Highway Safety Manual Application for Design Information Bulletin 94 Projects

Learning Objectives

1. Explain the difference between a quantitative analysis and a qualitative analysis.
2. Determine if an HSM analysis can be used for a DIB 94 segment.
3. Know where to find Caltrans' HSM-related resources.

AGENDA

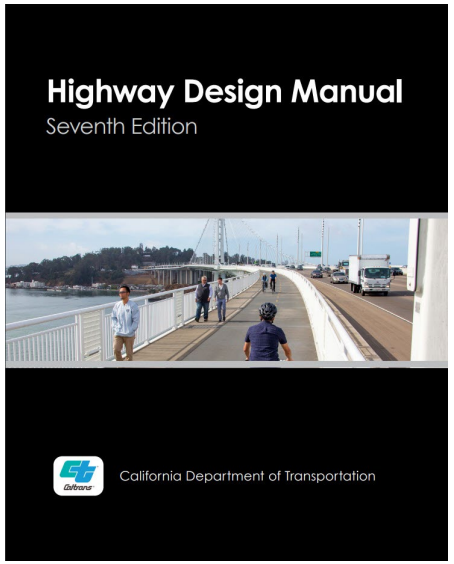
1. Overview: Highway Safety Manual (HSM) Foundational Concepts
2. Caltrans' HSM Policy Memo
3. Applying the HSM to Design Information Bulletin (DIB) 94 Projects
4. Best Practices
5. Resources

DISCLAIMER

This presentation assumes the attendee is familiar with the HSM and its methods.

HSM Foundation Overview

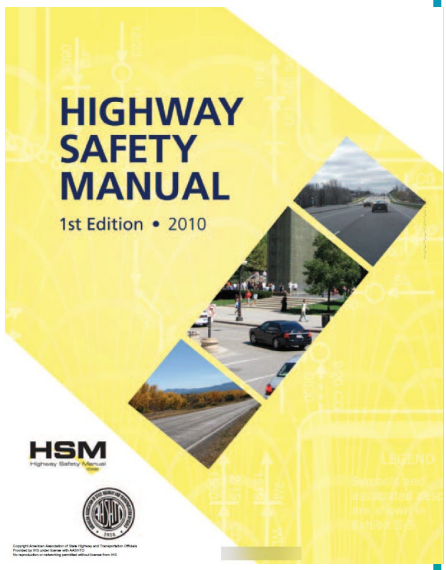
Nominal Safety



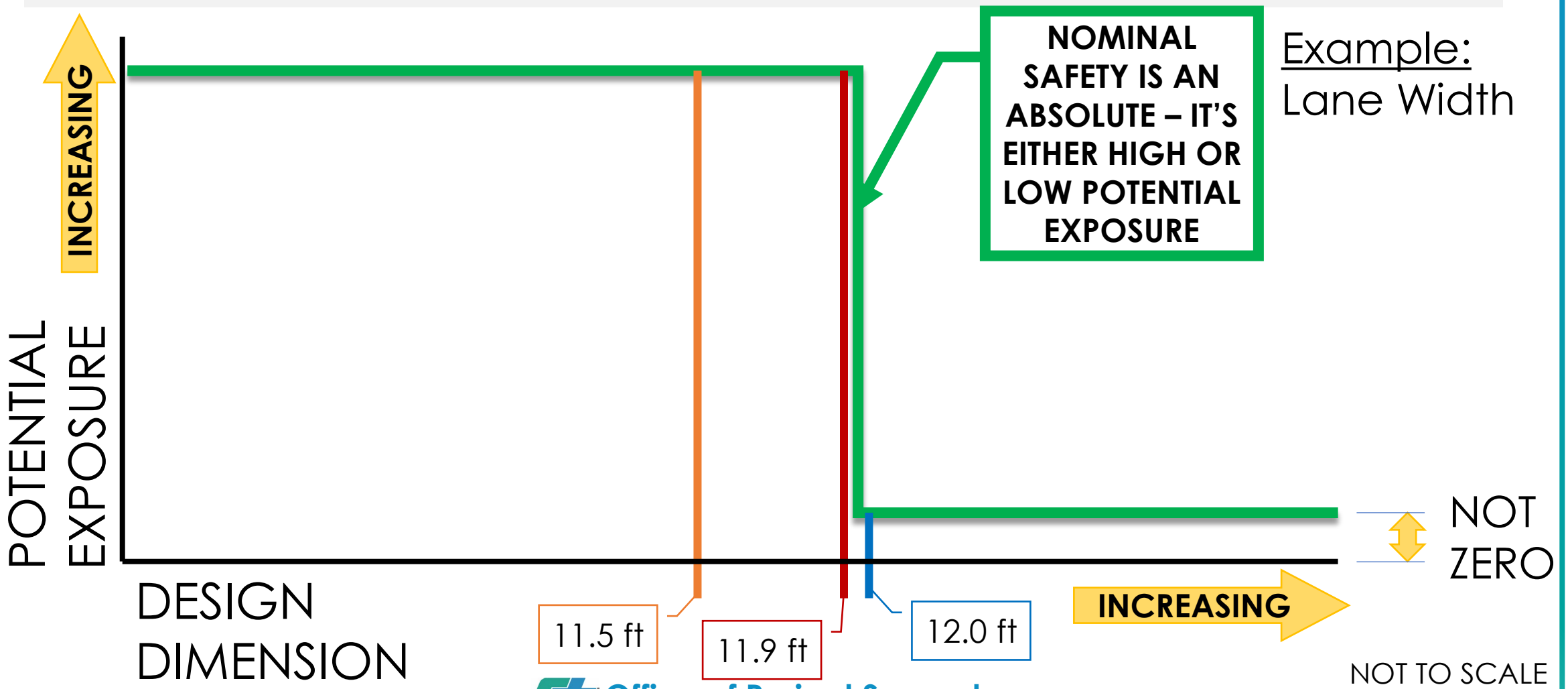
- Binary analysis
- Measurement: compliance with minimum design criteria

Substantive Safety

- Data-driven analysis
- Measurement: actual crash data + site characteristics



Nominal Safety Example



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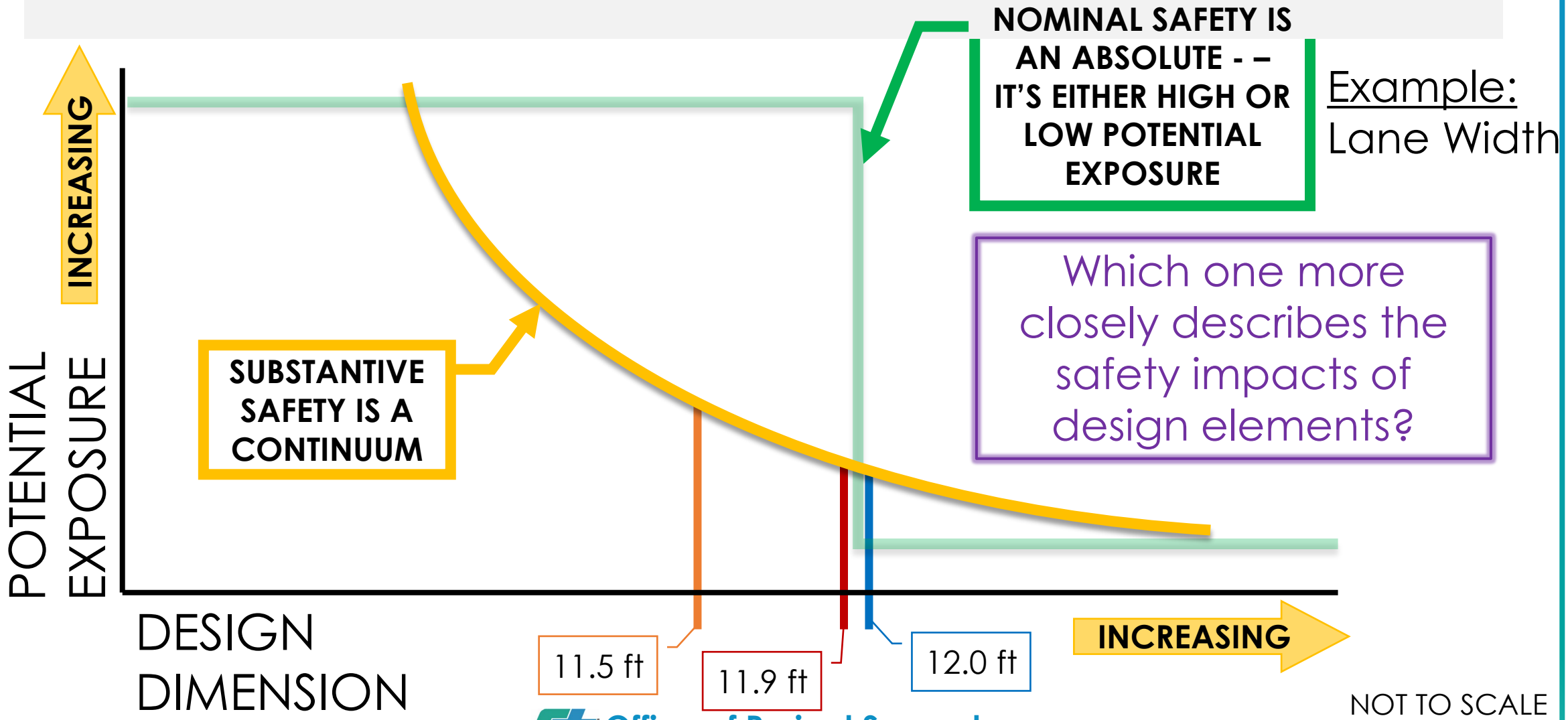
Substantive Safety Example



