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 described in Sections 5, 6, and 7.

At this time, the HSM does not include a quantitative Part C safety analysis methodology specifically for pedestrians, bicyclists, or transit. A quantitative analysis may be achieved by combining a completed Part C analysis for motorized users with an appropriate Part D Crash Modification Factor (CMF) to account for cross section changes or for other transportation modes. Aside from a quantitative analysis, a qualitative safety analysis based on the HSM methodologies, which include HSM Part D and the CMF Clearinghouse[1], could be used, along with engineering judgment, as an alternative safety evaluation.

If a Part D CMF is applied to any of these place types, refer to the "Analysis" requirements in Attachment 1 of the April 4, 2022 "*Performance-Based Decision-Making Using the Highway Safety Manual*" memorandum[2] (Memo).

Application of the HSM

Rural Areas, Special Use Areas, and Protected Lands

The Rural Areas, Special Use areas, and Protected Lands described in DIB 94 Section 3.1 and HDM Topic 81.3 are the most compatible place types for the application of the HSM Part C on the State Highway System (SHS). The rural 2-lane, 2-way roads (HSM Chapter 10) and rural multilane highways (HSM Chapter 11) methodologies can analyze various lane and shoulder width combinations, as discussed in the DIB, to determine the safety performance for motorized users. Those quantitative effects, along with consideration of the qualitative effects from a Part D CMF from the HSM or CMF Clearinghouse to address pedestrians, bicyclists, or transit, may be evaluated in conjunction with engineering judgment to provide a more inclusive and holistic safety analysis for the project.

Urban or Suburban Areas

The Urban and Suburban areas described in DIB 94 Section 3.1 and HDM Topic 81.3 are the least compatible with the practical application of the HSM Part C on the SHS. The urban and suburban arterials (HSM Chapter 12) methodologies do not include the ability to analyze any lane or shoulder widths. Thus, any proposed combinations cannot

---

[1] https://www.cmfclearinghouse.org/

[2] https://dot.ca.gov/programs/design/design-memoranda

be analyzed quantitatively using only the urban and suburban arterial Part C methodologies. A qualitative or quantitative analysis may be accomplished if a Part C analysis was completed to address other proposed changes and the appropriate Part D CMF was applied.

Example Project

Disclaimers:

- This example does not represent, nor is it intended to capture all components, elements, or changes for all projects. The concepts presented can be used to assist in developing an HSM analysis for DIB 94 eligible projects or reviewing projects with completed HSM analyses.
- This example below summarizes information and methodologies contained in the 2010 HSM with the 2014 Supplement. For additional details regarding the analyses presented, see the HSM.
- The terminology used in this document is not consistent with the 2010 HSM and/or with the 2014 Supplement. The current HSM uses the acronym "CMF" to describe a crash modification factor used for the Part C and Part D methodologies. This document describes a Part C CMF as an Adjustment Factor (AF) and a Part D CMF as a CMF. This separate terminology is consistent with the forthcoming HSM2. For the purposes of this document, any reference to a "CMF" is meant to indicate a Part D CMF.

This example shows the application of a Part D CMF to a completed Part C analysis as previously discussed. The CMF Clearinghouse was accessed on July 20, 2023, and the search results reflect the CMFs that were available at the time. The CMF Clearinghouse is updated continuously, and periodic review is recommended to obtain new or more appropriate CMFs for each project.

Project Description

A local agency is proposing a road diet project on fictitious State Route 21 in an urban area with mixed land use comprised of residential and commercial zones with nearby schools. The limits of the project span a total of 5 blocks, from Sacramento Street to Oakland Street. Multiple intersections of various configurations and control types exist within the project limits. The purpose of the road diet project is to rehabilitate the existing pavement, reallocate the existing roadway width by reducing the number of through lanes from 4 to 2 lanes, introduce a two-way left-turn lane (TWTL), and install a Class II bike lane in both directions of travel using new pavement striping. See Table 1 and Figures 1 through 6 for a comparison of the before and after conditions throughout the project limits.

A project segment is identified as a DIB 94 project segment if it meets all the following criteria:

1. The Complete Streets project segment is located within an Urban Area, Suburban Area, and/or Rural Main Street place type;
2. Posted speed within the Complete Streets project segment does not exceed 45 miles per hour (mph), and

3. With the implementation of the project, a bicycle, pedestrian or transit facility will be provided or improved within a Complete Streets project segment according to the Complete Streets Decision Document[3].

This example project:

1. Is in an Urban Area
2. Has a 25 mph posted speed, and
3. Will be providing new bicycle facilities and maintaining the existing pedestrian facilities.

Therefore, this project qualifies as a DIB 94 project.

Analysis of the Existing Roadway

Given the project's existing land use type fits within an Urban Community place type, the HSM Part C Chapter 12 Urban & Suburban Arterials model was chosen to analyze the safety performance for the project's existing conditions.

Based on guidance contained in the HSM, the project limits were segmented into four homogenous segments and the "4U" roadway type analysis was used. The "4U" roadway type analysis meets the project's existing conditions because it considers the entire 4-lane roadway cross-section width as continuous width with no physical separation, such as having a median or a barrier, and provides two-way directional travel.

