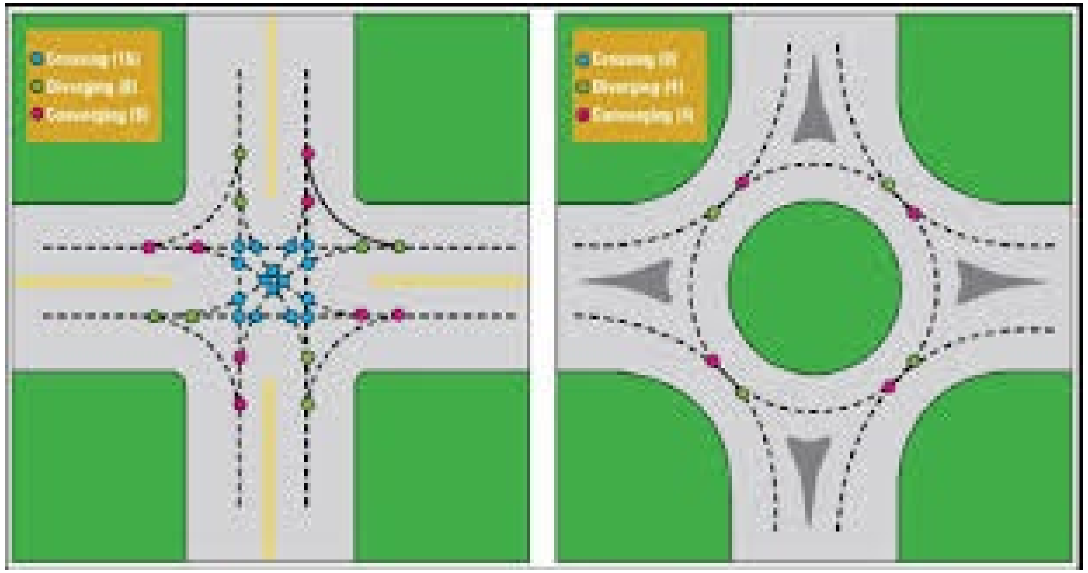
Methods to Estimate Combined Effect of Multiple Countermeasures	
Multiplicative	$\mathbf{CMF_t = CMF_1 * CMF_2}$ *CMF_1 = most effective countermeasure
Additive	$\mathbf{CMF_t = 1 - [(1 - CMF_1) + (1 - CMF_2)]}$ *maximum reduction = 100% (i.e., CMF = 0)
Dominant effect	$\mathbf{CMF_t = CMF_1}$ *only consider countermeasure with smallest CMF
Dominant common residuals	$\mathbf{CMF_t = (CMF_1 * CMF_2)^{CMF_1}}$

Method Selection Process

1. Define scenario of interest
2. Understand limits of combined countermeasure effect
3. Determine potential for overlapping countermeasure effects
4. Categorize magnitude of individual countermeasure effects

1. Define Scenario of Interest

- Countermeasures
- Roadway characteristics
- Traffic volume
- Crash type and severity
- Time of day
- Specific treatment location