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Parts of the HSM

- Part A – Introduction, Human Factors, and Fundamentals
- Part B – Roadway Safety Management Process
- Part C – Introduction to the HSM Predictive Method
- Part D – Crash Modification Factors

HSM Part C Chapters

- Chapter 10: Rural 2-lane, 2-way Roads
- Chapter 11: Rural Multilane Highways
- Chapter 12: Urban & Suburban Arterials
- Chapter 18: Freeways
- Chapter 19: Ramps & Ramp Terminal Intersections

HSM Part C

- General Crash Prediction Model:

$$N_p = N_{spf} \times CMF_{lw} \times CMF_{sw} \ldots \times C$$

Where:

N_p = Predicted Crashes

N_{spf} = Safety Performance Function (SPF)

CMF_i = Crash Modification Factors (CMF) [also known as Adjustment Factor (AF)]

C = Calibration Factor

Quantitative Results

Parts of the HSM

- Part A – Introduction, Human Factors, and Fundamentals
- Part B – Roadway Safety Management Process
- Part C – Introduction to the HSM Predictive Method
- Part D – Crash Modification Factors

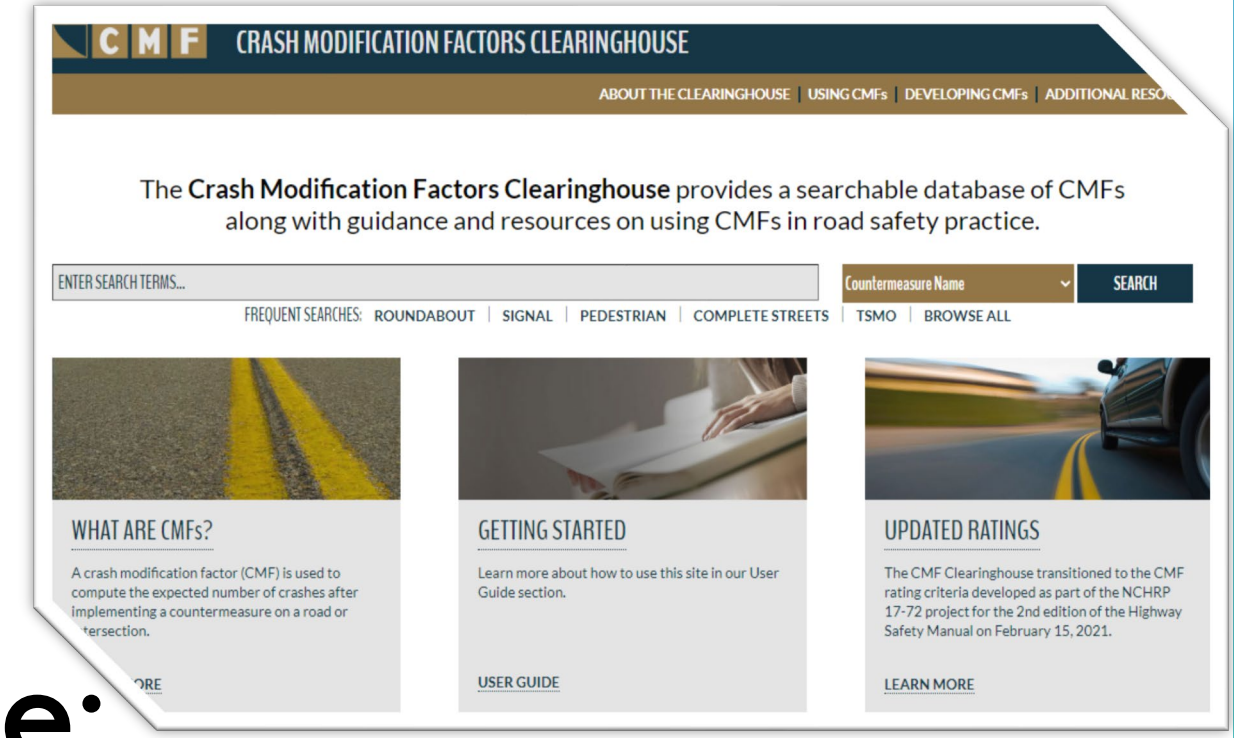
HSM Part D CMFs

- A CMF represents the relative change in crash frequency due to a change in one specific condition (all other conditions & site characteristics remain constant).
- CMFs can be applied (in order of preference):
  1. Quantitatively: part D CMF is applied to a completed Part C analysis that captures a change not available in the Part C models.
  2. Qualitatively: to indicate an anticipated change in crash frequency by applying a specific countermeasure, if a Part C model is not applicable. Therefore, a part D CMF is NOT applied to a completed Part C analysis.

Quantitative or Qualitative Results

HSM Part D CMFs

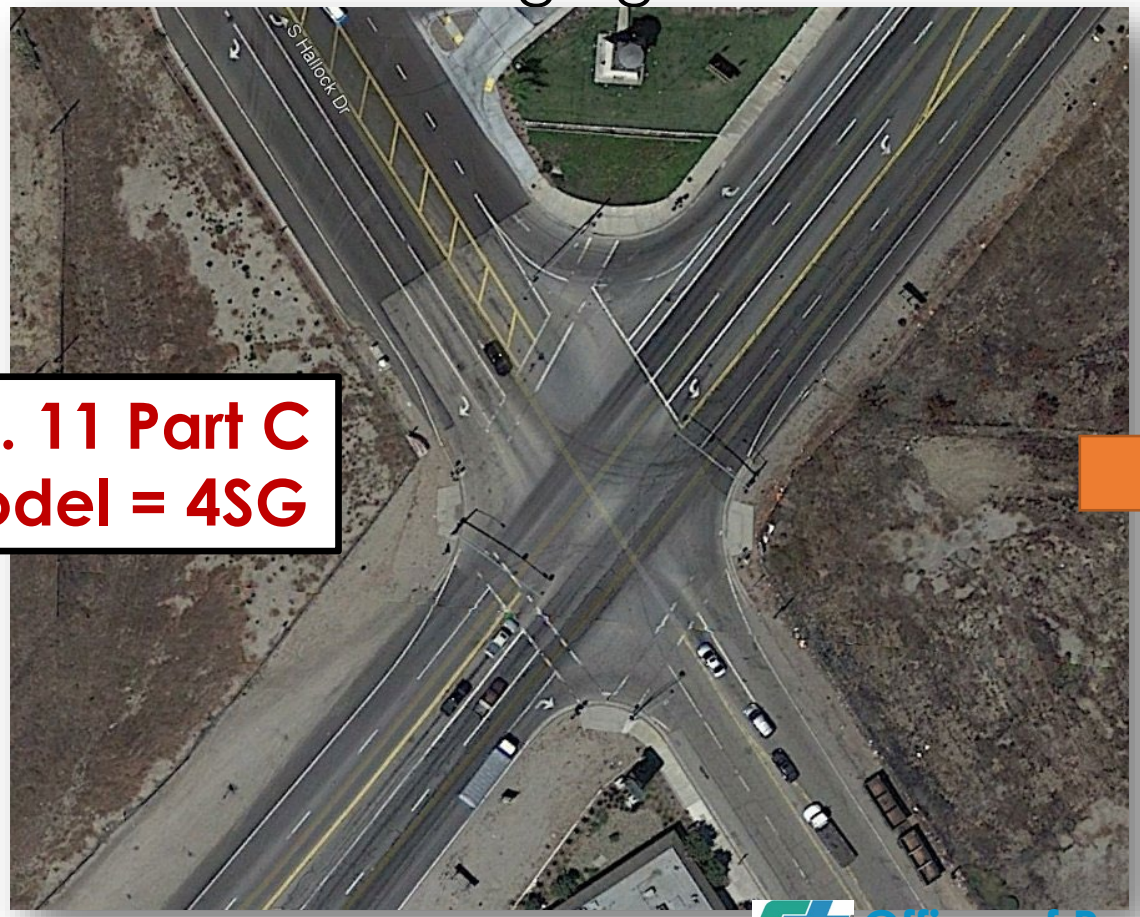
- Chapter 13: Roadway Segments
- Chapter 14: Intersections
- Chapter 15: Interchanges
- Chapter 16: Special Facilities & Geometric Situations
- Chapter 17: Road Networks



