Overview of CMF Guidebook

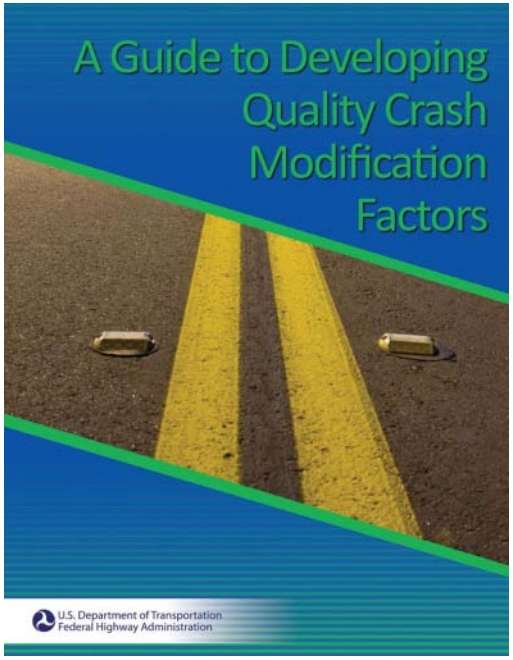
A Guide for Developing Quality CMFs

TRB International Workshop on CMFs

January 23, 2011

Objective

- Provide overview of guidebook
- Identify various methods for developing CMFs
- Set stage for afternoon
  - Issues with various methods



Overview of Guidebook

Intent – provide direction to agencies interested in developing CMFs

Audience – transportation safety practitioners, consultants, and researchers

Overview of Guidebook

Prerequisites – experience and/or education in the theory and practice of:

- Road safety engineering
- Basic analytical procedures
- Statistical concepts

Overview of Guidebook

Content

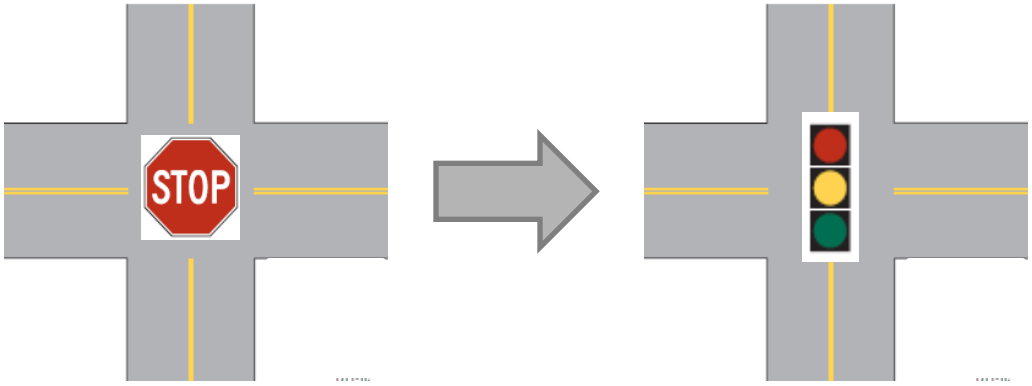
- Background on CMFs
  - Definitions, purpose, application, general issues
- Study Designs
  - Overview, sample size considerations, and strengths and weaknesses
- Resources
  - Identify appropriate analysis method
  - Improving completeness/consistency in reporting

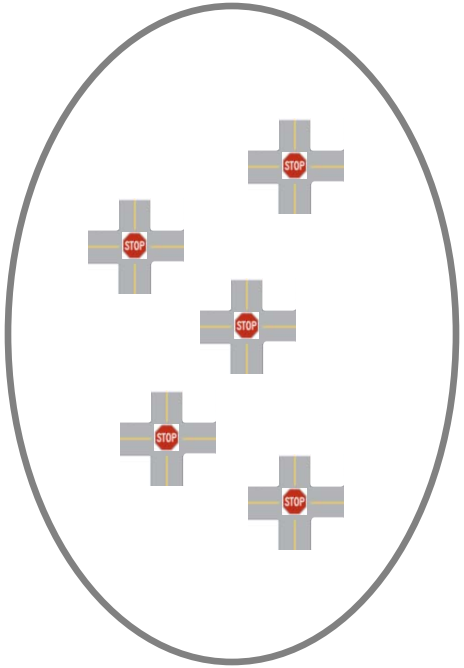
Methods

- Before-After
  - Comparison Group
  - Empirical Bayes
  - Full Bayes
- Cross-Sectional
- Case-Control
- Cohort
- Alternative Approaches