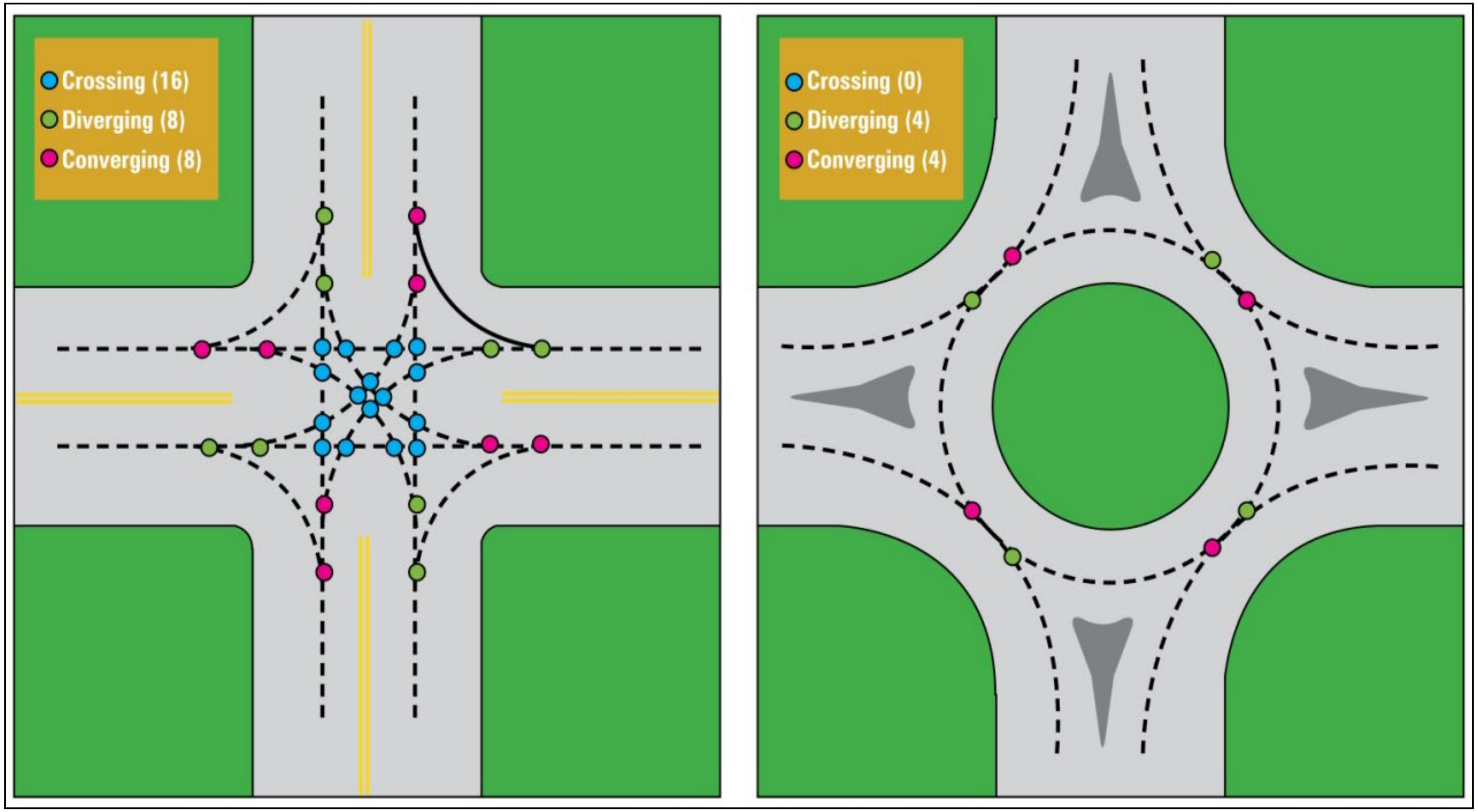
2. Understand Limits of Combined Effect

a) 1+1 = 2	b) 1-1 = 0
c) 1-1-1 = -1	d) 1+1 = 3

3. Determine Potential for Overlapping Effects

- Defined with respect to *target* crashes
  - Represents likelihood that individual countermeasures would address similar crashes
- Different than *applicability* of CMF
  - Reflects crash types used to develop CMF

3. Determine Potential for Overlapping Effects



Convert intersection with minor-road stop control to roundabout	
CMF	0.13
Crash Type	All
Crash Severity	Injury
Area Type	Rural
CMF ID	230

3. Determine Potential for Overlapping Effects

Scenario

- Location: 2-way, stop-controlled intersection
- CM1: install lighting on major road
- CM2: install intersection warning signs on minor road

Question

- Do you think there would be no overlap, some overlap, or complete overlap in the target crashes?

