Developing CMFs

Study Types and Potential Biases

Frank Gross

VHB

Three Objectives

1. Explain difference between before-after and cross-sectional studies
2. Identify potential biases related to before-after study designs
3. Identify potential biases related to cross-sectional study designs

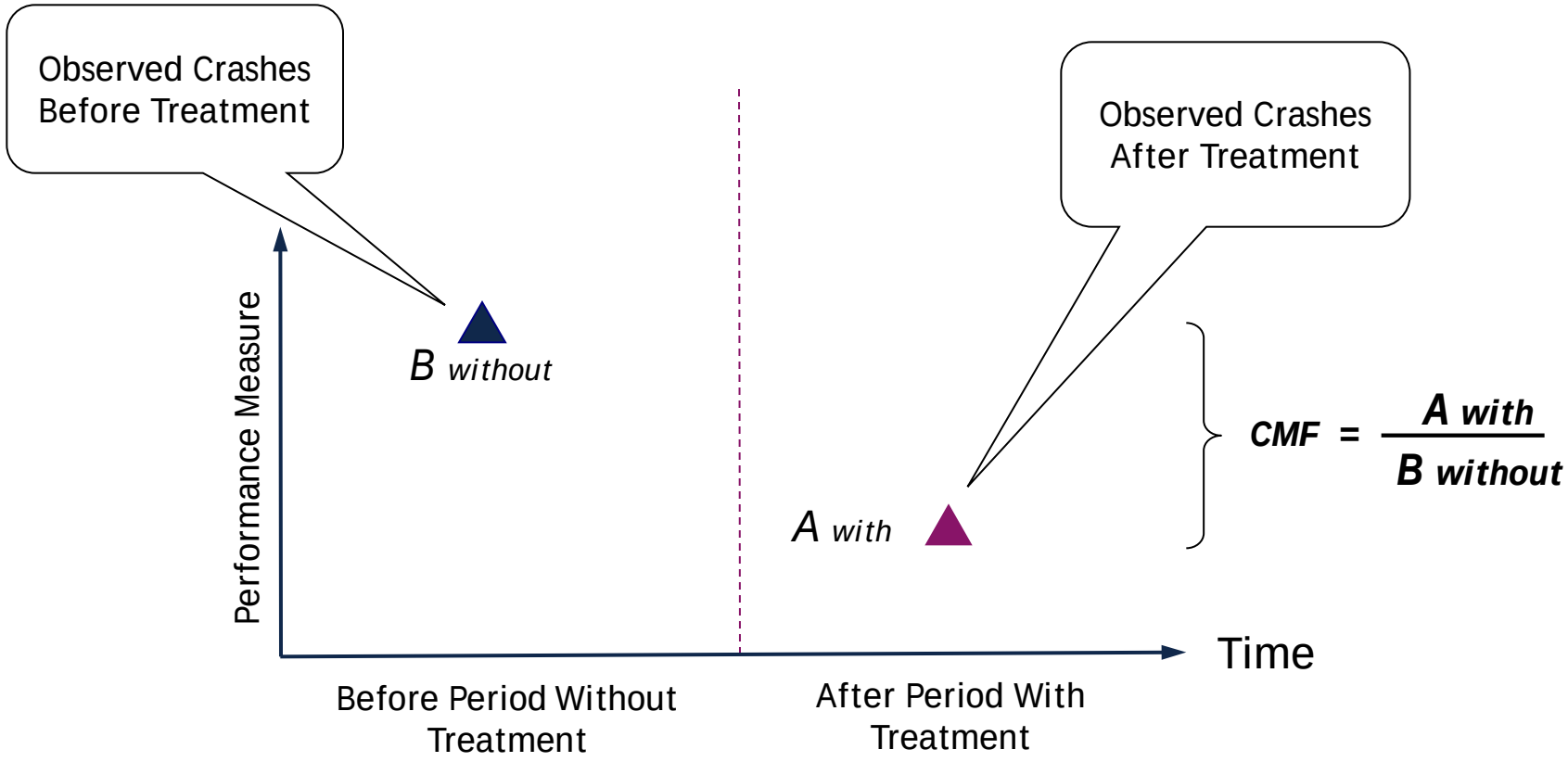
Overview of Before-After and Cross-Sectional Studies

Before-After vs. Cross-Sectional

Before-After Studies

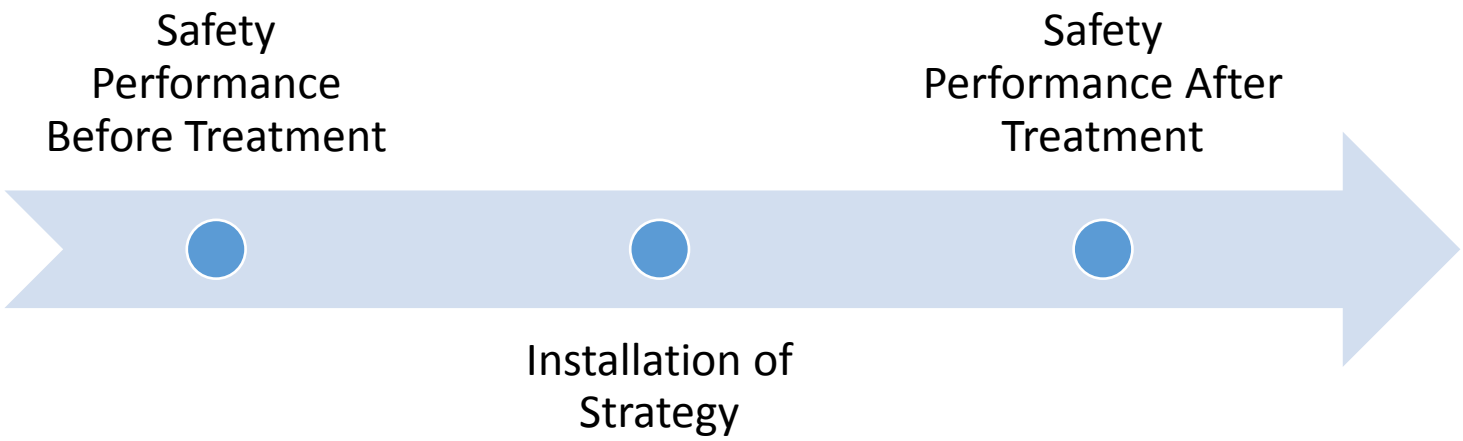
- Comparison of safety performance of site(s) before and after the application of a treatment

Before-After Studies



Strengths of Before-After Studies

- Primary benefit is time series of events
  - Definite change before and after treatment



Limitations of Before-After Studies

- Changes other than treatment of interest
  - Traffic volume
  - Temporal trends (weather, crash reporting, etc.)
- Identifying sufficient treatment sites
  - Prevalence of strategy
  - Records of location and installation date