Several AFs are available for the HSM Part C Chapter 12 Urban & Suburban Arterial analysis. The following paragraphs will briefly discuss how some of the AFs were determined, including any assumptions that were documented for the purpose of the analysis. Although all four segments were analyzed individually then aggregated to provide the values contained in the Summary, the information contained below is not intended to serve as replicative data and may be lacking appropriate precision.

The width of the existing four lanes is 10.5 feet, and the width of the existing shoulder is 9.5 feet. Note that the HSM Chapter 12 prediction models do not include an AF for lane width or shoulder width of any type. This means that the safety performance for any lane or shoulder width modifications, or combinations thereof, that utilize the HSM Chapter 12 facility and place type cannot be captured by the current version of the HSM.

There are numerous driveway types throughout the project limits that serve both sides of the roadway. In total over the 4 segments, there are 42 residential driveways that were identified as minor, and 3 industrial/institutional driveways that were identified as minor as defined by the HSM.

The HSM notes that the median width AF is applicable to divided facilities only and that divided is considered a separation by traversable space without traffic barriers. Since the existing conditions do not present this scenario, median width was set to "Not Present."

---

[3] Project Development Procedures Manual – Appendix FF: Complete Streets Decision Documentation: https://dot.ca.gov/-/media/dot-media/programs/design/documents/pdpm-appendixff-a11y.pdf

Table 1 – A Sample of the Project’s Existing and Proposed Conditions

Feature	Existing Conditions	Proposed Conditions
Place Type	Urban	N/C
Number of Through Lanes	4	2
Lane Width	10.5 feet	N/C
Presence of Median	None	Two-Way Left-Turn Lane (TWLTL)
Presence & Type of Parking	Parallel parking on both sides	N/C
Presence of Lighting	Continuous lighting throughout	N/C
Presence of Automated Speed Enforcement	None	N/C
Presence of Driveways	Multiple	N/C
Presence of Fixed Objects	Multiple	N/C
Posted Speed Limit	25 mph	N/C
Presence of Bicycle Facility	No delineated bikeways	Class II Bike Lane
Width of Bicycle Facility	N/A	6 feet
Presence of Pedestrian Features	Sidewalk	N/C
Width of Pedestrian Features	12 feet	N/C
Length of Section (miles)	0.34	N/C
AADT (vehicles/day) (2020 values)[4]	9,200	N/C
Truck Percentage	2.5%	N/C

Notes:

N/C = No change from existing condition

---

[4] Typically, an HSM analysis on the SHS uses existing and project volumes are used over the project’s design life; however, for this example only one year was analyzed.

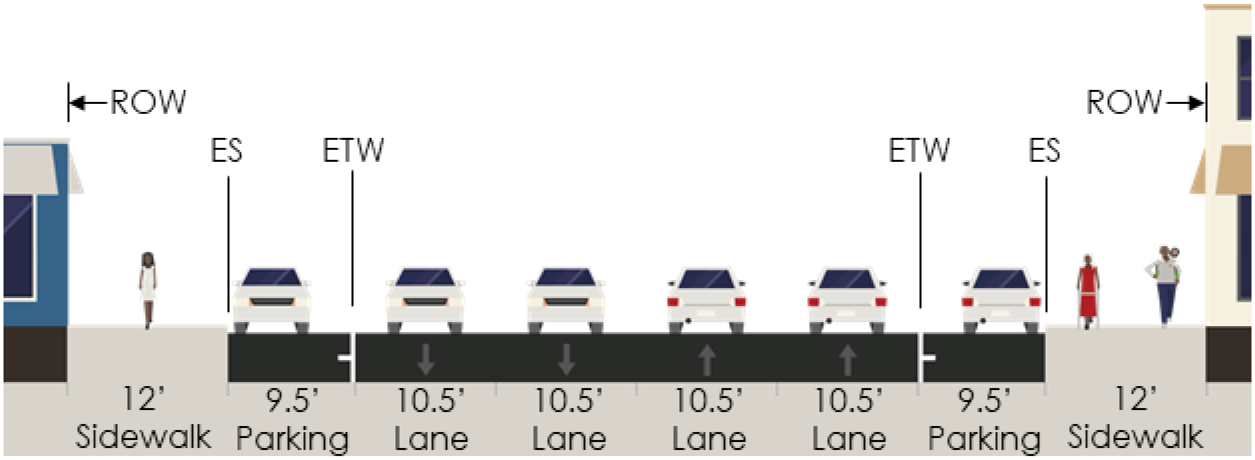
Figure 1 – Location 1 Existing Street View