3. Determine Potential for Overlapping Effects

Potential Overlap
Zero Overlap
Complete Overlap
Some Overlap
Enhancing Effects
Counteracting Effects

3. Determine Potential for Overlapping Effects

4. Categorize Magnitude of Individual Effects

Individual Effect	Assigned Magnitude
< 10% change	Small
10 – 25% change	Medium
> 25% change	Large

Select Method to Estimate Combined Effect

*(CMFs apply to **same** crash type and severity)*

Magnitude	Overlap	Method
One or more CMFs > 1.0	Not Applicable	Multiplicative
Both CMFs < 1.0	Zero Overlap or Enhancing Effects	Additive
	Complete Overlap	Dominant effect
	Some Overlap	Dominant effect OR Dominant common residuals; whichever produces greatest reduction (i.e., smallest combined CMF)

Example Application

Countermeasure	CMF	Applicable Crash Type	Applicable Severity	Applicable Facility Type	CMF ID
Install two-way-left-turn lane	0.80	All	All	Rural, 2-lane roads	2341
Reduce driveway density from 15 to 10 driveways per mile	0.89	All	All	All 2-lane roads	2248

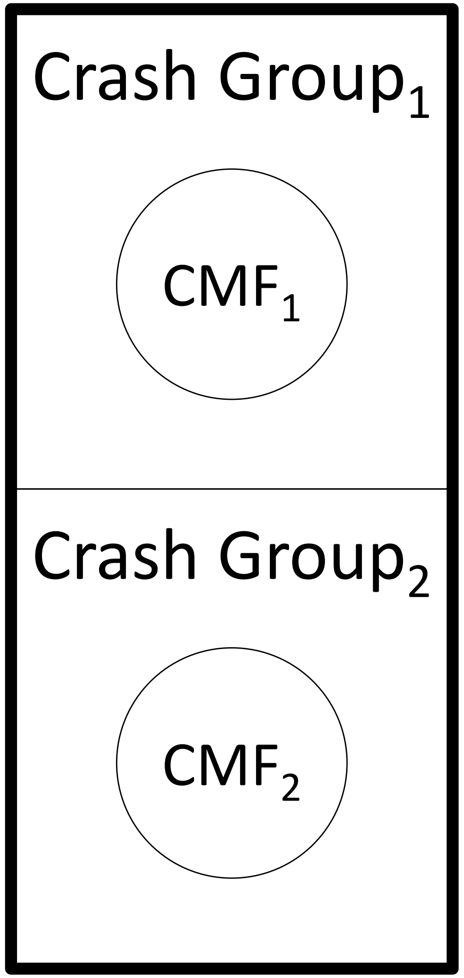
$$\mathrm{CMF_t} = (\mathrm{CMF_1} * \mathrm{CMF_2})^{CMF_1} = (0.80 * 0.89)^{0.80} = 0.76$$