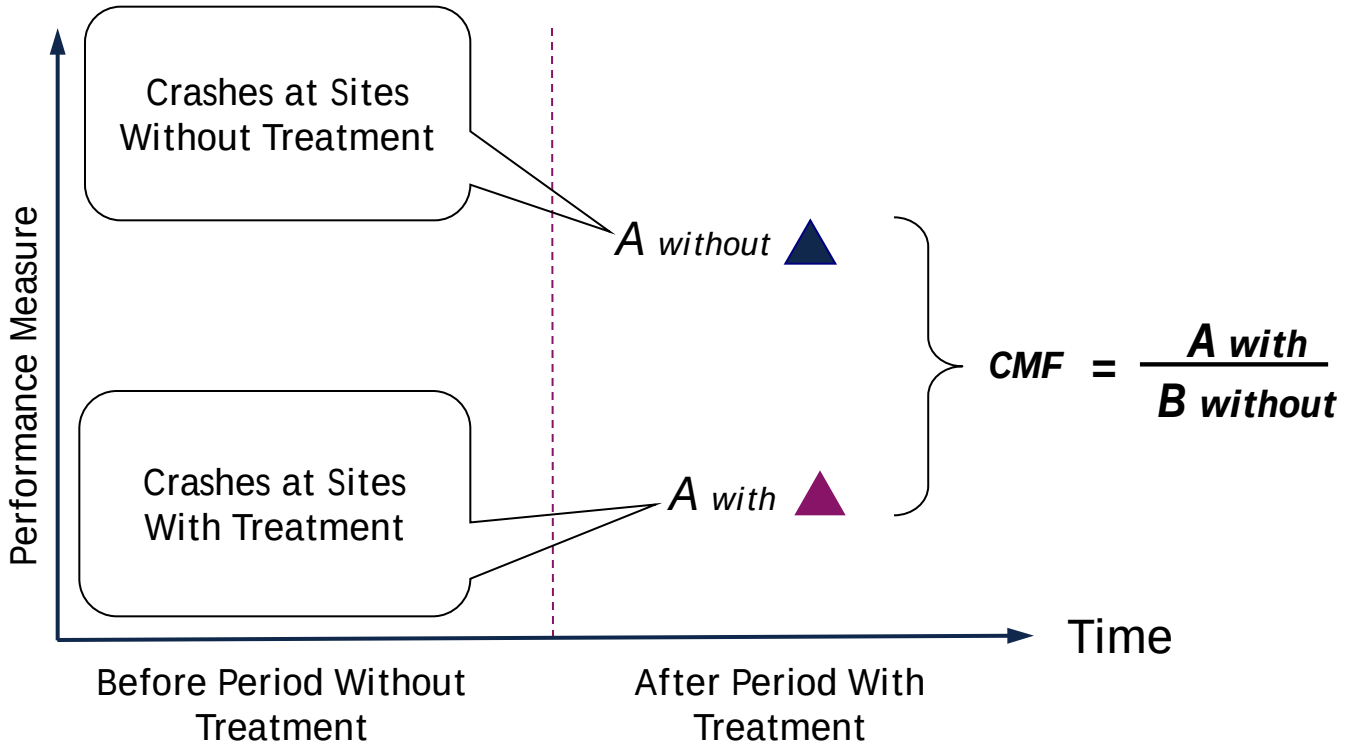
Cross-Sectional Studies

- Comparison of the safety performance of sites with and without a treatment during the same time period.

Site 1: No centerline or chevron treatment

Site 2: Centerline and chevron treatment

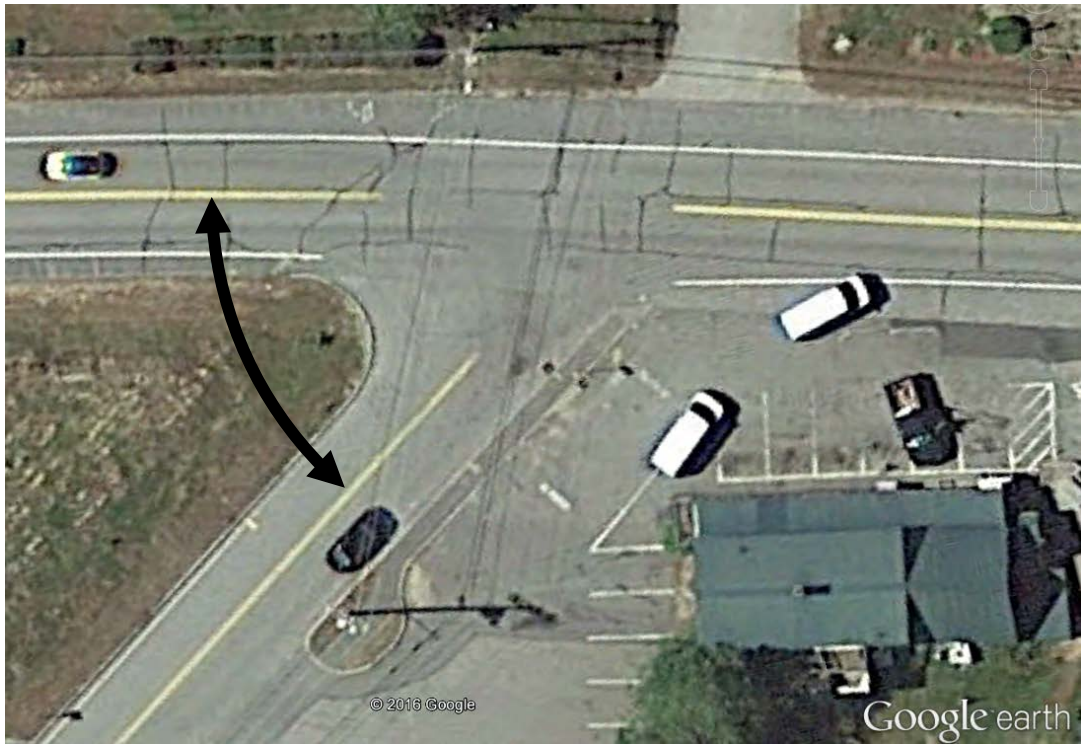
Cross-Sectional Studies



$$CMF = \frac{A\ with}{B\ without}$$

Strengths of Cross-Sectional Studies

- Before-after studies not always possible
- No actual treatment required



Limitations of Cross-Sectional Studies

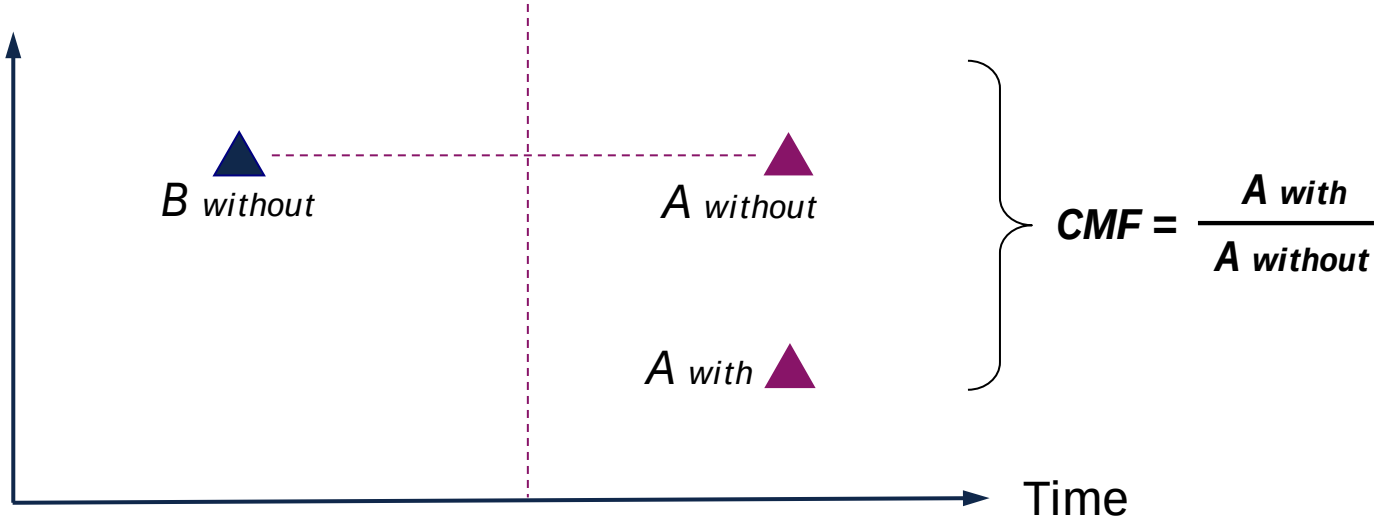
- Comparison between two distinct groups
- Need to account for differences between groups
  - Geometric and traffic characteristics
  - Reason for treatment
  - Driver demographics
  - Weather patterns