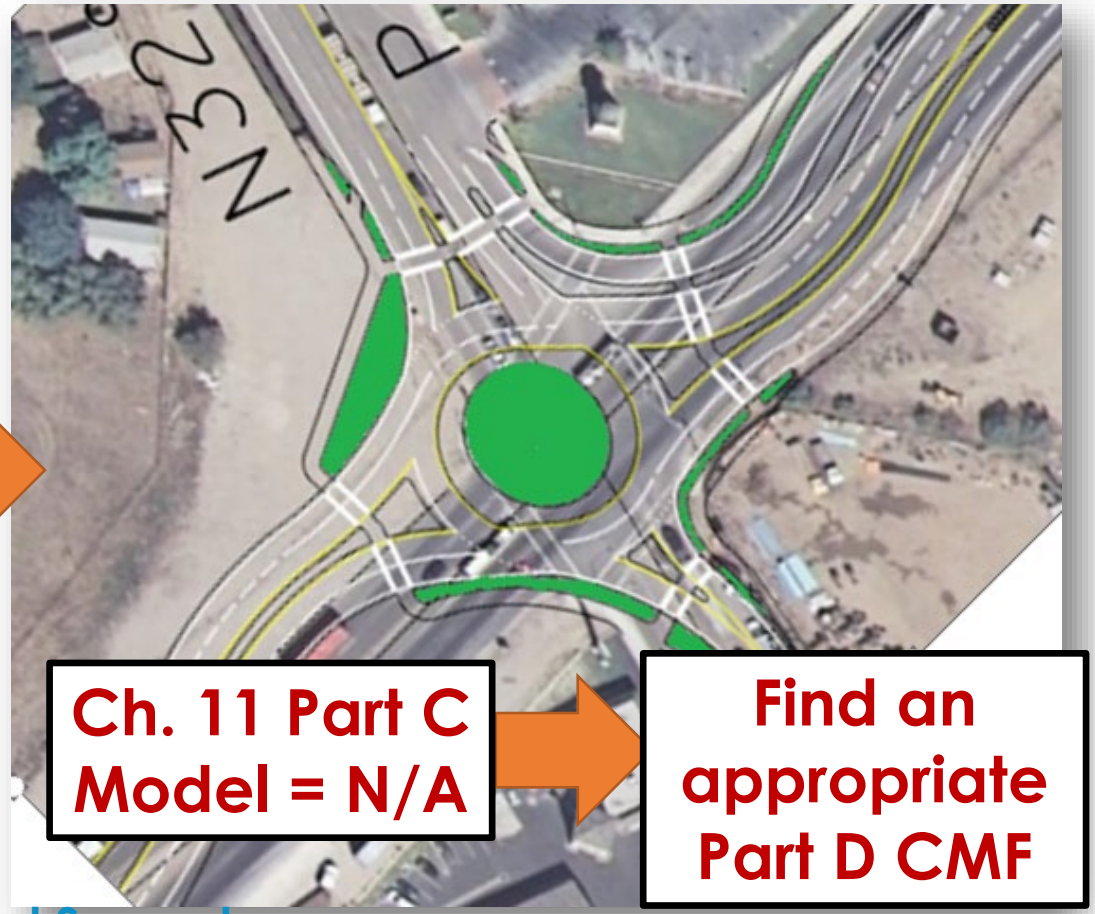
- **CMF Clearinghouse:** https://www.cmfclearinghouse.org/

Quantitative Example: Part D CMF Applied to a Part C Analysis

- Convert existing signalized intersection to a roundabout



Ch. 11 Part C Model = 4SG



Ch. 11 Part C Model = N/A

Find an appropriate Part D CMF

PART D CMF APPLIED TO A PART C ANALYSIS

- 4SG Part C Analysis Output Result:

Existing N_{int} = 18.3 crashes/yr

Convert Signal to Modern Roundabout Part D CMF (from CMF Clearinghouse)	Std Error for Roundabout Part D CMF (from CMF Clearinghouse)	CMF Upper and Lower Limit (95% Confidence Interval)	Predicted Crashes for Existing Condition (Crashes/Year)	Part D CMF Applied to a Part C Analysis (Crashes/Year)	Predicted Crashes for Proposed Condition (Crashes/Year)
0.52 (CMF ID: 225)	0.05	0.42 – 0.62	18.3	18.3 x .42 = 7.68 18.3 x .62 = 11.3	7.68 – 11.3

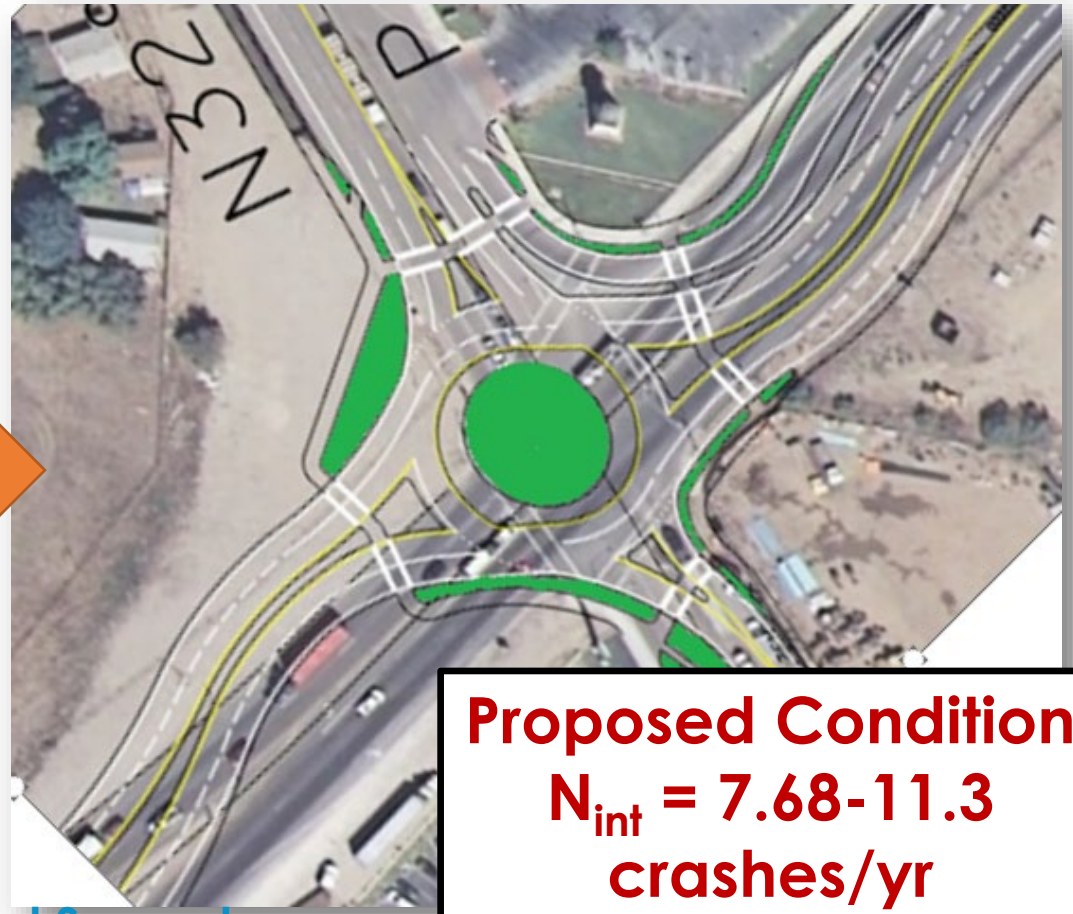
- Lower limit: 0.52 – 1.96×0.05 = 0.52 – 0.098 = 0.42
- Upper limit: 0.52 + 1.96×0.05 = 0.52 + 0.098 = 0.62

(1.96 = a constant based on 95% confidence interval. See https://www.cmfclearinghouse.org/userguide_advancedusers.php)

Quantitative Example: Results of Part D CMF Applied to a Part C Analysis

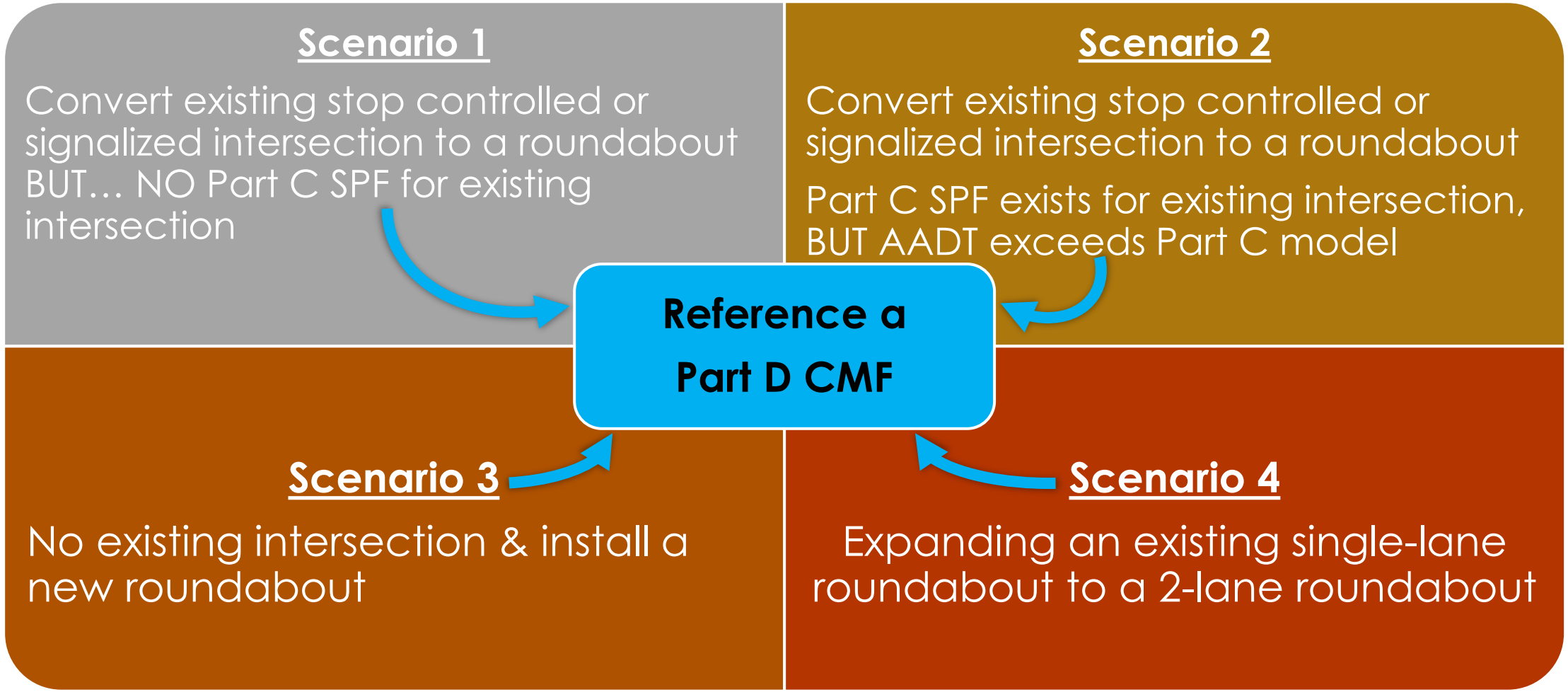
- Convert existing signalized intersection to a roundabout