Figure 2 – Location 1 Proposed Street View

Figure 3 – Location 2 Existing Street View

Figure 4 – Location 2 Proposed Street View

Figure 5 – Existing Cross-Section



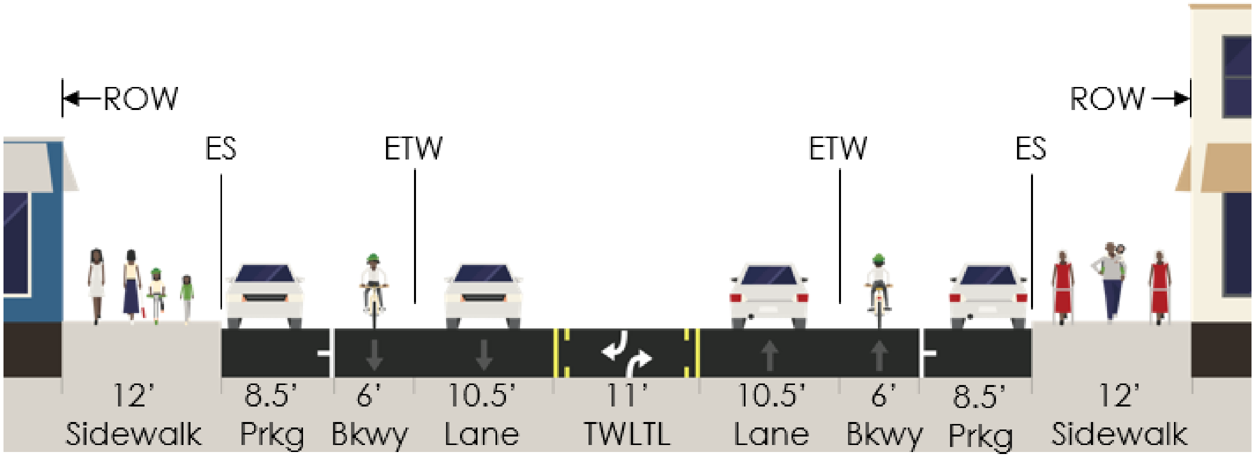
Notes:

ES = Edge of Shoulder

ETW = Edge of Traveled Way

ROW = Right-of-Way

Figure 6 – Proposed Cross-Section



Notes:

Bkwy = Class II Bike Lane

ES = Edge of Shoulder

ETW = Edge of Traveled Way

Prkg = Parking

ROW = Right-of-Way

TWLTL = Two-way Left-Turn Lane

As would be expected in an urban environment, the roadside includes many fixed objects, such as trees, utility poles, lighting, traffic signal poles, fire hydrants, and fence lines on both sides of the roadway. Per the HSM guidance for identifying and tallying fixed objects, an average roadside fixed object density of 96.65 fixed objects per mile was calculated.

The variety of roadside fixed objects and their purposes results in a similar variety in offsets from the edge of traveled way. For example, a continuous fence line may be located further away to protect a residential complex or a business; a fire hydrant will be located closer to better serve emergency needs; or a traffic signal pole may be located closer so that the signal heads line up with the travel lanes. The average offset to roadside fixed objects for all four segments was 11 feet.

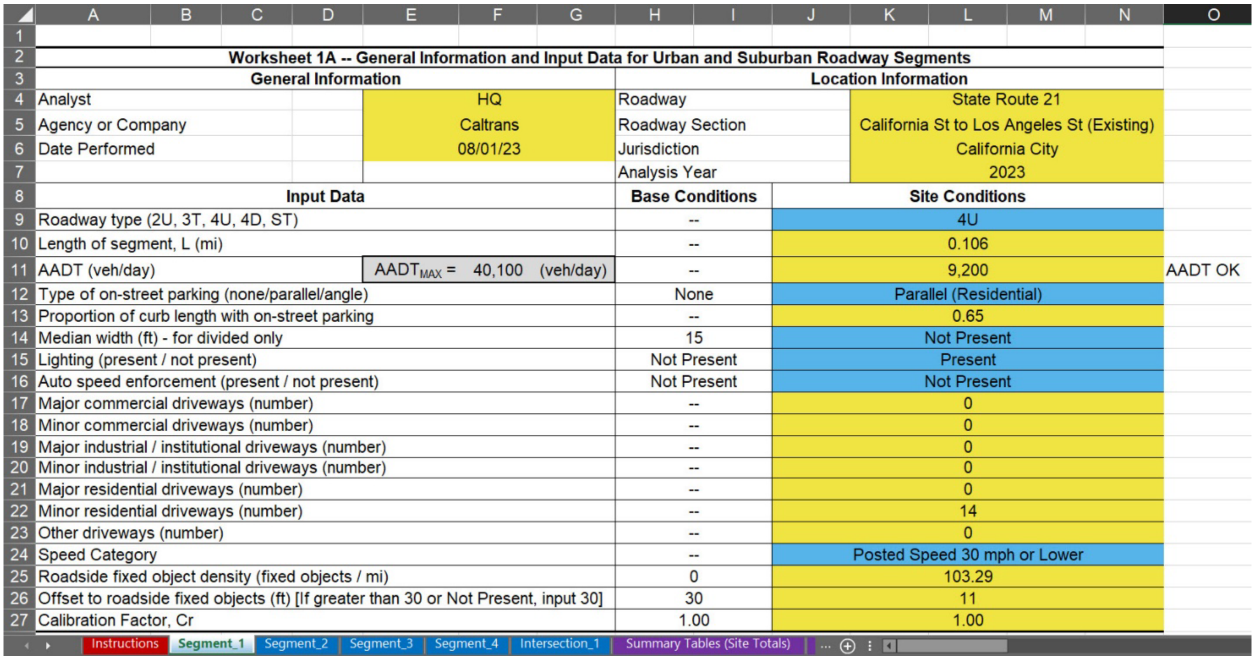
The HSM Chapter 12 Urban & Suburban Arterials analysis includes a methodology to predict fatal and injury (F&I) bicyclist-vehicle and pedestrian-vehicle collisions, which is calculated as a proportional factor of the total vehicle crashes for a selected roadway type. The "4U" roadway type with posted speeds less than 30 miles per hour includes a "Pedestrian Crash Adjustment Factor" (f_{pedr}) of 0.022 and a "Bicycle Crash Adjustment Factor" (f_{biker}) of 0.011. These factors are integrated into the analysis tools and thus are not included as input variables. The output of the analysis is a predicted F&I collision rate between vehicles and bicycles or vehicles and pedestrians.