Potential Biases

Before-After vs. Cross-Sectional

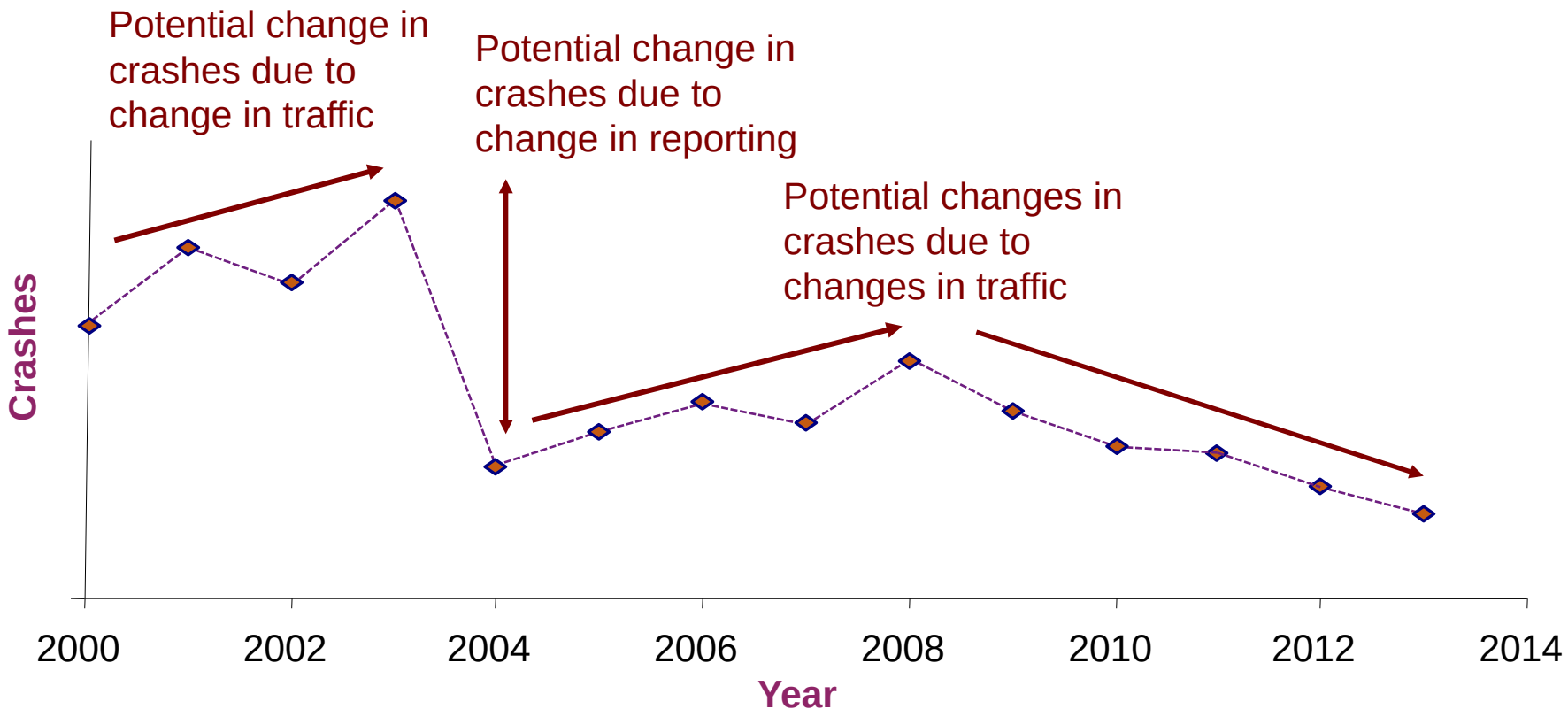
Potential Biases: Before-After Studies

- Changes over time
  - Traffic, crash reporting, weather, drivers, vehicles
- Statistical issues
  - Regression-to-the-mean
  - Suitability of comparison or reference group
- Regional differences



Changes Over Time Impact Crash Frequency

- Traffic, crash reporting, weather, drivers, vehicles

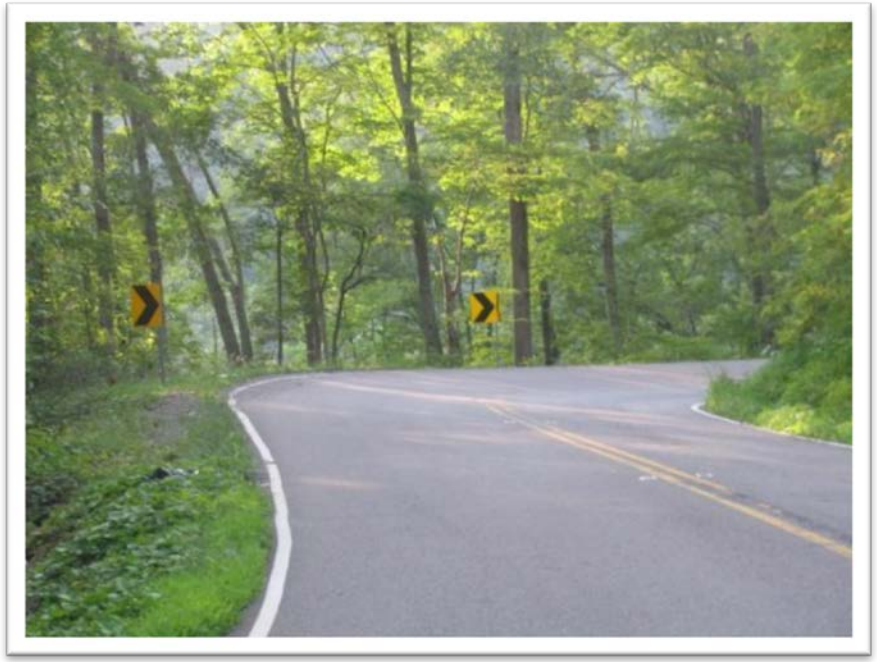


Regression-to-the-Mean

- Random variation in crashes over time

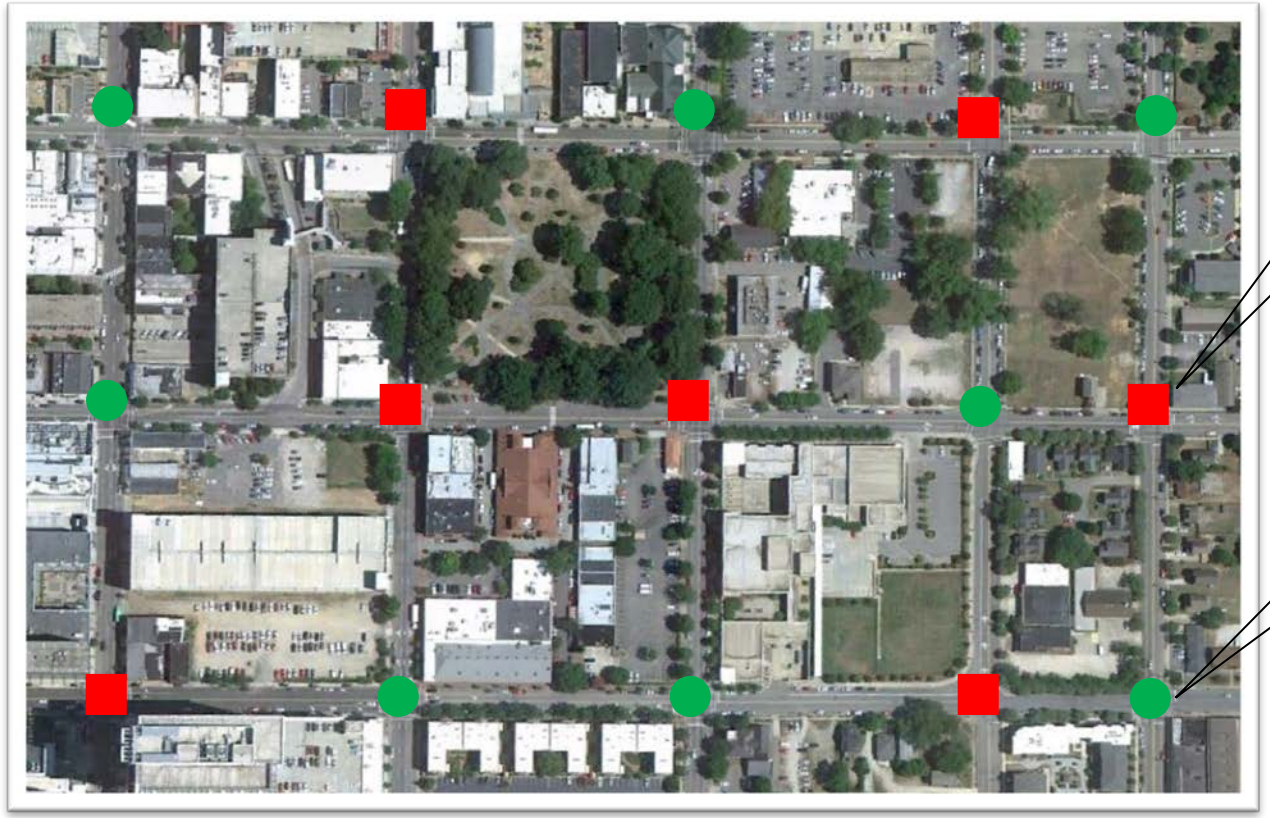
Suitability of Comparison or Reference Group