Existing Condition
N_{int} = 18.3 crashes/yr

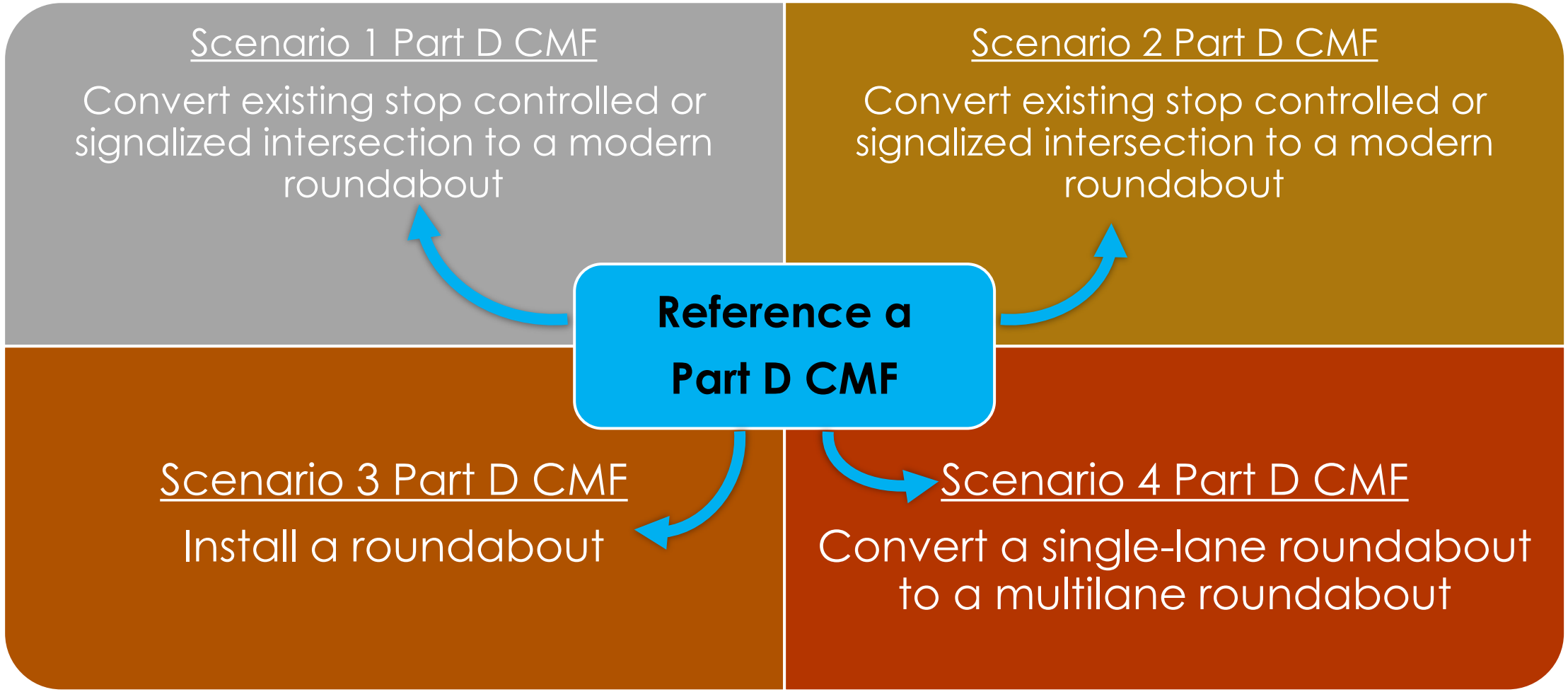


Proposed Condition
N_{int} = 7.68-11.3 crashes/yr

Qualitative Use of a Part D CMF



Qualitative Use of a Part D CMF Cont.



Part D CMF Application Criteria & Tips

Criteria (see HSM Implementation Memo Attachment 1[1] for more info):

- CMF should coincide with project's before & after conditions
- CMF should be statistically significant
  - CMF does NOT pass through 1.0 w/ standard error applied
- District HSM SMEs must concur on Part D CMF chosen/applied
- Only one Part D CMF per segment and intersection

Tips:

- Filters available for country, area type, crash type, crash severity, etc.
- Star rating can be used to determine quality of CMF
- Utilize the Comparison Tool

Caltrans' Current HSM Policy

- "Project Application" requirements:

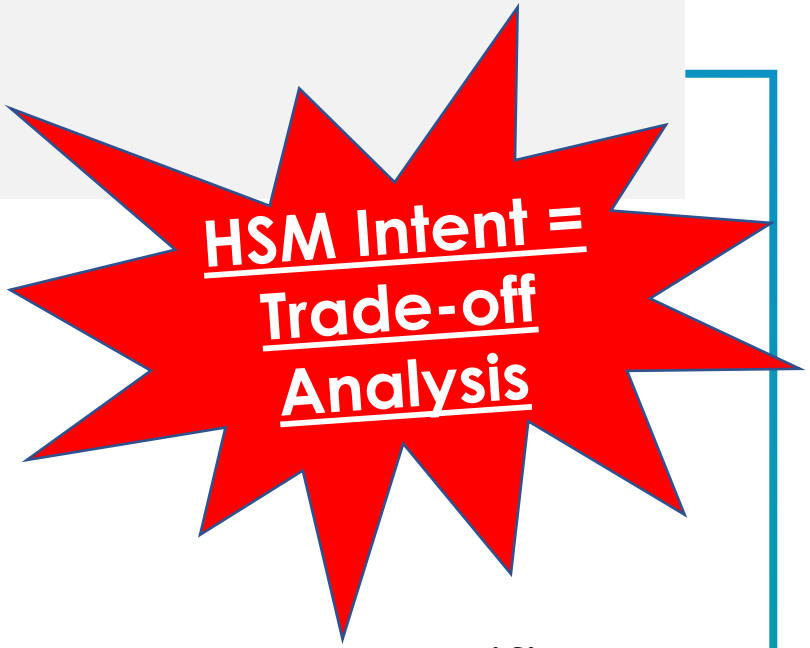
> Where the HSM Part C predictive methods can be applied, the HSM shall be used for all projects on the SHS regardless of project sponsor or funding source, if it is proposing any of the following:
>
> - Nonstandard design feature(s).
> - A geometric or operational feature that varies from the existing condition or from other project alternatives.
> - New or modification to an interchange as part of the alternative selection process and Interstate New Access Report or Modified Access Report.