The presence of lighting throughout the project limits was included in the analysis to capture the effects of lighting on nighttime collisions. The presence of the individual lighting standards was included in the roadside fixed object density calculation to capture the effects of poles on run-off-the-road collisions. Automated speed enforcement was not included in the analysis for any of the segments and should not be included for most projects in California.

An example of the inputs for a roadway segment analysis for this project's existing condition using the Urban & Suburban HSM Spreadsheet Tool is presented below in Figure 7.

The predicted collision frequencies from the analysis of the existing roadway conditions are presented for each segment below in Table 2. Although the intersections within the project limits were analyzed, they are not included for the purpose of this example. Based on the analysis of the existing roadway for the entire project limits, the HSM predicts 1.59 total vehicle-vehicle collisions per year. This total breaks down to 1.07 property damage only (PDO) collision and 0.51 F&I collisions per year.

Figure 7 – Existing Condition Inputs for Segment 1 of the Example Roadway Segment Analysis



Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments

General Information		Location Information	
Analyst	HQ	Roadway	State Route 21
Agency or Company	Caltrans	Roadway Section	California St to Los Angeles St (Existing)
Date Performed	08/01/23	Jurisdiction	California City
		Analysis Year	2023

Input Data		Base Conditions	Site Conditions	
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U	
Length of segment, L (mi)		--	0.106	
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	9,200	AADT OK
Type of on-street parking (none/parallel/angle)		None	Parallel (Residential)	
Proportion of curb length with on-street parking		--	0.65	
Median width (ft) - for divided only		15	Not Present	
Lighting (present / not present)		Not Present	Present	
Auto speed enforcement (present / not present)		Not Present	Not Present	
Major commercial driveways (number)		--	0	
Minor commercial driveways (number)		--	0	
Major industrial / institutional driveways (number)		--	0	
Minor industrial / institutional driveways (number)		--	0	
Major residential driveways (number)		--	0	
Minor residential driveways (number)		--	14	
Other driveways (number)		--	0	
Speed Category		--	Posted Speed 30 mph or Lower	
Roadside fixed object density (fixed objects / mi)		0	103.29	
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	11	
Calibration Factor, Cr		1.00	1.00	

Analysis of the Proposed Roadway

The project's proposed land use type will continue to qualify as an urban community place type, so the HSM Part C Chapter 12 Urban & Suburban Arterials analysis was chosen again to analyze the safety performance for the project's proposed conditions.

Based on guidance contained in the HSM, the project limits were again segmented into four homogenous segments, and the "3T" roadway-type analysis was used. The "3T" roadway-type analysis correctly models the project's proposed conditions because it considers the entire cross-section width of the three-lane roadway as continuous and provides a lane in two directions of travel with a center lane serving as a TWLTL. Utilizing a "3T" roadway type not only models the proposed conditions, but also eliminates the need to use a CMF to assess the four-lane to two-lane road diet effects. Since the Memo's current guidance is to limit use of CMFs to one per segment or intersection, this approach allows for the potential application of a different CMF to capture other proposed changes.

Several AFs are available for the HSM Part C Chapter 12 Urban & Suburban Arterial analysis. The project's scope of work is limited to overlaying and restriping the roadway width to accommodate the addition of a Class II bike lane in each direction so there are no changes from the existing conditions for the following AFs:

- Driveways
- On-street parking
- Roadside fixed object density*
- Lighting

- Automated speed enforcement

  *Although the roadside fixed object density stays the same, the offset from the edge of traveled way changes which is discussed in more detail below.

Table 2 – Predicted Safety Performance for the Existing Conditions (Analysis Year: 2020)[5]

Segment #	Collision Type	Predicted Total Collision Frequency (collision/year)	Predicted F&I Collision Frequency (collision/year)	Predicted PDO Collision Frequency (collision/year)
1	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.22	0.07	0.15
	Multiple-vehicle driveway-related	0.18	0.06	0.12
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.01	0.01	--
2	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.22	0.07	0.15
	Multiple-vehicle driveway-related	0.18	0.06	0.12
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.01	0.01	--
3	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.21	0.07	0.14
	Multiple-vehicle driveway-related	0.21	0.07	0.14
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.01	0.01	--
4	Single vehicle	0.04	0.01	0.03
	Multiple-vehicle non-driveway	0.11	0.04	0.08
	Multiple-vehicle driveway-related	0.02	0.01	0.01
	Vehicle-Bicycle	0.00	0.00	--
	Vehicle-Pedestrian	0.00	0.00	--
Totals	Vehicle Only	**1.59**	**0.51**	**1.07**
Totals	Vehicle-Bicycle	**0.03**	**0.03**	**--**
Totals	Vehicle-Pedestrian	**0.03**	**0.03**	**--**

---

[5] The HSM considers all vehicle-bicycle and vehicle-pedestrian predicted collisions as F&I collisions only.