Before-After – Comparison Group

- Account for changes in crashes unrelated to the treatment
  - Time trends
  - Traffic volume changes

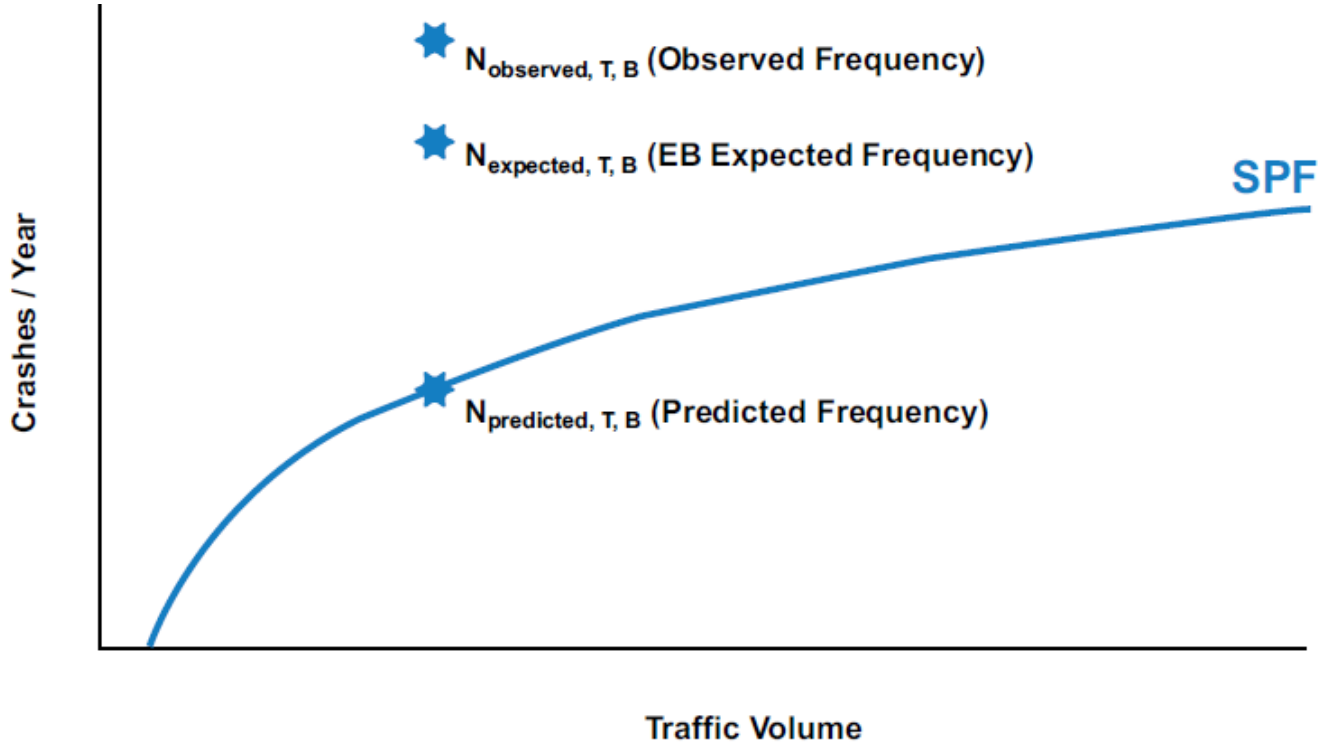




Time Period	Treatment Group	Comparison Group
Before	$N_{observed,T,B}$	$N_{observed,C,B}$
After	$N_{observed,T,A}$	$N_{observed,C,A}$

Before-After – Empirical Bayes

- EB approach properly accounts for changes in crashes due to:
  - Regression-to-the-mean
  - Better accounts for traffic volume and time trends