Source: https://dot.ca.gov/-/media/dot-media/programs/design/documents/performance-based-decision-making-using-the-hsm_2022_04-a11y.pdf

BENEFITS OF USING THE HSM

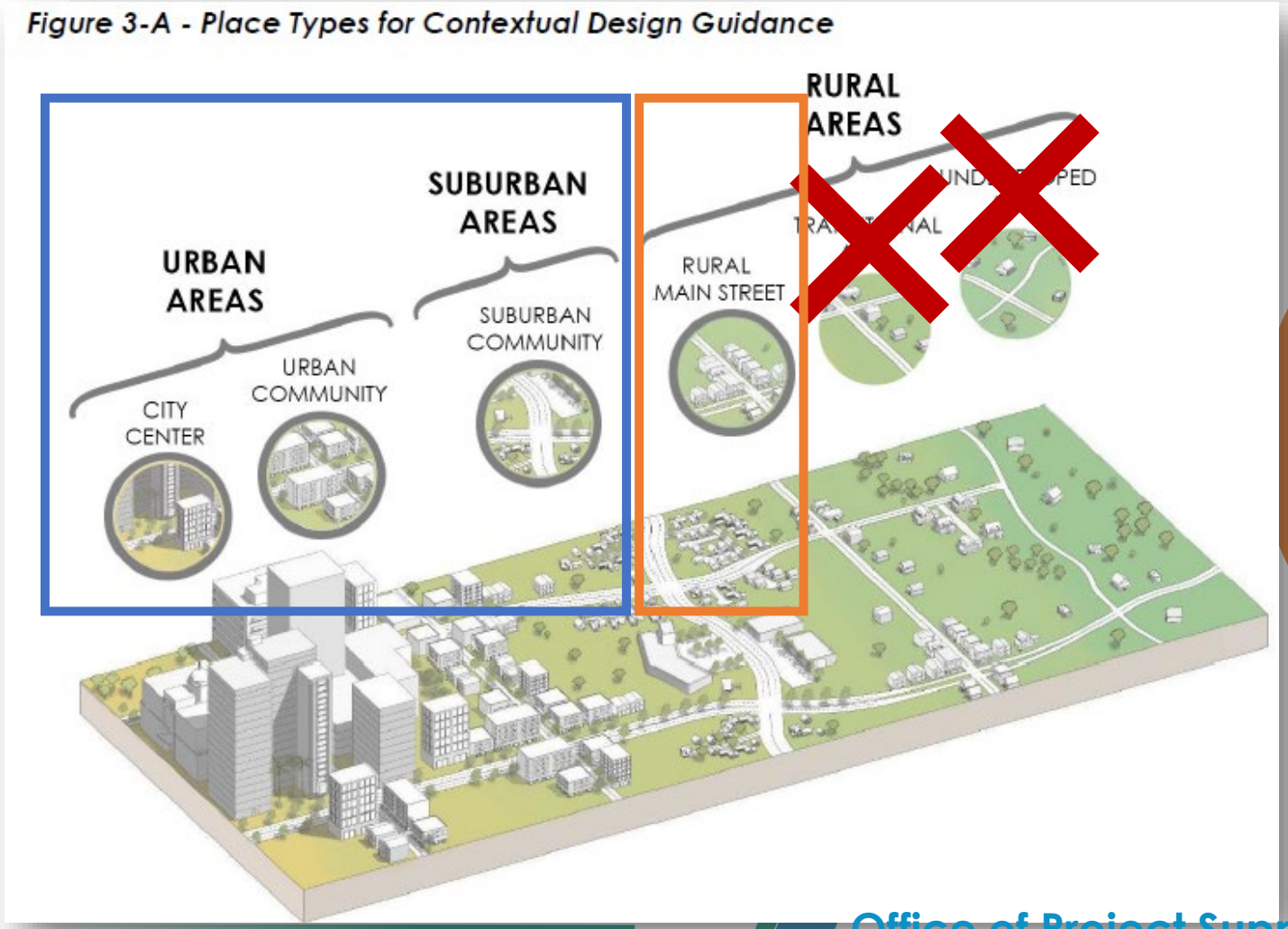
- Provide quantitative safety analysis
- Better inform the decision-making process with the goal of reducing fatal and injury crashes
- Provide additional justification and validate project decisions
- Integrate another dimension of safety (performance-based) into the design process which has been traditionally dominated by compliance with standards.
- Support the Department's safety-first mindset that is consistent with FHWA's Safe System Approach

DIB 94 Projects



- DIB 94 Intent
  - Reduce DSDDs for DIB 94 projects
  - DSDDs still required if DIB 94 standards are not met
- HSM Intent
  - Ideally, provide predictive safety performance on modified cross-sectional elements to add or enhance bike and pedestrian facilities
- HSM Application
  - Analysis methodology and limitations treated the same for all projects regardless of project type or funding.

DIB 94 Place Types vs HSM Part C Facility Types



Ch. 10 & 11	❑Rural 2 lane ❑Rural Multi-lane
Ch. 12	❑Urban and Suburban arterials
Ch. 18 & 19	❑Freeways ❑Ramps

Documentation Requirements

Your project is DIB 94 eligible and opted-in to use DIB 94 standards.

1) Complying with the underlined standards of the DIB 94

Refer to DIB 94

Remember to document decisions!

> Design standards in this DIB are presented as underlined standards, which requires a design standard decision document (DSDD) for noncompliance. Additionally, design decisions for the values in compliance with the underlined standard of this DIB will also require documentation in the project report or project approval document. A direct statement of the decision to opt-in is required if using the design standards of this DIB. After project approval, any change in the design decisions regarding the selected values of the underlined standard should be documented in a Memo to File. This documentation will explain the reasons for the values selected based on the unique characteristics and constraints of the project. Cost should not be the sole reason for the decision. This added discussion will contribute to the purpose and need of the project scope in support of multimodal accommodation based upon engineering judgement.

- With the support of the HSM analysis, document decisions
  - Quantitative analysis – include the results of the economic analysis
  - Qualitative analysis – use a Part D CMF to describe the effects of introducing or changing a feature
  - Quantitative or qualitative analysis wasn't available or appropriate

Documentation Requirements

Your project is DIB 94 eligible and opted-in to use DIB 94 standards.

2) Deviating from the underlined standards

Prepare a DSDD

- HSM analysis should not be attached or inserted into the DSDD
- Summary of HSM analysis results to be included:
  - Section 4 "Collision Analysis"
  - Section 2 "Features Requiring Design Decision Documentation"

- Refer to the "Application of the Highway Safety Manual Methodology for Project Development"(1)

Refer to the "Application of HSM for Project Development"(1) for sample language.

"Upon evaluating the difference in predicted collisions between meeting the standard width of X and the proposed nonstandard width of Y, the calculated collision benefit of meeting standard over the design life (B) compared to the cost required to meet that standard (C) results in a Benefit to Cost (B/C) Ratio analysis equal to "A." This indicates that for every dollar spent to meet the standard for this project, there would be "A" dollars of benefit that may be realized over the design life. The Net Value analysis (B – C) indicates that "D" dollars of calculated collision benefit will be realized over the project's cost spent to meet the required standard."

(1) https://dot.ca.gov/-/media/dot-media/programs/design/documents/application-of-the-hsm-methodolgy-for-project-development_2023-03_final-a11y.pdf

Chapter 10 – Predictive Method for Rural Two-Lane, Two-Way Roads

- How are the rural two-lane, two-way methodologies applied to DIB 94 rural main street segments?

- Qualifiers (should meet all):
  - Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;

    DIB 94 applies to **Rural Main Streets** and does not apply to Transitional, Underdeveloped, Special Use areas and Protected Lands.

  - Posted speed within the Complete Streets project segment **does not exceed 45 miles per hour**; and,
  - A bicycle, pedestrian, or transit facility will be provided or improved within a Complete Streets project segment according to the CSDD.

Chapter 10 – Predictive Method for Rural Two-Lane, Two-Way Roads

Application of the HSM Part C, Chapter 10 predictive method for rural main street segments:

Site Types w/ SPFs

- Rural two-lane, two-way roads

Adjustment Factors (AFs)

- Lane Width
- Shoulder Width
- Curve Radius
- Superelevation
- Grade
- CRZ
- Driveway Density
- Passing Lane
- Two-Way Left Turn
- Lighting

Chapter 10 – Predictive Method for Rural Two-Lane, Two-Way Roads

Application of the HSM Part C, Chapter 10 predictive method for rural main street segments:

Site Types w/ SPFs

- Rural two-lane, two-way roads

DIB 94 Complete Street standards

- ✗ Bike Lane presence & width
- ✗ Sidewalk presence & width

Adjustment Factors (AFs)

- Lane Width ✓
- Shoulder Width ✓
- Curve Radius
- Superelevation
- Grade
- CRZ
- D
- D
- Passing Lane
- Two-Way Left Turn
- Lighting

DIB 94 travel way standards

Research **CMF Clearinghouse for most appropriate Part D CMF** to account for complete street and/or traveled way features

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Chapter 11 – Predictive Method for Rural Multi-lane Roads

- How are the rural multi-lane methodologies applied to DIB 94 rural main street segments?

- Qualifiers (should meet all):
  - Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;

    DIB 94 applies to **Rural Main Streets** and does not apply to Transitional, Underdeveloped, Special Use areas and Protected Lands.

  - Posted speed within the Complete Streets project segment **does not exceed 45 miles per hour**; and,
  - A bicycle, pedestrian, or transit facility will be provided or improved within a Complete Streets project segment according to the CSDD.

Chapter 11 – Predictive Method for Rural Multi-lane Roads

Application of the HSM Part C, Chapter 11 predictive method for rural main street segments:

Site Types w/ SPFs

- Rural four-lane undivided segments (4U)
- Rural four-lane divided segments (4D)

Adjustment Factors (AFs)

- Lane Width
- Shoulder Width
- Shoulder Type (4U only)
- Side Slopes (4U only)
- Median width (4D only)
- Automated speed enforcement
- Lighting

Chapter 11 – Predictive Method for Rural Multi-lane Roads

Application of the HSM Part C, Chapter 11 predictive method for rural main street segments:

Site Types w/ SPFs

- Rural four-lane undivided segments (4U)
- Rural four-lane divided segments (4D)

DIB 94 Complete Street standards

- ✗ Bike Lane presence & width
- ✗ Sidewalk presence & width

Adjustment Factors (AFs)

- Lane Width ✓
- Shoulder Width ✓
- Shoulder Type (4U only)
- Side Slopes (4U only)
- Median (4D)
- Automated speed enforcement
- Lighting

DIB 94 travel way standards

Research **CMF Clearinghouse for most appropriate Part D CMF** to account for complete street and/or traveled way features

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Chapter 12 – Predictive Method for Urban & Suburban Arterials

- How are the urban & suburban arterial methodologies applied to DIB 94 urban & suburban street segments?
- Qualifiers (should meet all):
  - Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;

    DIB 94 applies to **Urban & Suburban Streets** and does not apply to Transitional, Underdeveloped, Special Use areas and Protected Lands.