Like the existing conditions analysis, the HSM notes that the median width AF is applicable to divided facilities only, meaning divided by traversable space without traffic barriers. Although a TWLTL can be considered traversable space from a practical driver's perspective, TWLTLs are identified specifically as not serving the purpose of a median for an HSM analysis. Therefore, since the proposed conditions also do not include a median, the median width AF was set to "Not Present." In addition, the TWLTL is already accounted for by selecting the "3T" roadway type.

The "3T" roadway type with posted speeds less than 30 miles per hour includes a "Pedestrian Crash Adjustment Factor" (f_{pedr}) of 0.041 and a "Bicycle Crash Adjustment Factor" (f_{biker}) of 0.027. These factors are integrated into the available analysis tools and thus are not included as input variables. The predicted bicycle and pedestrian collisions for the proposed conditions are anticipated to be higher than the existing conditions due to the higher factors associated with the "3T" roadway type. The analysis presents a predicted F&I collision rate between vehicles and bicycles or vehicles and pedestrians.

Although neither the fixed object density nor the location of the existing fixed objects has changed, a change to the offset to roadside fixed objects that represents the proposed conditions is required because the edge of traveled way has shifted. This has occurred due to the elimination of one through lane in each direction and the addition of 6-feet-wide Class II bike lanes in each direction. The average offset to roadside fixed objects for all four segments was 15 feet.

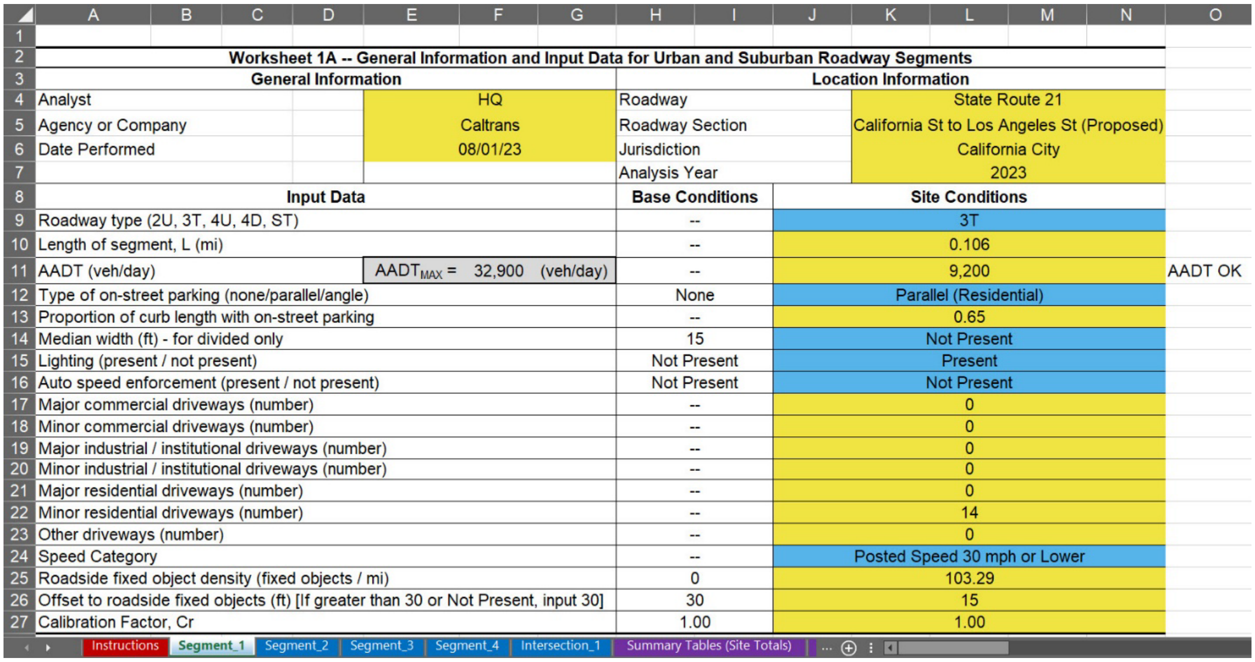
The width of the proposed two lanes is 10.5 feet, the width of the TWLTL is 11 feet, and the width of the proposed shoulder is 14 feet. As noted previously, the HSM Chapter 12 prediction models do not include an AF for lane width of any type, including the TWLTL, or shoulder width. This means that the safety performance for any modifications in lane and shoulder width, or combinations thereof including two-way left-turn lanes, that utilize the HSM Chapter 12 facility and place type cannot be captured by the current HSM.

An example of the inputs for a roadway segment analysis for the proposed project improvements using the Urban & Suburban HSM Spreadsheet Tool is presented below in Figure 8.

Although all four segments were analyzed individually then aggregated to provide the values contained in the summary, the information contained below is not intended to serve as replicative data and may be lacking appropriate precision.