Before-After – Full Bayes

- Not a type of evaluation study on its own
  - Modeling technique
  - Similar to generalized linear modeling procedure
  - Used to develop estimates of expected crashes
  - Can be used in before-after and development of cross-sectional models
- Before-After
  - Reference group is used similar to EB
  - Distribution is used instead of point estimate
    - Combined with observed crashes
    - Estimate expected crash frequency, variance, and variance of estimated CMF

Before-After – Full Bayes

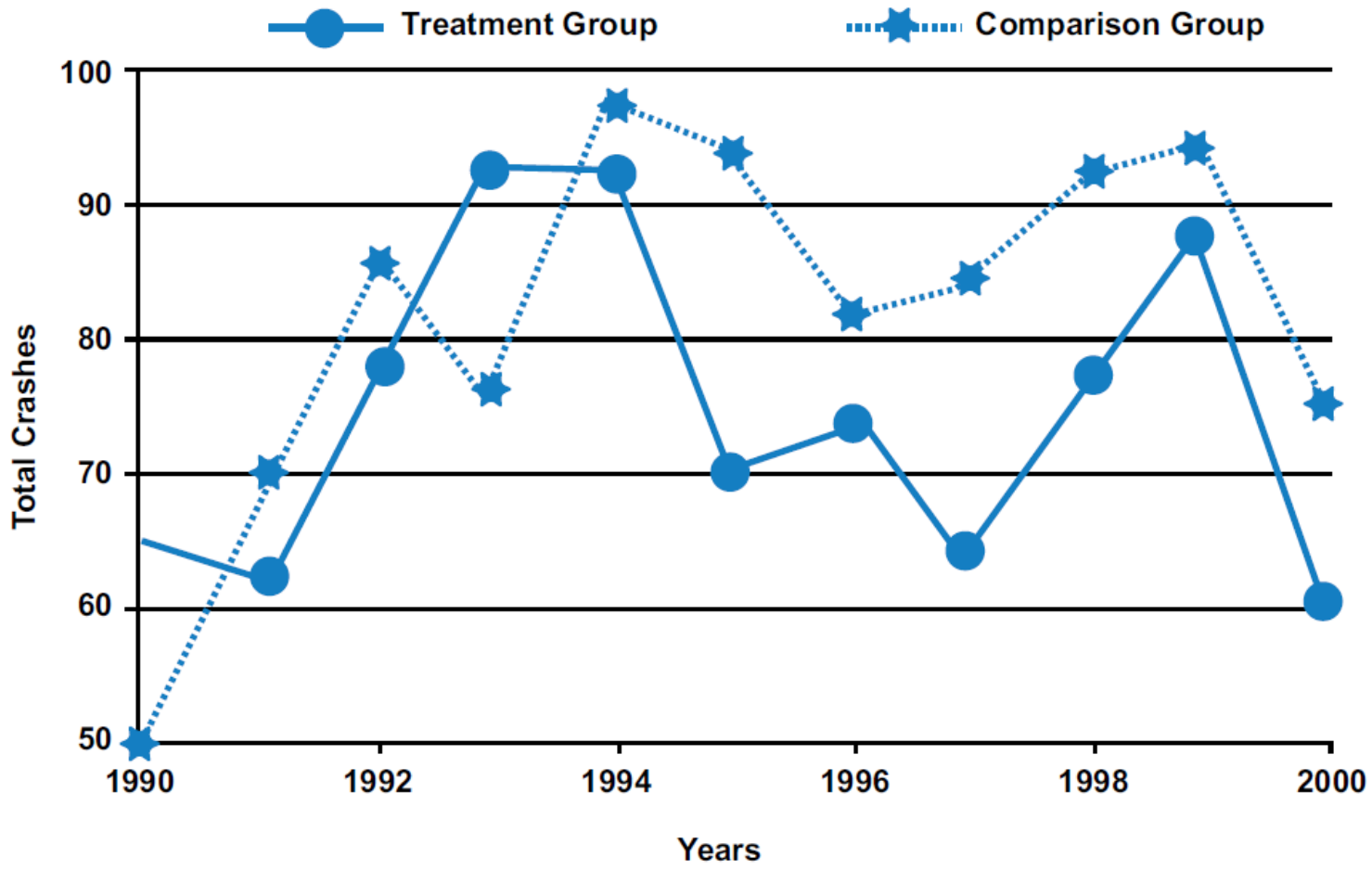
- Cross-sectional
  - Applied similar to generalized linear regression to relate:
    - Geometric characteristics
    - Operational characteristics
    - Expected crash experience
  - More flexible modeling tool
    - Allows for complex model forms
    - Estimation of valid models with small sample size
    - Ability to consider spatial correlation
    - Opportunity to incorporate prior knowledge