- Similar characteristics to treatment group
- Same before and after periods
- Safety performance NOT affected by treatment



Suitability of Comparison or Reference Group

- Potential spillover effects

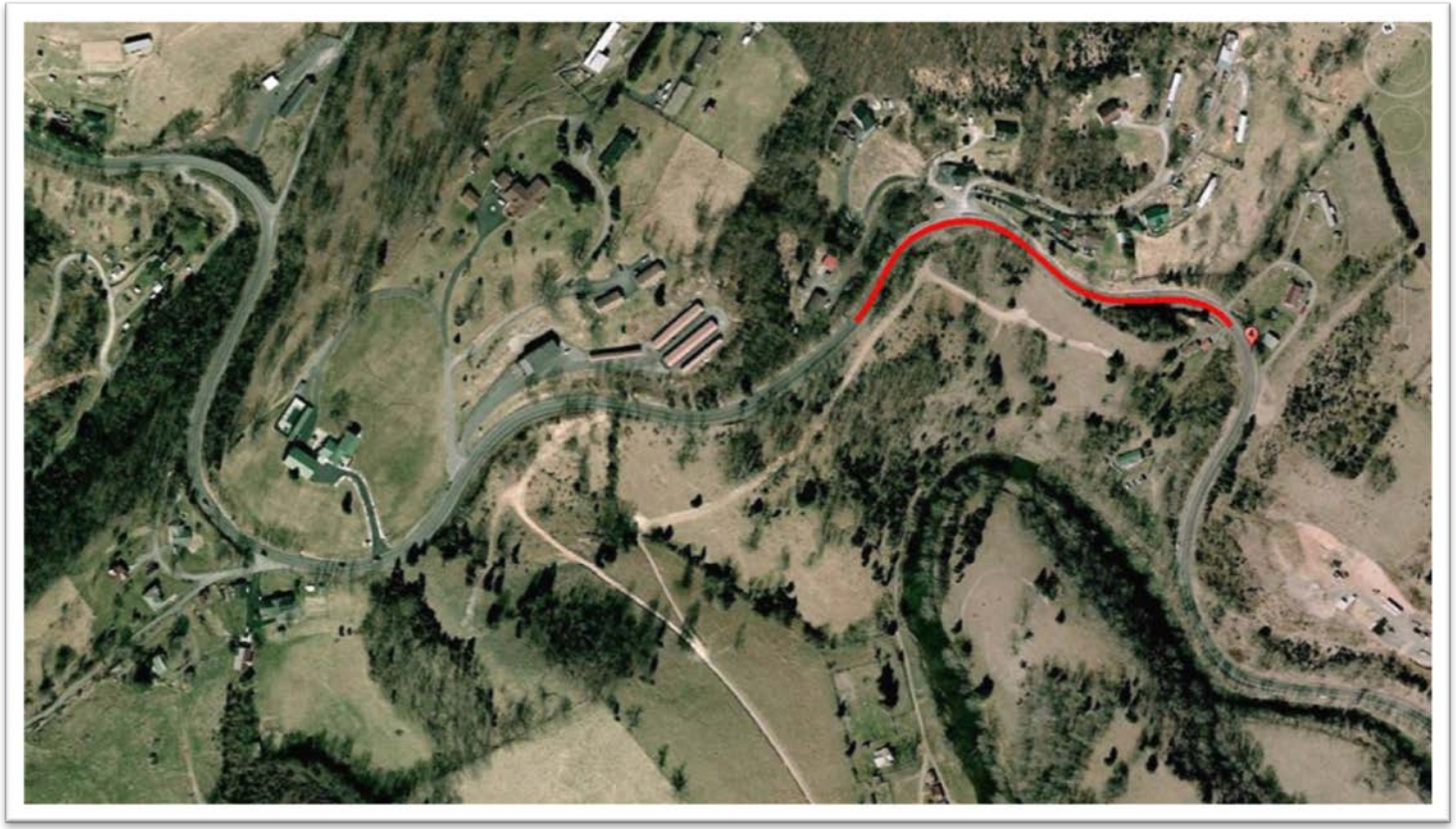


Red Light Running Camera

Normal Signalized Intersection

Suitability of Comparison or Reference Group

- Potential crash migration

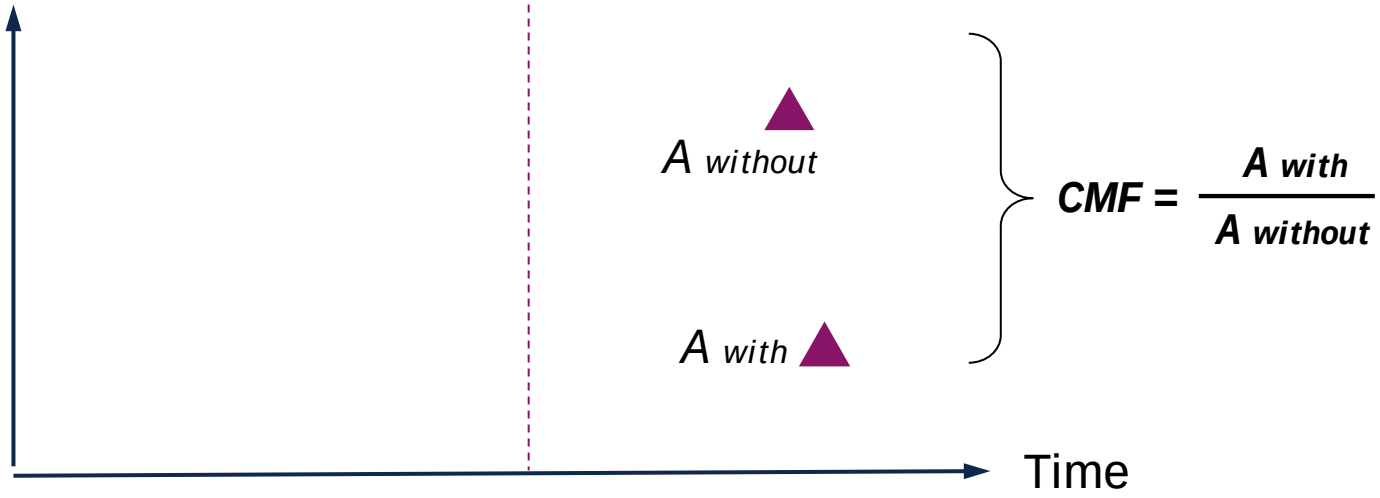


Regional Differences Impact Safety Performance

- Safety culture, climate, topography

Potential Biases: Cross-Sectional Studies

- Differences among sites
- Statistical issues
  - Inappropriate functional form
  - Omitted variable bias
  - Correlated and confounding variables



Differences Among Sites

- Regression-based models
  - Account for geometric, operational, and regional differences

$$Crash\ Frequency = majAADT^{\beta_1} * minAADT^{\beta_2} * ISD^{\beta_3} * exp(Constant + C_1X_1 + \cdots + C_nX_n)$$