  - Posted speed within the Complete Streets project segment **does not exceed 45 miles per hour**; and,
  - A bicycle, pedestrian, or transit facility will be provided or improved within a Complete Streets project segment according to the CSDD.

Chapter 12 – Predictive Method for Urban & Suburban Arterials

Application of the HSM Part C, Chapter 12 predictive method for urban & suburban street segments:

Site Types w/ SPFs

- Two-lane undivided arterials (2U)
- Three-lane arterials w/ TWLTL (3T)
- Four-lane undivided arterials (4U)
- Four-lane divided arterials (4D)
- Five-lane arterials w/ TWLTL (5T)

Adjustment Factors (AFs)

- On-street parking
- Roadside fixed objects
- Median width
- Lighting
- Automated speed enforcement

Chapter 12 – Predictive Method for Urban & Suburban Arterials

Application of the HSM Part C, Chapter 12 predictive method for urban & suburban street segments:

Site Types w/ SPFs

- Two-lane undivided arterials (2U)
- Three-lane arterials w/ TWLTL (3T)
- Four-lane undivided arterials
- [illegible]e divided arterials (4D)
- [illegible]e arterials w/ TWLTL (5T)

DIB 94 Complete Street standards

Adjustment Factors (AFs)

- On-street parking
- Roadside fixed objects
- Median width
- Lighting
- Automated speed [illegible]

DIB 94 travel way standards?

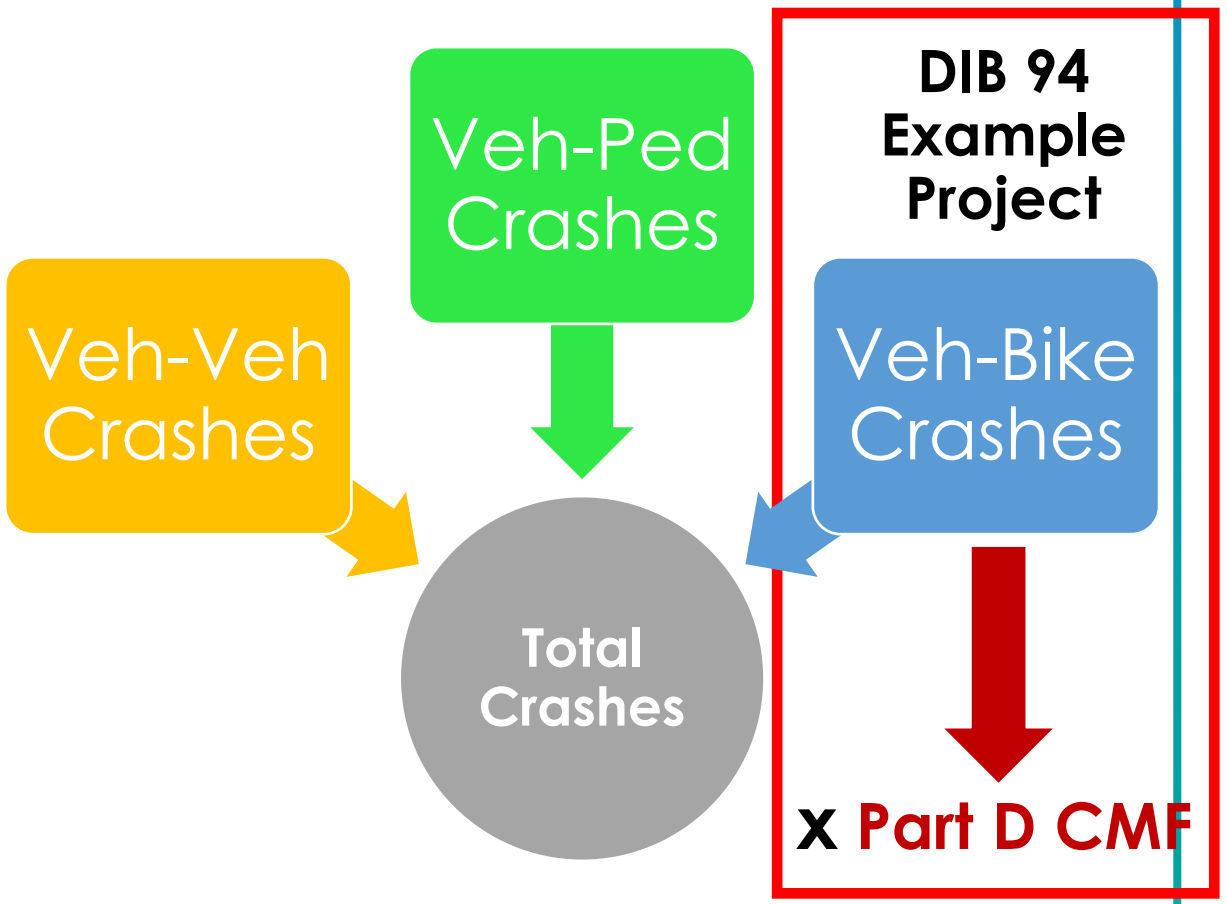
- ✗ Bike Lane presence & width
- ✗ Sidewalk presence & width

→ Research **CMF Clearinghouse for most appropriate Part D CMF** to account for complete street and/or traveled way features

Chapter 12 – Predictive Method for Urban & Suburban Arterials

Site Types w/ SPFs

- Two-lane undivided arterials (2U)
- Three-lane arterials w/ TWLTL (3T)
- Four-lane undivided arterials (4U)
- Four-lane divided arterials (4D)
- Five-lane arterials w/ TWLTL (5T)



Chapter 12 Example Project[1]: Context, Purpose, & Build Alternative

Applying a Part D CMF to a completed Part C analysis

- **Road Diet** – reallocate existing roadway width
  - Reducing number of through lanes from 4 to 2
  - Adding two-way left-turn lane (TWLTL)
  - ✓ Install Class II bike lanes in both directions
- ✓ Urban area
- ✓ Under 45-mph posted speed

Figure 5 – Existing Cross-Section

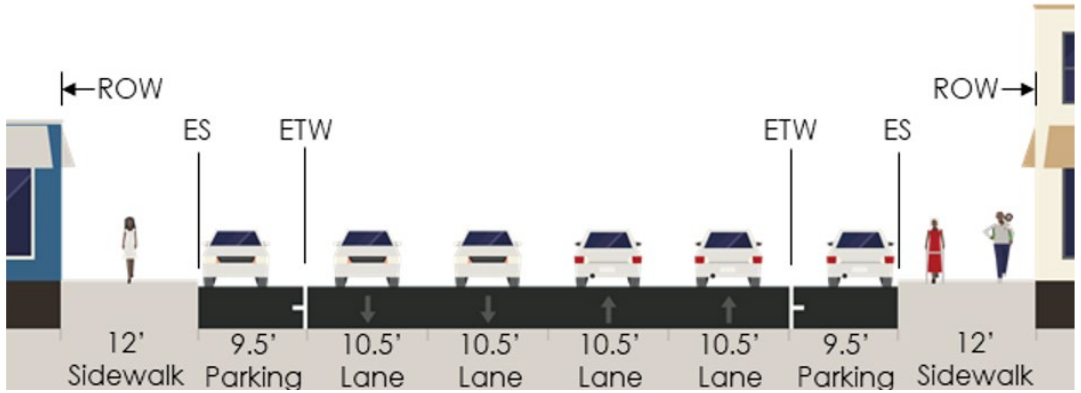
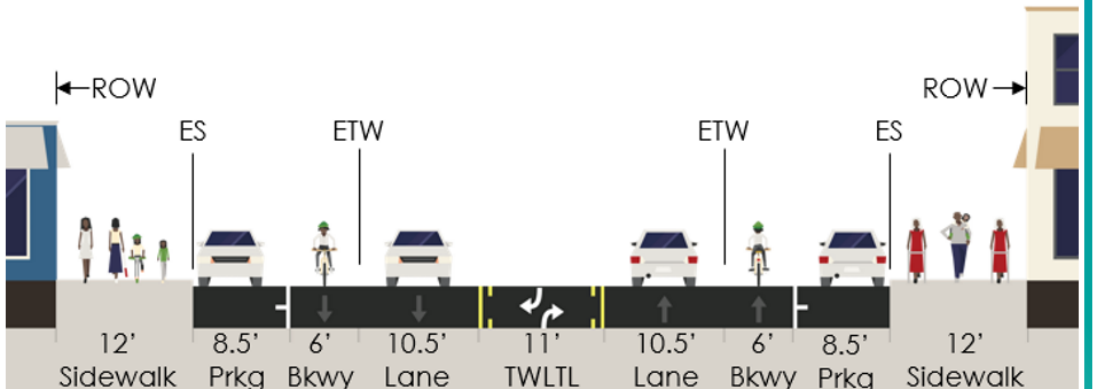