Select Method to Estimate Combined Effect

*(CMFs apply to **different** crash type or severity)*

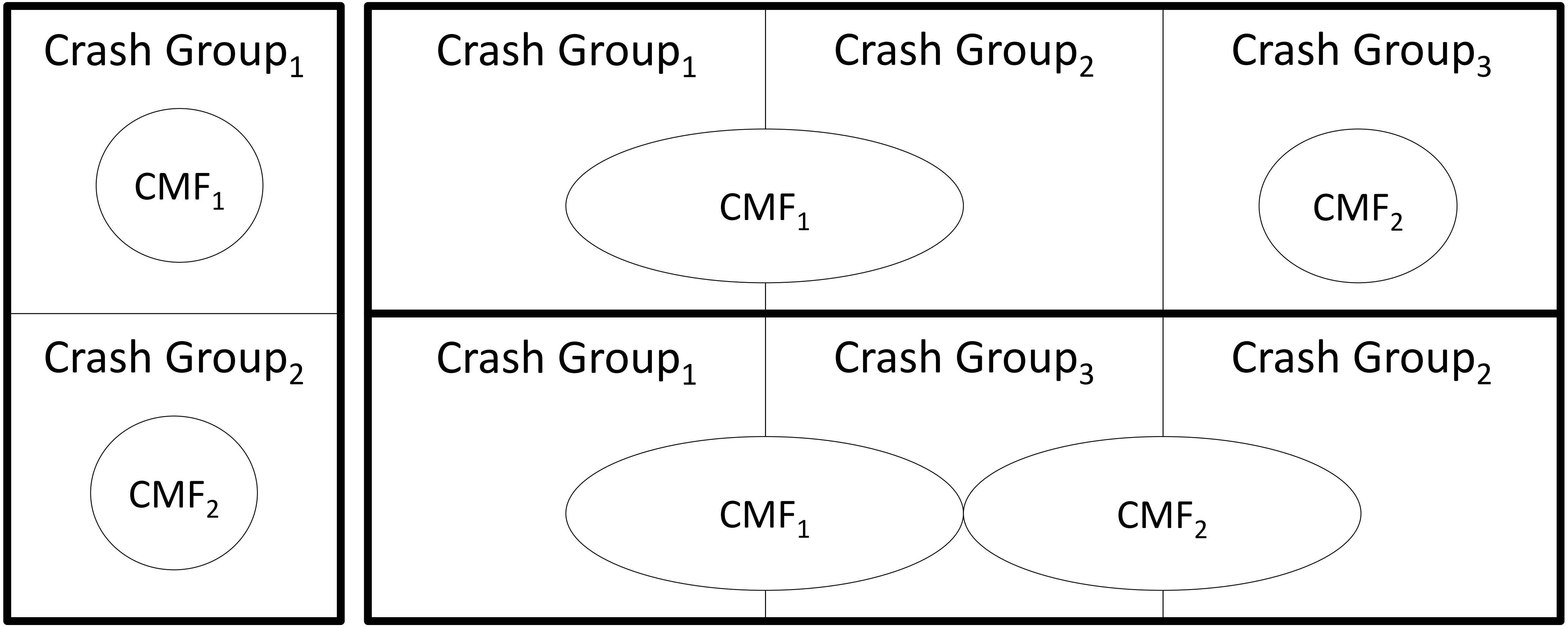
1. Apply smallest CMF to applicable crashes
   – Excluding crashes associated with other CMFs
2. Apply next smallest CMF to applicable crashes
   – Excluding crashes associated with other CMFs
3. *If necessary*, estimate CMF for combined effect and apply it to applicable crashes
4. Sum change in crashes to calculate combined effect
5. Check that estimated change ≤ 100%

Example Application



Total Crashes = X-median + ROR-right + S.S. same direction			
Crashes Without (9 total)	Crash Group 1 (3 X-median)	Crash Group 2 (4 ROR-right)	Crash Group 3 (2 S.S. same)
CMF applicability	X-median crashes	ROR-right crashes	--
CMF1	0.87	--	--
CMF2	--	0.93	--
Crashes With	CMF 1 * C.G. 1 0.87 * 3 = 2.61	CMF 2 * C.G. 2 0.93 * 4 = 3.72	2 S.S. same no CMFs, no change
Difference	3 – 2.61 = 0.39	4 – 3.72 = 0.28	2 – 2 = 0
Combined Countermeasure Effect = 0.39 + 0.28 + 0 = 0.67 Confirm this is ≤ Total Crashes (**0.67 < 9; confirmed!**)			

Example Application



HOW MANY CMFs/AFs CAN YOU APPLY?

How Many CMFs/AFs?

- AFs: unlimited
- CMFs: depends (2 to 3)

WRAP UP

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Resources

- Selecting a Method to Analyze Multiple CMFs
  - https://www.youtube.com/watch?v=OPvAjUpT6Dg&t=219s
- Applying a Method to Analyze Multiple CMFs
  - https://www.youtube.com/watch?v=48M7TBKTCM0&t=244s
- Investigation of Existing and Alternative Methods for Combining Multiple CMFs
  - https://cmfclearinghouse.fhwa.dot.gov/collateral/Combining_Multiple_CMFs_Final.pdf

Questions

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