$majAADT$ = major road annual average daily traffic

$minAADT$ = minor road annual average daily traffic

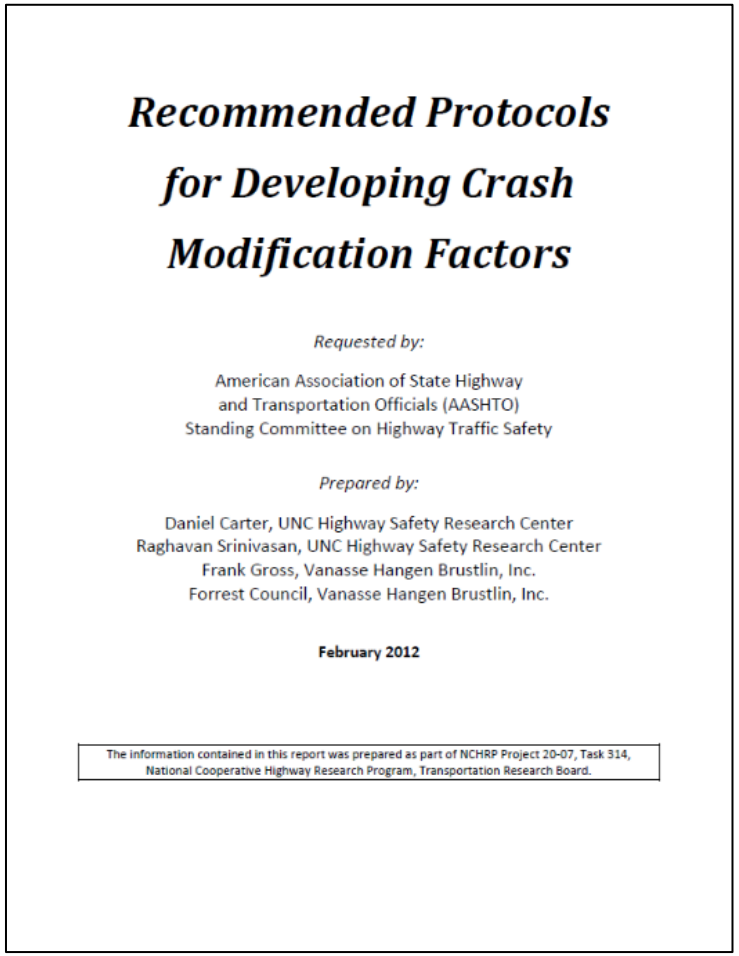
ISD = available ISD

X_i = vector of geometric, operational, and regional characteristics

$Constant$, β_i, C_i= Parameters estimated in the modeling process

Statistical Issues

- Inappropriate Functional Form
  - Over-fitting prediction models
  - Low sample mean and small sample size
  - Aggregated, averaged, or incomplete data
  - Misspecification of error structure



Recommended Protocols for Developing Crash Modification Factors

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)
Standing Committee on Highway Traffic Safety

Prepared by:

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February 2012

The information contained in this report was prepared as part of NCHRP Project 20-07, Task 314, National Cooperative Highway Research Program, Transportation Research Board.

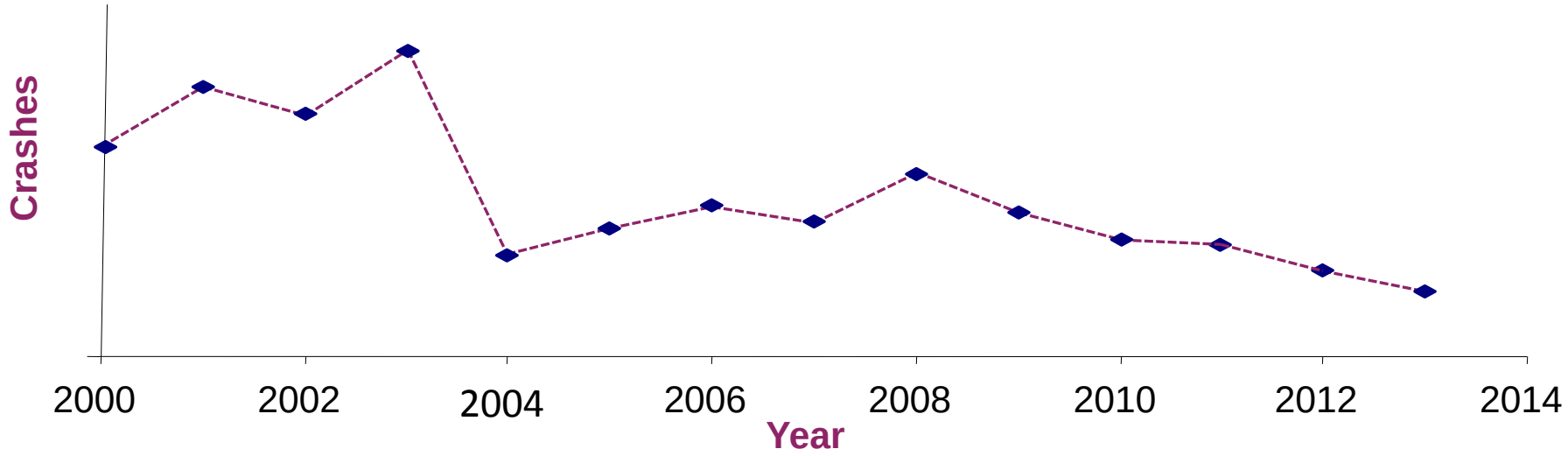
(http://www.cmfclearinghouse.org/collateral/CMF_Protocols.pdf)

Statistical Issues

- Omitted variable bias
- Correlation and confounding
- Example: Estimate CMF for Chevrons
  - Sample curves with and without chevrons
  - Analysis fails to account for roadside hazards
  - Curves with chevrons have more severe roadside hazards
  - Conclude chevrons increase crash severity

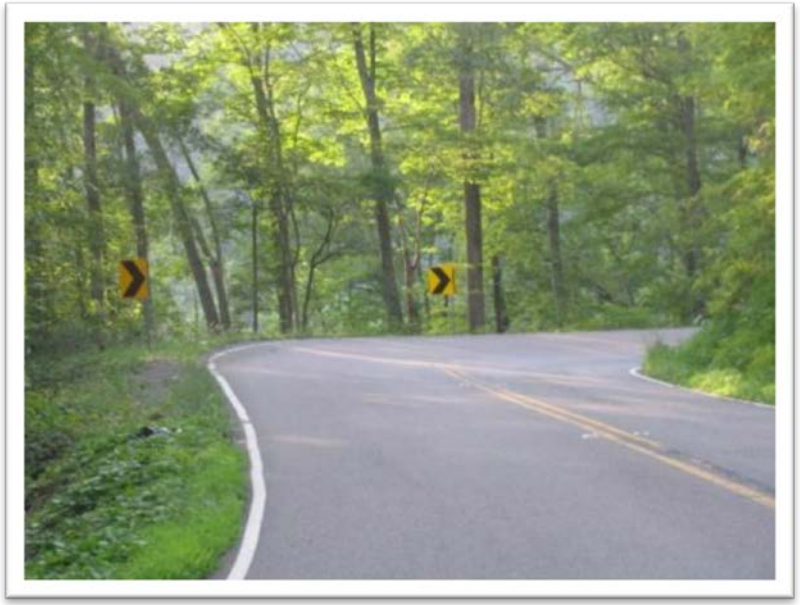
Review

- What are potential biases related to **Before-After Studies**?
  - Changes over time (traffic, crash reporting, etc.)
  - Statistical issues (RTM, suitability of comparison or reference group)
  - Regional differences