Figure 6 – Proposed Cross-Section



[1] https://dot.ca.gov/-/media/dot-media/programs/design/documents/hsm-application-for-dib-94-projects_2024-01-16_final-a11y.pdf

Chapter 12 Example Project: Quantitative Part C Analysis

1. Analyze the *existing condition* safety performance
   - Apply the "**4U**" SPF roadway type = 4 lane undivided arterial
2. Analyze the *proposed condition* safety performance
   - Apply the "**3T**" SPF roadway type = 3 lane arterial w/ TWLTL
3. Evaluate Results

Figure 5 – Existing Cross-Section

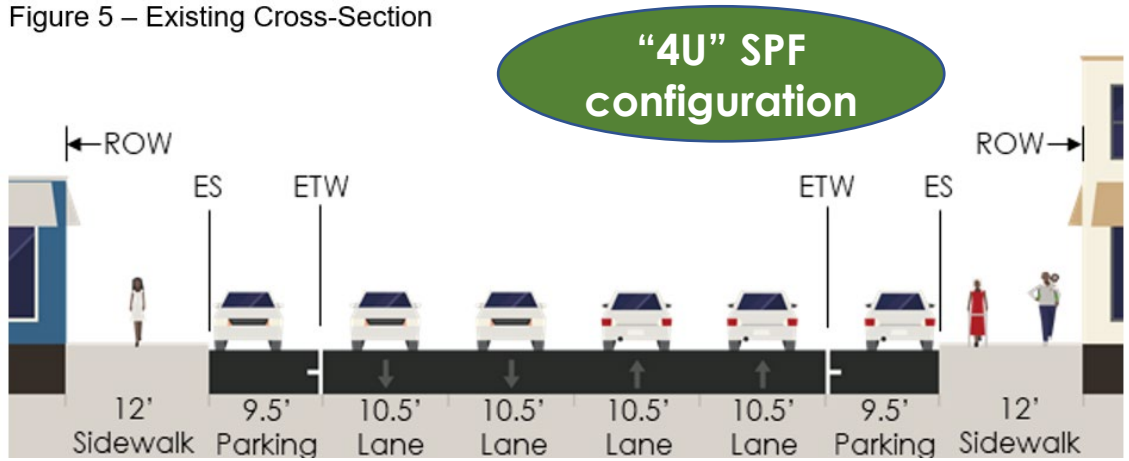
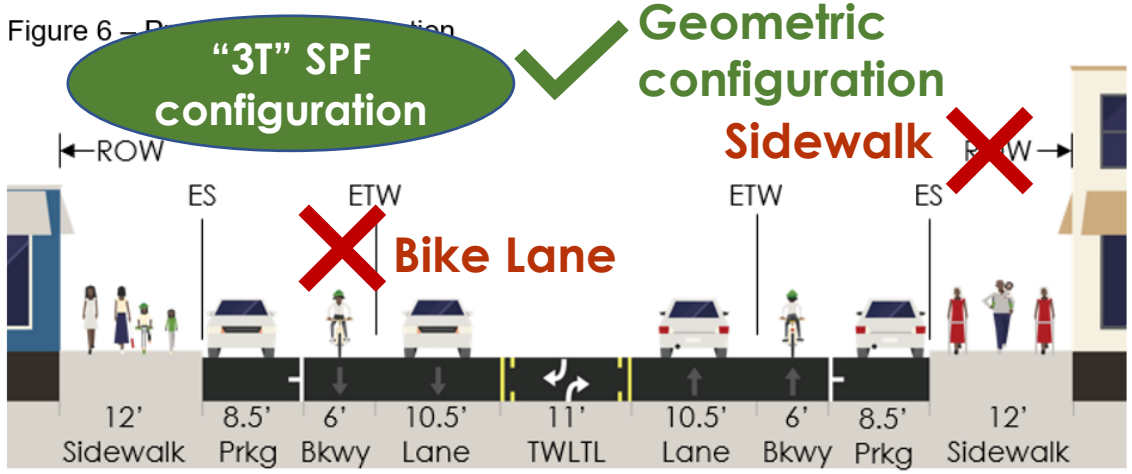


Figure 6 – [illegible]



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cross sectional element widths cannot be analyzed with Part C models

Chapter 12 Example Project[1]: Applying a Part D CMF Quantitatively

No inputs for presence or type for bicycle or pedestrian facilities

1. Can only apply 1 CMF to quantitative results. Determine which CMF should be used
   - The sidewalk is existing and unchanged. Whereas the bike lane is proposed and new feature. Therefore, will choose to find a Class II bike lane CMF.
2. Find the appropriate CMF from the CMF Clearinghouse.

   Part D CMF chosen = 0.40
3. Apply a Part D CMF to the Part C results.

Quantitative Results

Figure 5 – Existing Cross-Section

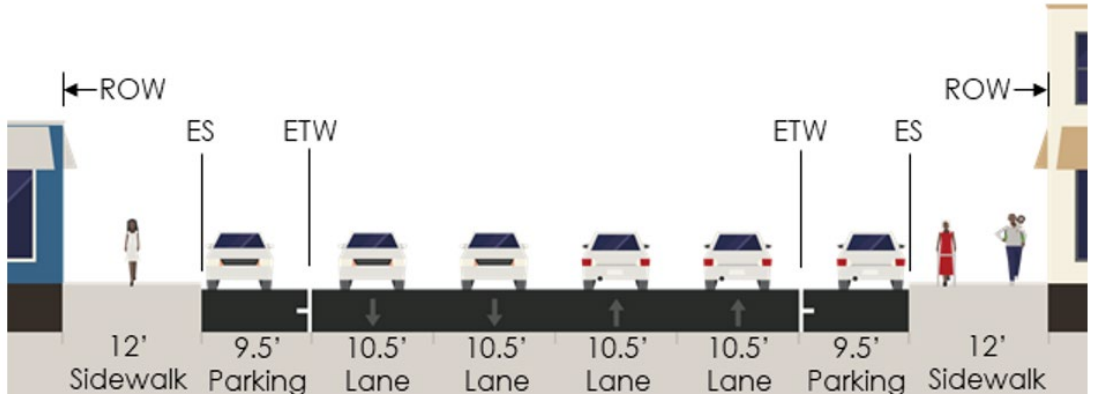
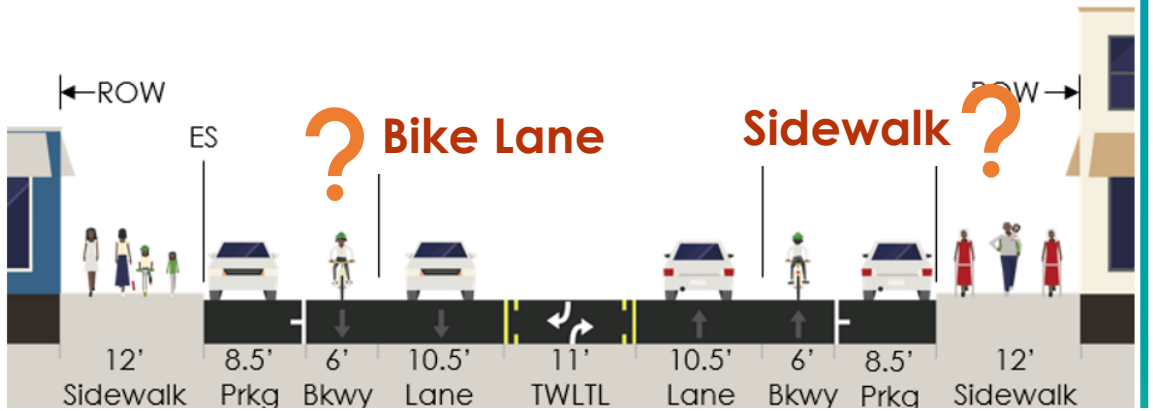


Figure 6 – Proposed Cross-Section



[1] https://dot.ca.gov/-/media/dot-media/programs/design/documents/hsm-application-for-dib-94-projects_2024-01-16_final-a11y.pdf

Chapter 18 – Predictive Method for Freeways

- How are the Freeway mainline methodologies applied to DIB 94 project segments?
- Will a DIB 94 project segment ever be on a Freeway mainline?
- Qualifiers (should meet all):
  - Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;
  - Posted speed within the Complete Streets project segment does not exceed 45 miles per hour; and,
  - A bicycle, pedestrian, or transit facility will be provided or improved within a Complete Streets project segment according to the CSDD.

Chapter 18 – Predictive Method for Freeways

- Conclusion
  - Freeway mainline facilities are not qualified as DIB 94 eligible.

The HSM may still be used to analyze proposed modifications for segments that:

1. **DO NOT** qualify for DIB 94 use, and
2. Meet the "Project Application" requirements in Caltrans' HSM policy.