Before-After – General Issues

- Observed change in crashes may be due to other factors
  - Traffic volume changes
  - Changes in reported crash experience
  - Regression-to-the-mean
  - Other improvements

Before-After – Comparison Group Issues

- Requires suitable comparison group



Before-After – Comparison Group Issues

- Difficult to account for RTM
  - Must match treatment and comparison sites based on crash occurrence
- Difficult to confirm RTM is not an issue
  - Crash frequency not considered in site selection
    - Blanket treatment
    - Truly random selection of sites for treatment
    - Safety evaluation is related to operational improvement

Before-After – Empirical Bayes Issues

- More complex than comparison group
- Identification of suitable reference group
  - Spillover
    - Treatment may affect the logical reference group
    - E.g., Red light camera programs

Before-After – Full Bayes Issues

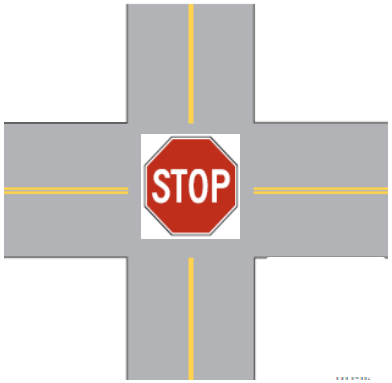
- More complex than empirical Bayes method
  - Requires high level of statistical training
- Software developed for application of empirical Bayes method
  - Seems to be difficult for the full Bayes method

Cross-Sectional

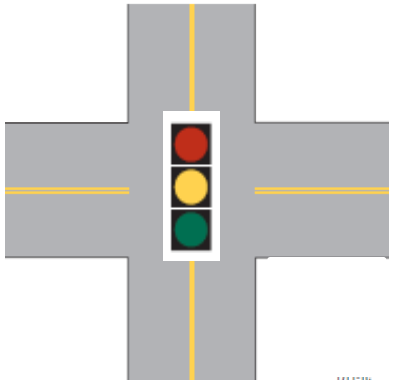
- Compare with and without rather than before and after
- Useful for estimating CMFs where there are insufficient instances of actual treatments
  - Several instances of sites with and without, but few changed from before to after
  - E.g., Compare 4-ft shoulder to 6-ft shoulder
    - Few projects where the shoulder is widened from 4 to 6 feet
    - Many segments with 4-ft shoulders and many with 6-ft shoulders

Cross-Sectional

- Question:
  - What are the safety effects of signalization?
- Scenario
  - 100 two-way stop-controlled intersections
  - 100 signalized intersections
  - Rural, 4-legged with similar traffic volumes



$$CMF = \frac{2.9}{3.4} = 0.85$$



3.4 crashes/year

2.9 crashes/year

Cross-Sectional Issues

- Comparison is between two distinct groups
  - Difference in crashes can be due to other factors (both known and unknown)
- Difficult to properly account for unknown, or known but unmeasured, factors
- Control for known factors through multiple variable regression
  - Science of assembling CMFs from multiple variable models is not fully developed
  - Inappropriate functional form, omitted variable bias, or correlation of variables

Case-Control

- Select sites based on outcome status and then determine prior treatment status
- Assess whether exposure to treatment is disproportionately distributed
  - Estimate odds ratio
  - Indicates likelihood of actual benefit

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

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

Case-Control Issues

- Cannot be used to determine relative risk
  - Indicates likelihood of outcome given presence of specific feature
- Cannot demonstrate causality
  - No time sequence of events
- Does not recognize differences between locations with multiple crashes

Cohort

- Select sites based on treatment status and then determine outcome status over time
- Assess whether exposure (time until event) is disproportionate between cohorts
  - Estimate relative risk
  - Direct estimate of CMF