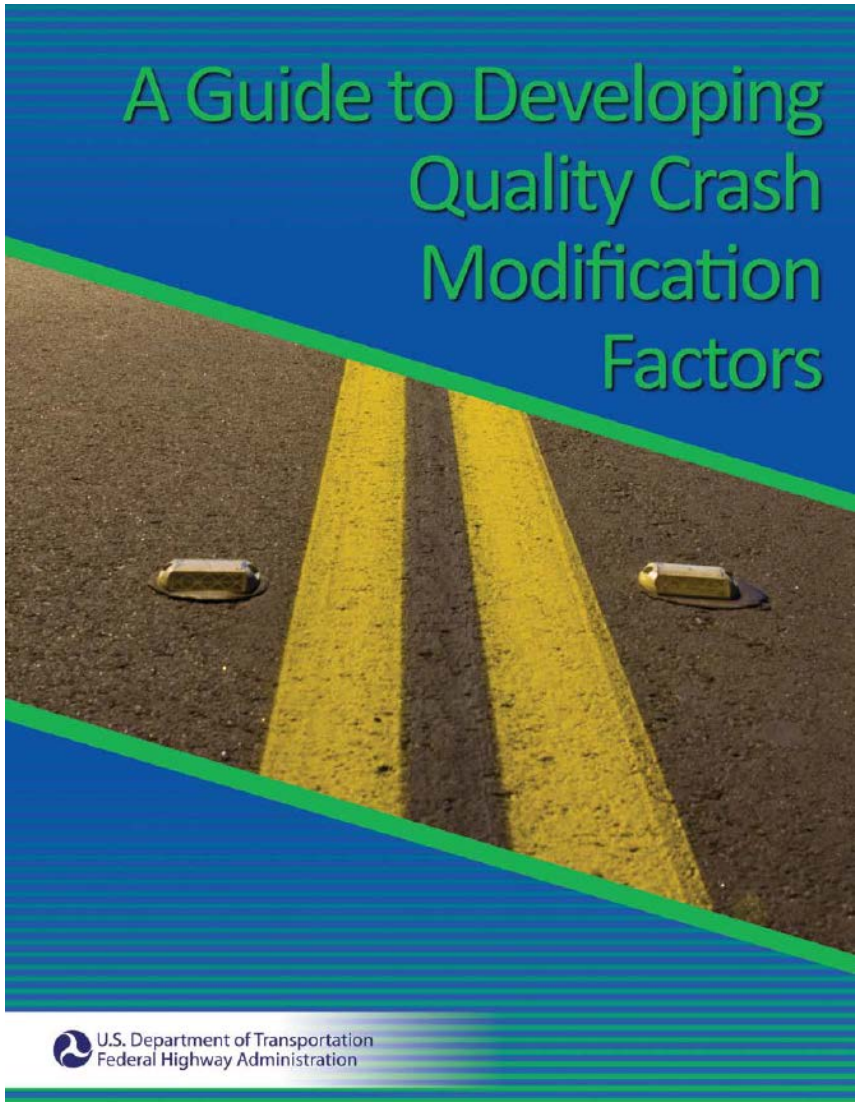


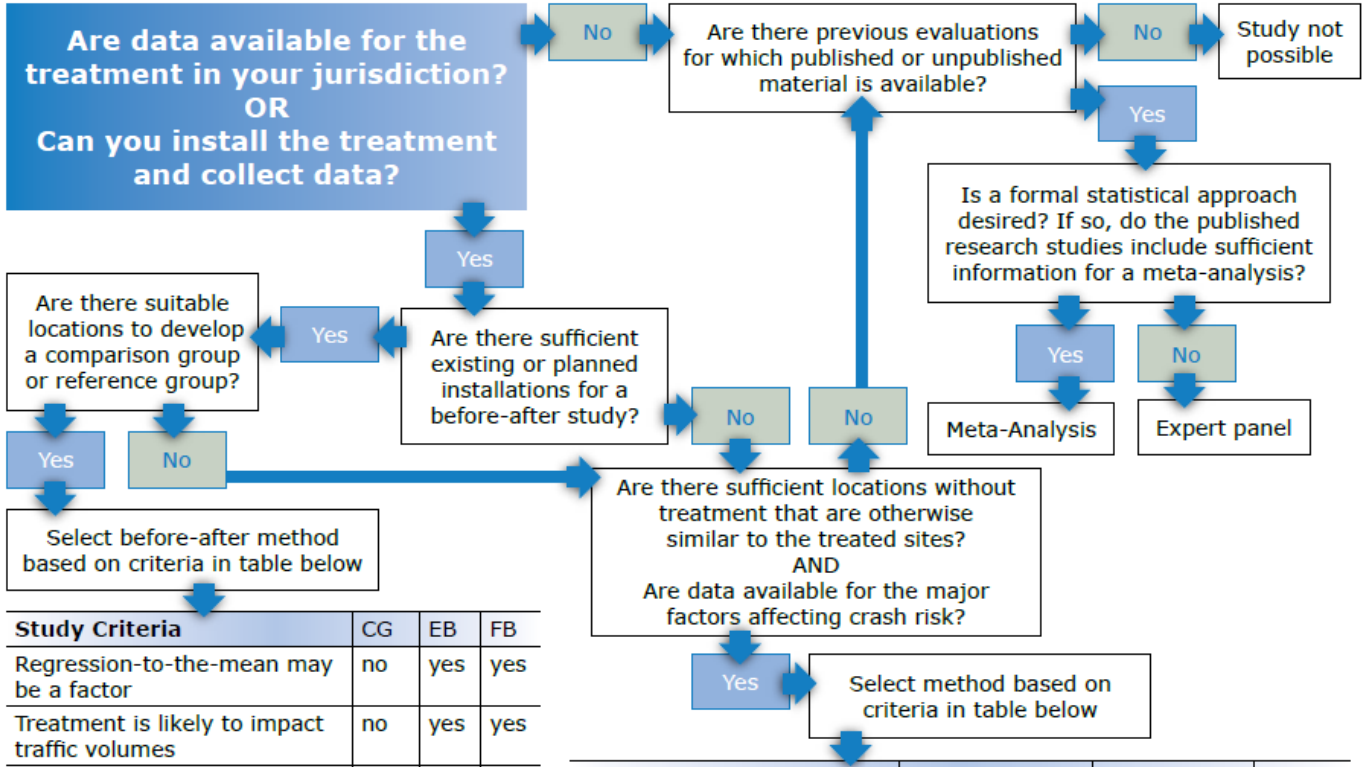
Review

- What are potential biases related to **Cross-Sectional Studies**?
  - Differences among sites
    - Geometric, operational, and regional
  - Statistical issues
    - Inappropriate functional form, omitted variable bias, confounding, correlation



Resource





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

FIGURE 5. Flow Chart for Study Design Selection.

Questions

- Can you:
  - Explain the difference between before-after and cross-sectional studies?
  - Identify potential biases related to before-after study designs?
  - Identify potential biases related to cross-sectional study designs?

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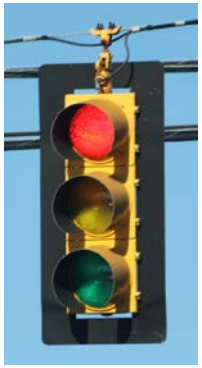
Importance of Good CMF Documentation

Daniel Carter

UNC Highway Safety Research Center

TRB Webinar, August 11, 2016

Intro Scenario



- An engineer plans to convert stop-controlled intersection to signalized intersection
- Her goal is to reduce fatal and serious injury crashes
- She needs a CMF for the benefit-cost analysis

Identified: **CMF (fatal and serious injury crashes) = 0.6**

<u>Information reported:</u>

- Based on 80 sites
- Data from CA, MN, WA
- Before/after study

<u>Not reported:</u>

- Number of lanes?
- Urban or rural?
- Traffic volume?
- “Serious” injury = A?

Why is good CMF documentation important?

1. To know the <u>conditions</u> where the CMF can be applied most appropriately
2. To judge the <u>quality</u> of the CMF

What conditions should be reported?

- Countermeasure
  - What was installed or converted?
  - How was it implemented?
  - What was the prior condition?

~~Installed median barrier~~

Installed three-strand high-tension cable median barrier

~~Installed flashing beacons~~

Installed overhead and sign post mounted flashing beacons (flashing yellow for the major road and red for the minor road)

What conditions should be reported?

- Roadway Class
- Divided vs. Undivided
- State/Municipality
- Urban vs. Rural
- Number of Lanes
- Speed Limit
- Traffic Volume Range
- Traffic Control, Intersection Type, Intersection Geometry
- Other Relevant Details

Install a traffic signal

Intersection Type:	Roadway/roadway (not interchange related)
Intersection Geometry:	3-leg,4-leg
Traffic Control:	Stop-controlled
Major Road Traffic Volume:	Minimum of 3261 to Maximum of 29926 Annual Average Daily Traffic (AADT)
Minor Road Traffic Volume:	Minimum of 101 to Maximum of 10300 Annual Average Daily Traffic (AADT)

What conditions should be reported?

- Crash characteristics
  - Crash type
  - Crash severity
  - Time of day

"Bicycle and moped riders, all injuries, non intersection"

"CMF applies only to red-light-related crashes"

"Applies to driveway-related crashes. A rectangular buffer area is used to identify driveway-related crashes. CMF applies to high-turnover driveways (i.e., fast food, gas station, drive-thru bank)."

What information is needed to judge quality of the CMF?

- CMF Clearinghouse: Study design, sample size, standard error, data source, potential biases
- HSM 1st Edition Part D: Study design, standard error, potential biases
- HSM 2nd Edition: *TBD* (NCHRP 17-72)

What information is needed to judge quality of the CMF?

- Sample size
  - Years of data
  - Number of sites or miles
  - Number of crashes
- Study methodology (e.g., before-after, cross-sectional)
- Standard error
- Selection criteria for treatment and reference sites
- Bias avoidance/addressing (Frank's topic)

- If something is <u>unknown</u>, rating is lowered

Resources

CMF Clearinghouse
www.cmfclearinghouse.org

sing CMFs | Developing CMFs | Additio

About the CMF Clearinghouse | Using CMFs | Developing CMFs | Additional Resources

Home » Developing CMFs

Developing CMFs

Many researchers conduct studies in which they develop CMFs. However, it takes planning and intentional study design to produce good quality CMFs. The following resources provide guidance on how to produce the best quality CMFs as well as information on current CMF research needs.