The predicted collision frequencies from the analysis of the proposed conditions are presented by segment below in Table 3. Although the intersections within the project limits were analyzed, they are not included for the purpose of this example. Based on the proposed roadway analysis of the entire project limits, the HSM predicts 1.49 total vehicle-vehicle collisions per year. This total breaks down to 1.13 PDO collision and 0.36 F&I collisions per year.

Figure 8 – Proposed Condition Inputs for Segment 1 of the Example Roadway Segment Analysis



1					
2	**Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments**				
3	**General Information**		**Location Information**		
4	Analyst	HQ	Roadway	State Route 21	
5	Agency or Company	Caltrans	Roadway Section	California St to Los Angeles St (Proposed)	
6	Date Performed	08/01/23	Jurisdiction	California City	
7			Analysis Year	2023	
8	**Input Data**		**Base Conditions**	**Site Conditions**	
9	Roadway type (2U, 3T, 4U, 4D, ST)		--	3T	
10	Length of segment, L (mi)		--	0.106	
11	AADT (veh/day)	$AADT_{MAX}$ = 32,900 (veh/day)	--	9,200	AADT OK
12	Type of on-street parking (none/parallel/angle)		None	Parallel (Residential)	
13	Proportion of curb length with on-street parking		--	0.65	
14	Median width (ft) - for divided only		15	Not Present	
15	Lighting (present / not present)		Not Present	Present	
16	Auto speed enforcement (present / not present)		Not Present	Not Present	
17	Major commercial driveways (number)		--	0	
18	Minor commercial driveways (number)		--	0	
19	Major industrial / institutional driveways (number)		--	0	
20	Minor industrial / institutional driveways (number)		--	0	
21	Major residential driveways (number)		--	0	
22	Minor residential driveways (number)		--	14	
23	Other driveways (number)		--	0	
24	Speed Category		--	Posted Speed 30 mph or Lower	
25	Roadside fixed object density (fixed objects / mi)		0	103.29	
26	Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	15	
27	Calibration Factor, Cr		1.00	1.00	

Table 3 – Predicted Safety Performance for the Proposed Conditions (Analysis Year: 2020)[6]

Segment #	Collision Type	Predicted Total Collision Frequency (collision/year)	Predicted F&I Collision Frequency (collision/year)	Predicted PDO Collision Frequency (collision/year)
1	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.25	0.06	0.19
	Multiple-vehicle driveway-related	0.13	0.03	0.10
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.02	0.02	--
2	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.24	0.06	0.19
	Multiple-vehicle driveway-related	0.13	0.03	0.10
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.02	0.02	--
3	Single vehicle	0.07	0.02	0.05
	Multiple-vehicle non-driveway	0.27	0.05	0.18
	Multiple-vehicle driveway-related	0.15	0.04	0.11
	Vehicle-Bicycle	0.01	0.01	--
	Vehicle-Pedestrian	0.02	0.02	--
4	Single vehicle	0.03	0.01	0.02
	Multiple-vehicle non-driveway	0.12	0.03	0.09
	Multiple-vehicle driveway-related	0.01	0.00	0.01
	Vehicle-Bicycle	0.00	0.00	--
	Vehicle-Pedestrian	0.01	0.01	--
Totals	Vehicles Only	**1.49**	**0.36**	**1.13**
Totals	Vehicle-Bicycle	**0.03**	**0.03**	**--**
Totals	Vehicle-Pedestrian	**0.07**	**0.07**	**--**

A segment-to-segment and collision-type to collision-type comparison of the F&I annual collision frequency is shown below in Table 4. The analysis shows an improvement in vehicular safety in the proposed conditions. Not only did the total predicted annual vehicle-vehicle collision frequency reduce from 1.59 to 1.49, but more importantly, the F&I annual vehicle-vehicle collision frequency reduced from 0.51 to 0.36. However, the

---

[6] The HSM considers all vehicle-bicycle and vehicle-pedestrian predicted collisions as F&I collisions only.

analysis shows a diminished safety performance for pedestrians. A segment-to-segment comparison indicates that the predicted change is due to an increase in predicted vehicle-pedestrian collisions for the proposed condition. Utilizing different roadway types for the existing and proposed conditions analyses and their inherently different Bicycle and Pedestrian Crash AFs may be the primary reason for the predicted change.

Table 4 – Predicted Safety Performance Comparison of the F&I Collisions for the Existing vs Proposed Conditions[7]

Segment #	Collision Type	Predicted F&I Collision Frequency for Existing Conditions (collision/year)	Predicted F&I Collision Frequency for Proposed Conditions (collision/year)
1	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.06
	Multiple-vehicle driveway-related	0.06	0.03
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
2	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.06
	Multiple-vehicle driveway-related	0.06	0.03
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
3	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.05
	Multiple-vehicle driveway-related	0.07	0.04
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
4	Single vehicle	0.01	0.01
	Multiple-vehicle non-driveway	0.04	0.03
	Multiple-vehicle driveway-related	0.01	0.00
	Vehicle-Bicycle	0.00	0.00
	Vehicle-Pedestrian	0.00	0.01
Totals	Vehicles Only	**0.51**	**0.36**
Totals	Vehicle-Bicycle	**0.03**	**0.03**
Totals	Vehicle-Pedestrian	**0.03**	**0.07**

---

[7] The HSM considers all vehicle-bicycle and vehicle-pedestrian predicted collisions as F&I collisions only.