Cohort	Outcomes	Non-Outcomes	Total At-Risk
With	A	B	A + B
Without	C	D	C + D

$$Relative\ Risk = CMF = \frac{A/(A+B)}{C/(C+D)}$$

Cohort Issues

- Large samples are often required
  - Relatively expensive
- Site characteristics are subject to change
  - Particularly for lengthy study periods
- Does not recognize differences between locations with multiple crashes

Alternative Approaches

- Meta-analysis
  - Aggregate analysis of past research
  - Systematically combine knowledge on CMFs
- Expert panels
  - Critically evaluate findings of published and unpublished research
  - Derive CMFs through consensus
- Surrogates
  - Derive a CMF indirectly using data other than crash data
    - E.g., vehicle speeds, traffic conflicts, etc

Surrogate Example

Mean Pre-Treatment Speed (mph)	Speed Reduction (mph)				
	5	4	3	2	1
45	0.70	0.76	0.82	0.88	0.94
50	0.73	0.79	0.84	0.89	0.95
55	0.76	0.81	0.86	0.90	0.95
60	0.78	0.82	0.87	0.91	0.96

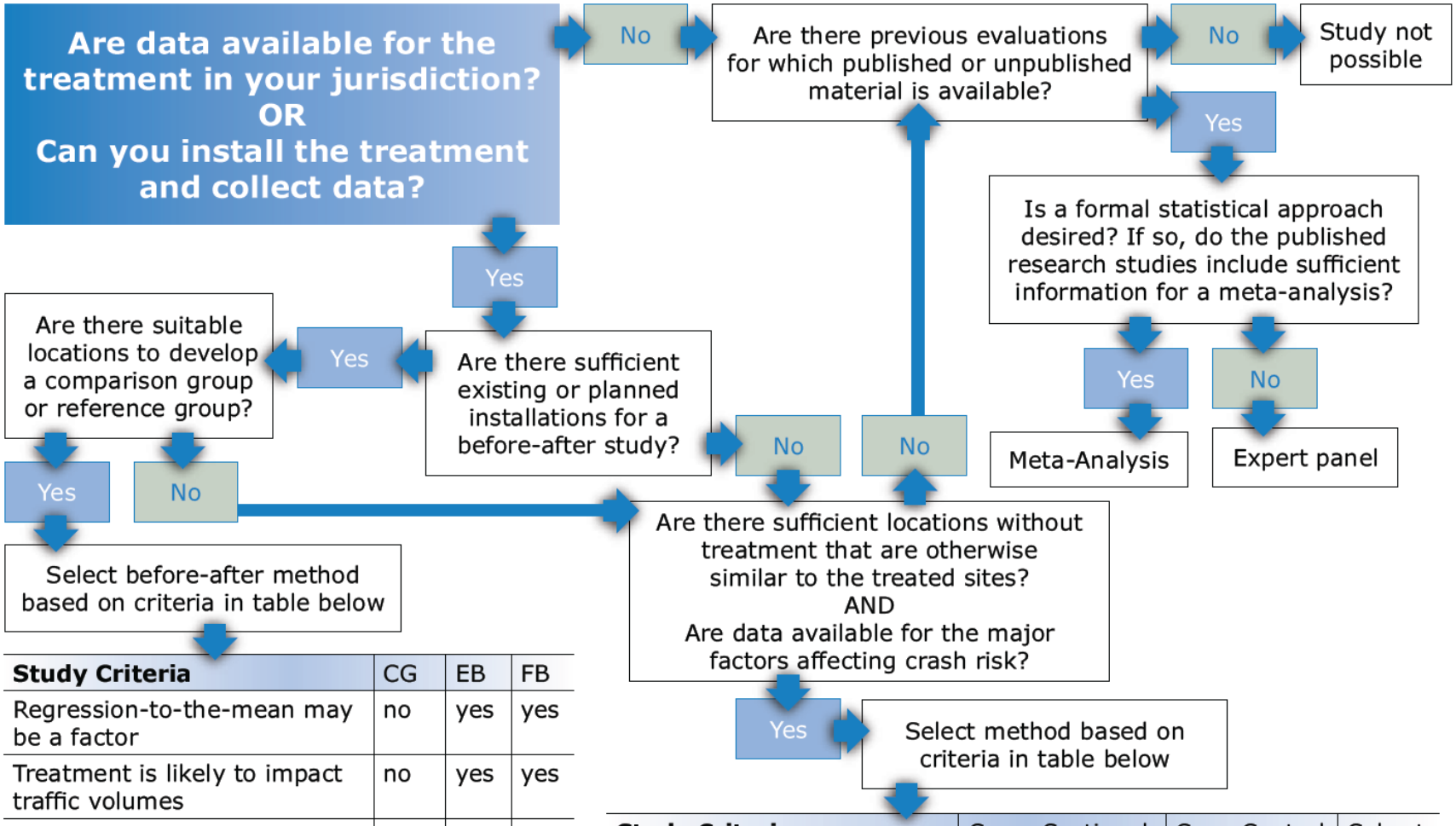
NCHRP Report 617

Alternative Approaches Issues

- Meta-analysis
  - Ensure all studies used are of sufficient quality
  - Sensitivity and publication bias
- Expert panels
  - Informal (based on expert consensus)
  - Difficult to derive estimates of uncertainty
- Surrogates
  - Need to establish relationship between surrogate and crashes

Which Method is Preferred?

- Before-after
  - Comparison group
  - Empirical Bayes
  - Full Bayes
- Cross-sectional
- Case-control
- Cohort
- Alternative methods
- **It depends!**



Study Criteria	CG	EB	FB
Regression-to-the-mean may be a factor	no	yes	yes
Treatment is likely to impact traffic volumes	no	yes	yes
Include spatial correlation (either among treated sites or among treated and comparison or reference sites)	no	no	yes
A complex model form is required	no	no	yes
Include prior knowledge of model or CMF estimates in the analysis	no	no	yes

Study Criteria	Cross-Sectional	Case-Control	Cohort
Crash type is rare	no	yes	no
Treatment is rare	no	no	yes
Accounts for locations with multiple crashes (rather than first occurrence)	yes	no	no
CMFunction desired	yes	no	no

Scenario 1

- Jurisdiction implemented a 1.5 second all-red phase at 16 traffic signals in CBD
  - Blanket treatment
  - All 4-legged intersections
  - No other signalized intersections in vicinity
  - Several 2-way stop-controlled intersections along same two routes