CMF Clearinghouse Flyer: "Better CMFs, safer roadways: Tips for building high-quality CMFs"
This two-page flyer provides a basic overview on how to develop high-quality CMFs, with information on questions such as, "What does a quality CMF study look like?" and "Why is documentation important?"

A Guide to Developing Quality Crash Modification Factors
The purpose of this guide is to provide direction to agencies interested in developing crash modification factors (CMFs). Specifically, this guide discusses the process for selecting an appropriate evaluation methodology and the many issues and data considerations related to various methodologies.

Recommended Protocols for Developing Crash Modification Factors
The CMF Protocols provide guidance for the development and documentation of research studies that develop CMFs. The major goal of these protocols is to describe what pieces of the research study should be documented by the study authors and how various potential biases should be addressed.

CMF Needs

- **CMF Most Wanted List**
  The research topics in this list represent areas where crash-based safety evaluation research is needed.
- **CMF Needs Assessment**
  This report summarizes the proceedings of a workshop in 2014 that brought together CMF stakeholders to identify CMF research needs.
- **Submit a CMF Research Need**
  If you see a lack of CMFs for a particular topic, submit your idea for a future research need.

Trainings

- **Developing Quality CMFs**
  Coming soon via NHI

Submit a CMF
If you have conducted a study that produced CMFs, submit your report to be reviewed and included on the Clearinghouse.

Flyer on Developing High Quality CMFs

Guide to Developing Quality CMFs

Recommended Protocols for Developing CMFs

Contact

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TRB WEBINAR:
GUIDANCE ON DEVELOPING CRASH MODIFICATION FACTORS
AUGUST 11, 2016

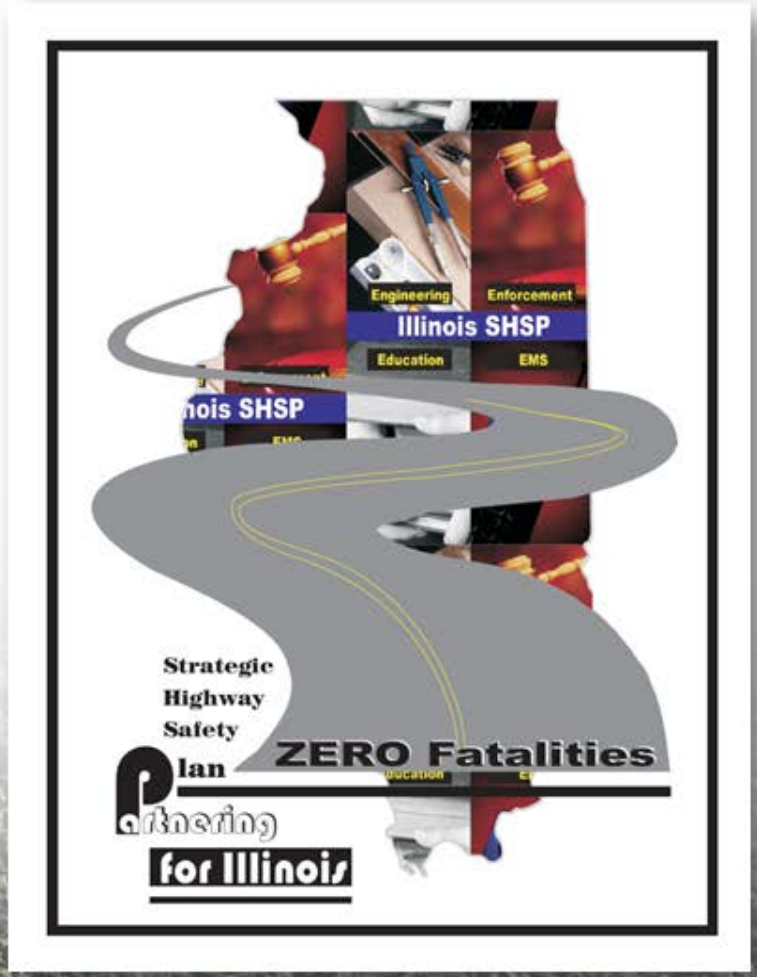
STATE DEPARTMENT OF TRANSPORTATION CONSIDERATIONS & CASE STUDY

Randy Laninga, Illinois Department of Transportation

Kerrie Schattler, Bradley University

Illinois SHSP

- Zero Fatality Goal
- All public roads
- Severe Crashes
- Substantive Safety
- 4E Partnership
- Continual Evaluation



Driving Zero Fatalities to a Reality

Partnering for Illinois

Strategic Highway Safety Plan

- Sets the vision, goal and performance metrics
- Uses data to identify safety priorities
- Provides data analysis resources for stakeholder safety planning
- Provides collaboration and coordination opportunities
- Provides strategies for implementation consideration
- Unifying document for safety statewide

Use of CMFs

- Setting Priorities
- Accurate Benefit to Cost ratio
- Best use of Funds
- Analysis of alternative designs
- Not only the safety projects but all highway projects

Considerations using CMFs

- Don't use a CMF blindly
  - ✓Geographical Location
  - ✓Spot or systemic
- Does the situation match
- Applying multiple CMF's

Our CMF Research

- CMFs are produced whenever we do a safety study
- Follow up on safety projects that use CMFs to see if they are reasonable
- Change our policy to reflect what we have found

Example Project

- Flashing Yellow Arrows in Peoria
- Dr. Kerrie Schattler from Bradley University performed the evaluation study
- State provide data
  - ✓Where and when installed
  - ✓Crash data
  - ✓Updates
  - ✓Guidance

Case Study

FYA Study Sites

- FYAs installed at 112 intersections
  - ✓At 26 intersections, other safety improvements were also installed
    - Excluded from study
- Sample Size for Evaluation
  - ✓86 test intersections
  - ✓164 approaches
- Located across 10 cities in Peoria area
  - ✓On state routes

FYA Study Sites

- 164 FYA approaches
  - ✓All had dedicated left-turn lanes
  - ✓At 90 approaches FYA supplemental sign was installed
- Intersection Characteristics
  - ✓Average Daily Traffic (ADT) 8,500 to 40,700 veh/day
  - ✓3- and 4- legged urban configurations with various geometries
  - ✓Freeway ramps
  - ✓One way streets, divided highways

FYA Study Sites

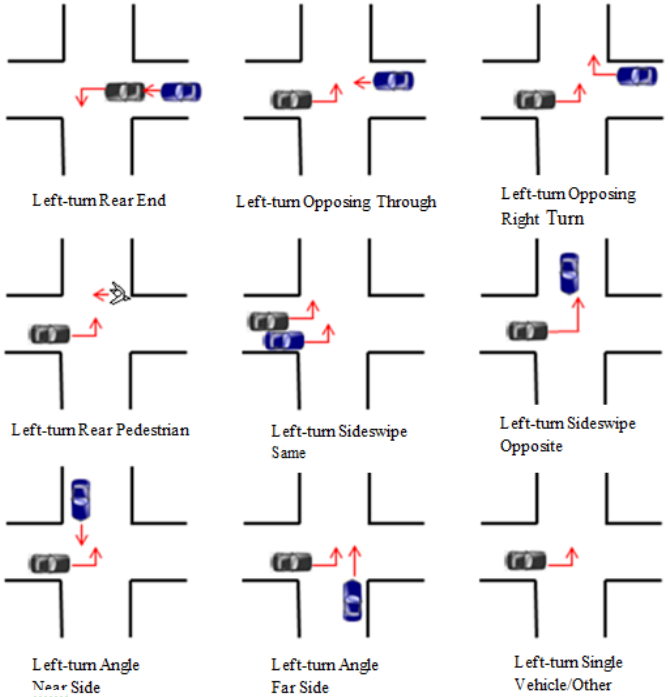
- All 164 FYA approaches
  - ✓In ***before*** and ***after*** conditions, signals operated with protected/permissive left-turn (PPLT) control
  - o Yellow & all-red intervals following ***both*** the protected and permissive phases
  - ✓Permissive left-turn interval of PPLT phasing
    - o Before Condition ⇒ 5-section signal heads with Circular Green (CG)
    - o After Condition ⇒ 4-section signal heads with FYA