Part D Crash Modification Factor

Caltrans' "Project Application" guidance in the Memo includes several reasons for utilizing a CMF, one of which is overcoming Part C model limitations. For this project, a limitation of the HSM Part C Chapter 12 Urban & Suburban Arterials roadway model is the lack of a more thorough and representative bicycle and pedestrian feature analysis. Although the HSM Part C models provide vehicle-bicycle and vehicle-pedestrian collision frequency outputs, no inputs are available to account for the presence and type of bicycle or pedestrian facilities. Based on the project scope and available AFs in the Chapter 12 crash prediction models, a CMF could be sought and applied to determine the safety performance of installing a Class II bike lane or the presence of a sidewalk.

The CMF Clearinghouse was used to identify an appropriate CMF for this project. Focusing on the pedestrian features in the project, a sidewalk is present in the existing conditions and the same unchanged sidewalk will be present in the proposed conditions. Although the HSM analysis shows a predicted increase in collision frequency for pedestrians, this appears mainly due to the different "Pedestrian Crash Adjustment Factor" (f_{pedr}) associated with the different existing and proposed roadway types.

This presents an opportunity to pause and consider a holistic view of the project with all the project factors combined. A comparison of the quantitative analysis that the HSM provides to engineering judgement could be made to assess anticipated effects of the bike lane addition to the safety performance of the sidewalk. From a practical user's perspective and use of engineering judgement, the proposed conditions could result in improved safety due to increased offset from roadside fixed objects. The proposed conditions move the edge of traveled way closer to the center of the roadway which provides additional separation between a motorized user in the roadway and a pedestrian using the sidewalk.

The project team has concluded and documented the following assumption: since the sidewalk will be unmodified by the project, there's no anticipated additional pedestrian safety performance gained by leaving the sidewalk as-is and there is no anticipated degradation in pedestrian safety performance by the proposed roadway reconfiguration. Therefore, a CMF that captures the presence of the sidewalk is not necessary. This is documented as Assumption #1.

Focusing on the bicycle features in the project, the project proposes to add a new Class II bike lane in both directions of vehicular travel to facilitate easier and more comfortable bicycle use. The two new bike lanes will each be 6 feet in width. Since this is a feature that will be modified from the existing conditions, a change in safety performance may be expected for various road users. Exploring the CMF Clearinghouse for bike lanes, or similar terminology, could determine how much of a change in safety performance can be expected.

Finding an Appropriate CMF

The CMF Clearinghouse contains over 8,300 CMFs, from those compiled in the Highway Safety Manual Part D, to those developed from other national and international research. CMFs were developed from sites with certain prior project characteristics, such as a specific traffic volume range, place type, number of lanes, etc., and comparing them to the same or other comparable post-project sites. Many of these characteristics are available on an individual CMF Details website under the "Applicability," "Developmental Details," or "Other Details" sections or from the research that developed the CMF, which is sometimes available.

The "appropriateness" of a CMF can be linked to:

- Matching a project's conditions to the CMF's "Applicability."
- Verifying that the "Developmental Details" adequately represent the project.
- Verifying that any "Other Details" coincide with the project features.
- Verifying the CMFs crash type and/or crash severity represent the desired safety performance measure (e.g., fatal, F&I, vehicle-pedestrian, vehicle-bicycles, etc.).
- Determining whether it is statistically significant. A statistically significant CMF does not pass through 1.0 with its error applied within the selected confidence interval.

There may be situations where one or more of the criteria above may not be met for a specific CMF, but it is determined that utilizing it is still reasonable in a qualitative analysis. Although a quantitative analysis is the first preference, it is not always possible, however, a qualitative analysis may still be available as a second preference. A qualitative analysis is the theoretical application of a CMF to describe an anticipated trend. These can be applied holistically to the project as a whole or for a specific feature.

When using a CMF, both the District Design and Traffic Operations/Safety HSM subject matter experts (SMEs) must concur with the intended application of the CMF and supporting justifications for use of the CMF must be documented in the appropriate document, as described in the Memo.

"Bicycle," "Bike," "Bike Lane," "Bikeway," and "Bike way" were all terms used when searching the CMF Clearinghouse for a CMF to capture the installation of the Class II bike lanes for this project and the potential candidates were identified below, along with a brief summary of the CMF's intended effects and why they may or may not be a good fit for this project:

- CMF ID: 3092 – Install Bicycle Boulevard (https://www.cmfclearinghouse.org/detail.php?facid=3092)
    - This CMF represents a bicycle boulevard in an urban environment in Berkeley, CA where a traffic-calmed area which prioritizes bicycles is installed in an area where one did not exist previously, but traffic-calming measures were still present. This CMF applies to vehicle-bicycle collisions. The example project does not propose to install a bicycle boulevard.
- CMF ID: 10737 – Install Bicycle Lanes (https://www.cmfclearinghouse.org/detail.php?facid=10737)
    - This CMF represents the installation of bicycle lanes on urban four-lane undivided roadways in Texas for all collision types and all collision severities. The installation results in reduced lane or shoulder width and

    no change in bicycle volumes. The base condition was 11-foot lanes, no shoulder, and no median. The example project's existing 10.5-foot lane width does not match the CMF's base condition lane width of 11 feet. In addition, the example project's existing shoulder width does not match the base condition for this CMF.