  - Reasonable to believe that treatment does not impact safety at stop-controlled intersections
- **Before-after with comparison group**

Scenario 2

- Jurisdiction converted 2-way stop-controlled intersections to roundabouts
  - Suspected that safety benefits in this jurisdiction may be less than those found elsewhere
  - No new roundabout conversions until further study
  - Data will be used only from this jurisdiction
  - Limited before-after data exist for 10 conversions
  - All converted sites have similar characteristics
  - Large pool of 2-way stop-controlled intersections that have not been converted
  - Conversion is likely to change traffic volumes
- **Empirical Bayes Before-After**

Scenario 3

- Need to estimate CMF for flattening horizontal curves on rural, 2-lane roads
  - Agency's crash data system has been updated Only latest 5 years of crash data are available
  - Few curves have undergone reconstruction and many were completed > 5 years ago
  - Data for 350 curves on rural, 2-lane roads
  - Data available for curve radii as well as other geometric and traffic volume data
- **Cross-sectional**

Scenario 4

- Develop CMF for increasing paved shoulder width on 2-lane rural roads
  - Several miles with narrow or no paved shoulders
  - Several more miles with 3 – 4 foot shoulders
  - Do not intend to implement treatment unless it is cost-effective to address run-off-road crashes
  - High frequency of ROR crashes, but spread-out over the network
    - Several segments with no crashes over 3 years
    - Several segments have only 1 or 2 crashes
  - Geometric and traffic volume data are available to control for factors other than the treatment
- **Case-Control**

Scenario 5

- Consider previous scenario, but now focus on mountainous regions instead of all 2-lane, rural roads
  - Crashes more prevalent in mountainous regions
  - Most segments experience at least 1 crash/year
  - Fewer miles for analysis
  - Do not intend to implement treatment unless it is cost-effective to address run-off-road crashes
  - Geometric and traffic volume data are available to control for factors other than the treatment
- **Cohort**

Resources

- Annotated outline
  - Improve completeness/consistency in reporting
- User must determine quality of CMF
  - Need complete and consistent information
- Highway Safety Manual and CMF Clearinghouse assess quality of CMFs
  - Need complete and consistent information