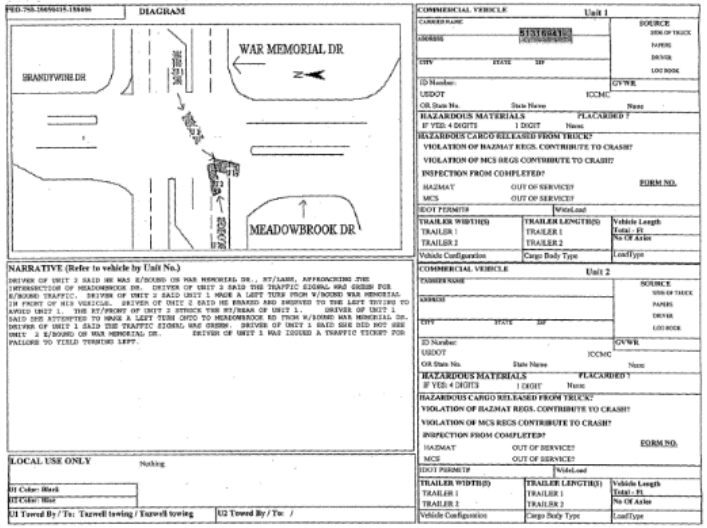
5-section signal head with CG

4-section signal head with FYA

Traffic Crash Evaluation

- 3,307 crash reports analyzed
  - ✓Over a 6-year period
    - 3 years of before data
    - 3 years of after data
  - ✓Focused on left-turn crashes, categorized into 9 crash types
- Targeted Crash Types
  - ✓Left-turn (LT) -related
  - ✓Left-turn Opposing-Through (LTOT)





Empirical Bayes Method

- Increases precision of estimation and corrects for the regression-to-mean bias
- Calculates expected crash frequency
  - ✓Observed crash frequency
  - ✓Predicted crash frequency
    - o Safety Performance Functions (SPF)

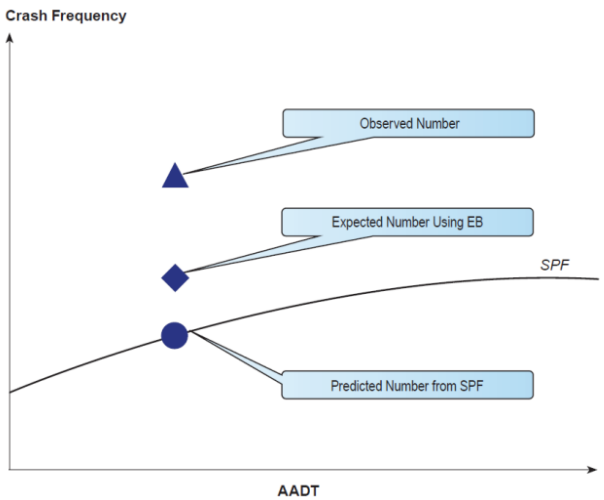
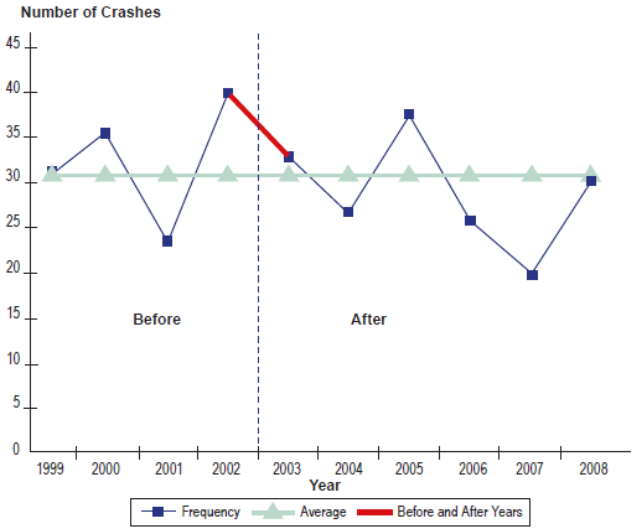


Figure 2.3 Example of Regression to the Mean



Source: Highway Safety Improvement Program, FHWA 2010

Safety Performance Functions

- SPFs developed for project
  - ✓100 comparison sites in central Illinois
  - ✓Located in 8 cities in central IL, outside the Peoria area
  - ✓266 approaches operating with PPLT with CG
  - ✓Data Collected
    - Crash Data by type and severity (2009 to 2011)
    - Average Daily Traffic
      - Intersection ADT
      - Minor street ADT
      - Major street ADT
      - Approach ADT
    - Laneage
    - Speed limit

Safety Performance Functions

- Models developed
  - ✓Assuming Poisson/negative binomial distribution
  - ✓Variables with statistically significant relationship with crashes

$$P_{\text{intersection}} = e^{\alpha} * e^{(Approach\ ADT)\beta 1}$$

$$P_{\text{total}} = e^{\alpha} * e^{(Total\ Intersection\ ADT)\beta 1} * e^{\left(Prop.\frac{App}{TotalADT}\right)\beta 2} * e^{(OppThruLanes)\beta 3}$$

$$P_{\text{injury}} = e^{\alpha} * e^{(Total\ Intersection\ ADT)\beta 1} * e^{(OppThruLanes)\beta 2}$$

$$P_{\text{LT-related}} = e^{\alpha} * e^{(Approach\ ADT)\beta 1} * e^{(OppThruLanes)\beta 2}$$

$$P_{\text{LTOT}} = e^{\alpha} * e^{(Total\ Intersection\ ADT)\beta 1} * e^{(OppThruLanes)\beta 2}$$

Safety Performance Function

- Standard error of the coefficients
  - ✓ Measure quality of an SPF
  - ✓ Represents ability of SPF to predict crashes accurately
- Small standard error with respect to the magnitude of coefficients indicates SPF predicts crashes accurately
  - ✓ Standard error $\Rightarrow$ 0.000005 to 0.4
  - ✓ Ratio of standard error/coefficient value $\Rightarrow$ 0.08 to 0.41

Crash Modification Factors

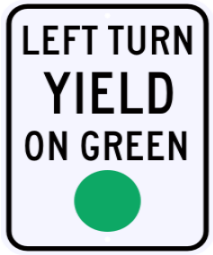
- Determined for targeted crash types on an approach basis
  - ✓Per the **empirical Bayes** method, using
    - Observed crash frequency
    - Predicted crash frequency using SPFs
    - Expected crash frequency
    - Weighting factors as a function of overdispersion factor, k
    - Unbiased estimate of effectiveness (θ), CMF
      - Variance of θ, Standard error of θ
    - Unbiased safety effectiveness (percent reduction, crash reduction factor)
      - Variance, Standard Error
    - Statistical Significance
    - Confidence Interval of CMF

Crash Modification Factor Results

- **LT-related crashes at FYA approach**
  - ✓Percent Reduction = 38.3%
  - ✓CMF = 0.617
    - 95% confidence interval = $0.617 \pm 1.96 \times 0.063$ = **0.494 to 0.740**
- **LT-related crashes at FYA approach with supplemental sign**
  - ✓Percent Reduction = 41.1%
  - ✓CMF = 0.589
    - 95% confidence interval = **0.425 to 0.753**
- **LTOT crashes at FYA approach**
  - ✓Percent reduction = 28.6%
  - ✓CMF = 0.714
    - 95% confidence interval = **0.545 to 0.883**
- **LTOT crashes at FYA approach with supplemental sign**
  - ✓Percent reduction = 29.8%
  - ✓CMF = 0.711
    - 95% confidence interval = **0.474 to 0.948**

Recommendations

- FYAs continue to be installed on state routes in Illinois because they were found to have significant safety impacts and reduce left-turn crashes at locations where installed
- Supplemental signs should be used when implementing the FYA in Illinois
  - ✓Especially while the FYA remains a new traffic control device
  - ✓In Peoria, especially on city roads, supplemental signs are commonly displayed at other left-turn signals, in addition to the FYA



- Additional research is needed to justify the long-term and continual use of the FYA supplemental sign, once more drivers become familiar with its meaning


THANK
YOU