Chapter 19 – Predictive Method for Ramps (and Ramp Terminal Intersections)

- How are the ramp & ramp terminal intersection methodologies applied to DIB 94 projects?
- Qualifiers (should meet all):
  - Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;
  - Posted speed within the Complete Streets project segment does not exceed 45 miles per hour; and,
  - A bicycle, pedestrian, or transit facility will be provided or improved within a Complete Streets project segment according to the CSDD.

Chapter 19 – But…

- Lane Width

The minimum through, left-turn, and right-turn lane widths should be 10.5 to 12 feet, except this lane width standard does not apply to crossroads (local road or State highway) at interchange locations in the State highway right of way.

Source: DIB 94, pg 42

- Shoulder Width

For right shoulders: The minimum continuous usable paved shoulder width should be 4 feet. In situations where a sidewalk, Class I or Class IV bikeway is provided, the shoulder width of 0 to 4 feet is allowable except the minimum width should be 4 feet at an interchange crossroad (local road or State highway) or adjacent to a barrier or railing.

Source: DIB 94, pg 44

Chapter 19 – Predictive Method for Ramps (and Ramp Terminal Intersections)

- Conclusion
  - DIB 94 lane & shoulder width range flexibility does not apply within the interchange boundary.
  - Lane width must comply with the HDM & shoulder width must comply with DIB 94's 4-feet minimum.

The HSM may still be used to analyze proposed modifications for segments that:

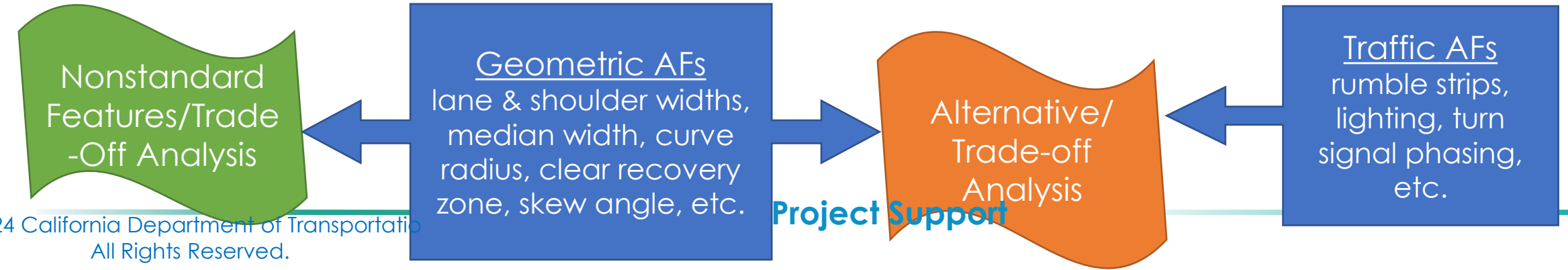
1. **DO NOT** qualify for DIB 94 use, and
2. Meet the "Project Application" requirements in Caltrans' HSM policy.

Presentation Recap

- Overview: HSM Foundational Concepts
- Quantitative vs. Qualitative HSM Analysis
- Caltrans' HSM Policy Memo
- Applying the HSM facility types to DIB 94 Projects
  - Chapter 10 – Rural 2-lane Roads
  - Chapter 11 – Rural Multilane Highways
  - Chapter 12 – Urban & Suburban Arterials
    - Example Project = Quantitative Alternative/Trade-Off HSM Analysis w/ a Part D CMF applied to account for proposed Class II bike lanes
  - Chapter 18 – Freeway Mainline
  - Chapter 19 – Freeway Ramps & Ramp Terminal Intersections

Best Practices: Part C Screening Process – Site-type, Limitations & Features

1) Identify the most appropriate HSM facility type for the project
   - Rural 2 lane, Rural multi-lane, Urban/Suburban arterials, etc.
2) Identify the appropriate roadway/site-type
   - E.g., Rural 4-lane undivided (4U), Five-lane arterial including a TWLTL (5T), etc.
3) AADT limitations for the SPF
   - Check if the project design year AADT falls within the SPF's applicable range
4) Features for consideration
   - Understand the features of the SPF's base conditions
   - Deviations from base conditions = AF

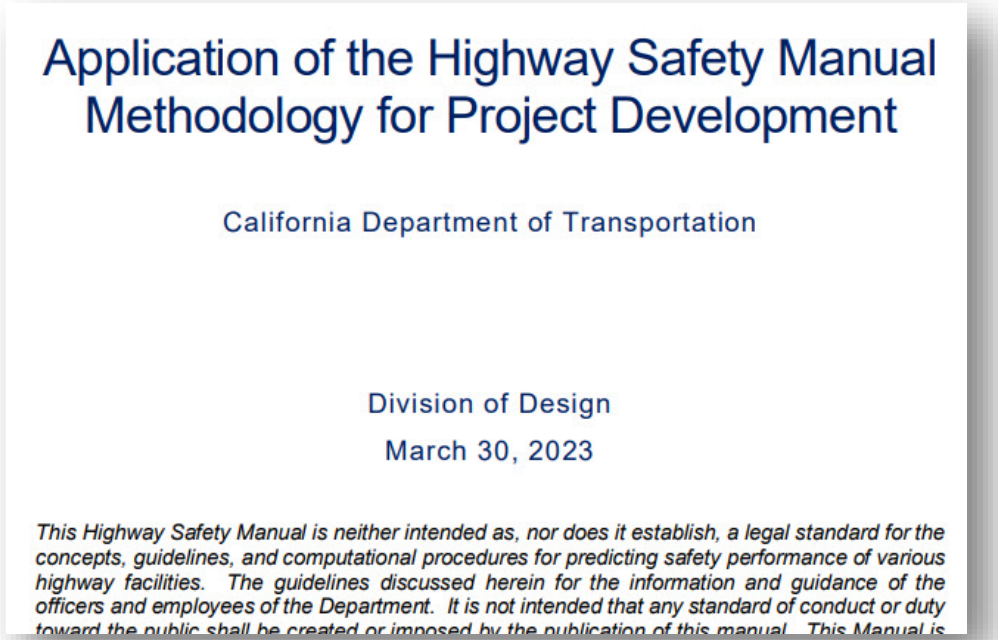


Best Practices: Consideration of HSM Analysis Limits

- Before performing the HSM analysis, determine the limits!
- For fair and accurate comparisons of predicted collision frequency
  - Analysis limits should be the same*:
    1) For all alternatives including the no-build alternative
    2) Between the nonstandard feature configuration and the standard feature configuration

    * Between alternatives or nonstandard and standard feature configuration, segmentation and roadway-type/site-type within the limits need not be the same
  - Limits may extend beyond where the alternatives or the features conform

Resources – Caltrans Guidance



Application of the Highway Safety Manual Methodology for Project Development

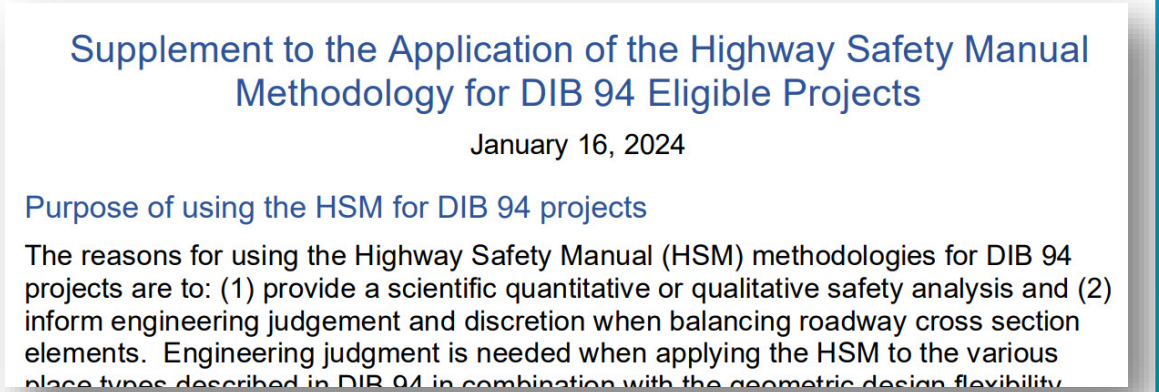
California Department of Transportation

Division of Design

March 30, 2023

This Highway Safety Manual is neither intended as, nor does it establish, a legal standard for the concepts, guidelines, and computational procedures for predicting safety performance of various highway facilities. The guidelines discussed herein for the information and guidance of the officers and employees of the Department. It is not intended that any standard of conduct or duty toward the public shall be created or imposed by the publication of this manual. This Manual is

https://dot.ca.gov/-/media/dot-media/programs/design/documents/application-of-the-hsm-methodolgy-for-project-development_2023-03_final-a11y.pdf



Supplement to the Application of the Highway Safety Manual Methodology for DIB 94 Eligible Projects

January 16, 2024

Purpose of using the HSM for DIB 94 projects

The reasons for using the Highway Safety Manual (HSM) methodologies for DIB 94 projects are to: (1) provide a scientific quantitative or qualitative safety analysis and (2) inform engineering judgement and discretion when balancing roadway cross section elements. Engineering judgment is needed when applying the HSM to the various place types described in DIB 94 in combination with the geometric design flexibility

https://dot.ca.gov/-/media/dot-media/programs/design/documents/hsm-application-for-dib-94-projects_2024-01-16_final-a11y.pdf

THANK YOU!