Resources – Relative Quality of CMFs

Relative Rating	Excellent	Poor
Study Design	Statistically rigorous study design with reference group or randomized experiment and control	Simple before / after study
Sample Size	Large sample, multiple years, diversity of sites	Limited homogeneous sample
Standard Error	Small compared to CRF	Large SE and confidence interval includes zero
Potential Bias	Controls for all sources of known potential bias	No consideration of potential bias
Data Source	Diversity in States representing different geographies	Limited to one jurisdiction in one State

Resources – Outline

- Objective
  - Identify treatment of interest
  - Discuss reason for conducting study
  - Identify target crash types and severities
- Background
  - Describe treatment of interest
- Literature Review
  - Summary of recent and salient literature

Resources – Outline

- Methodology
  - Discuss method used to develop CMF
    - Reason for selecting method
    - Strengths and weaknesses
  - Identify potential sources of bias
    - How these biases are addressed
    - Those that cannot be addressed

Resources – Outline

- Data
  - Data source(s)
  - Years of data
  - Number of sites (and/or miles if applicable)
  - Summary statistics
    - Average crashes per year
    - Annual, average, min, and max traffic volume
  - Applicability of CMFs

Resources – Outline

- Results
  - Present CMF(s)
  - Standard error of CMF
    - Calculate confidence interval
    - Judge quality and significance of results

Contact

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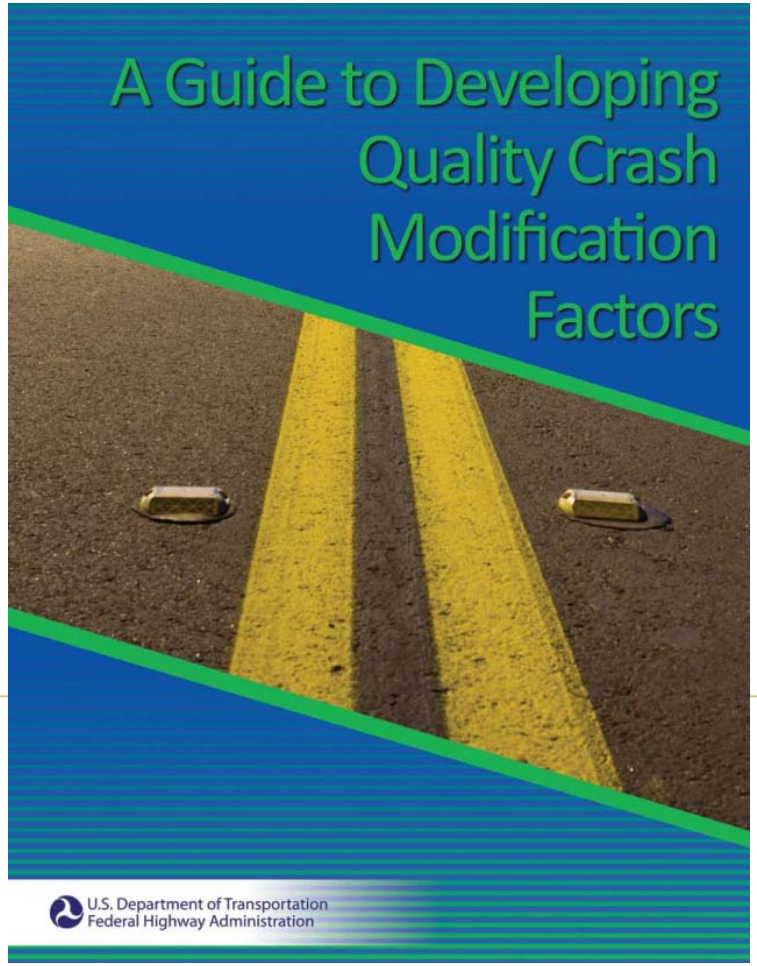

- Who covers general issues?
  - John, Frank, or Bhagwant?
- **Applying Multiple CMFs**
- **CMFs Derived From High Crash Locations**
- **Considerations Related to Before-After and Cross-Sectional Designs**
- **Factors Affecting the Quality of CMFs**