- CMF ID: 2152 – Install Bicycle Tracks (https://www.cmfclearinghouse.org/detail.php?facid=2152)
    - This CMF represents the installation of bicycle tracks in Denmark for multiple vehicle-pedestrian collisions of all severities. Note that this CMF identifies the pedestrians as pedestrians from the right specifically. The example project is not installing a bicycle track, also known in California as a Class IV bikeway[8], and the bicyclist and moped behavior in Denmark is different than that of this location in California. Additionally, the CMF did not have a large sample size and the analysis methodology was not strong.
- CMF ID: 2135 – Install Bicycle Tracks (https://www.cmfclearinghouse.org/detail.php?facid=2135)
    - This CMF represents the installation of bicycle tracks in Denmark for all collision severities. Note that this CMF applies to bicycle-moped collisions. The example project does not propose a bicycle track and the bicyclist behavior in Denmark is different than that of this location in California, and this location is not focused on moped-bicycle collisions. Additionally, the CMF did not have a large sample size and the analysis methodology was not strong.
- CMF ID: 4101 – Install Cycle Tracks, Bike Lanes, or On-street Cycling (https://www.cmfclearinghouse.org/detail.php?facid=4101)
    - This CMF represents the installation of cycle tracks, bike lanes, or on-street cycling in urban environments with one to three lanes on roads without prior cycle facilities in Montreal, Canada. Bike lanes are defined as unidirectional and are not separated from traffic by a physical barrier. This CMF applies to vehicle-bicycle collisions for A (severe injury), B (other visible Injury), and C (complaint of pain) collision severities. The example project is installing bike lanes as defined by the CMF, however the sample size that was available to develop the CMF was not large.
- CMF ID: 1719 – Provide Bike Lanes (https://www.cmfclearinghouse.org/detail.php?facid=1719)
    - This CMF represents the installation of bike lanes where there were not any previously, and applies to vehicle-bicycle collisions of K, A, B, and C severities. Further investigation into the research that developed the CMF identifies that it was focused on the application of bike lanes at intersections and is representative of driver and bicyclist behaviors in Denmark. As noted previously, this example is focused on the roadway analysis, not the intersection analysis, and the driver and bicyclist behaviors in Denmark are different than those at this location in California.

---

[8] Design Information Bulletin 89 – Class IV Bikeway Guidance (Separated Bikeway/Cycle Tracks): https://dot.ca.gov/-/media/dot-media/programs/design/documents/dib-89-02-final-a11y.pdf

- CMF ID: 10738 – Install Bicycle Lanes (https://www.cmfclearinghouse.org/detail.php?facid=10738)
    - This CMF represents the installation of bicycle lanes on urban four-lane undivided roadways in Texas for all collision types and all collision severities. The installation results in reduced lane or shoulder width and a 20% increase in bicycle volumes. The base condition was 11-foot lanes, no shoulder, and no median. The example project's existing 10.5-foot lane width does not match the CMF's base condition lane width of 11 feet.
- CMF ID: 2144 – Install Bicycle Tracks (https://www.cmfclearinghouse.org/detail.php?facid=2144)
    - This CMF represents the installation of bicycle tracks in Denmark for vehicle-bicycle collisions and all collision severities. Note that this CMF applies to collisions with multiple vehicles turning left with bicycles/mopeds. The example project does not propose a bicycle track and the bicyclist behavior in Denmark is different than that of this location in California, and this location is not focused on moped-bicycle collisions. Additionally, the CMF did not have a large sample size and the analysis methodology was not strong.
- CMF ID: 7841 – Install Bicycle Lanes (https://www.cmfclearinghouse.org/detail.php?facid=7841)
    - This CMF represents the installation of bicycle lanes on a minimum of two-lane roadways in Florida which applies to vehicle-bicycle collisions and K, A, B, and C collision severities. The example project's analysis is focused on F&I vehicle-bicycle collisions.

Utilizing the "appropriateness" criteria identified above, the CMF summaries, and engineering judgement, CMF ID 7841 - Install Bicycle Lanes represents the best match to the project. That CMF identifies a value of 0.4, with an unadjusted standard error of 0.09, when installing bicycle lanes on a two-lane road where there were none previously. The CMF applies to vehicle-bicycle collisions of F&I collision severities. Selection of this CMF is documented as Assumption #2.

Applying the Part D CMF

Per the Memo, "for a quantitative analysis, a Part D CMF must be applied to the output of a Part C method analysis." Therefore, to obtain a quantitative analysis that accounts for the installation of the Class II bike lanes, the proposed vehicle-bicycle Part C output shown is multiplied by the CMF in Table 3. The CMF can be applied in this way per each segment or to an aggregated total. This example will apply the CMF to the aggregated total F&I vehicle-bicycle collisions indicated in Table 3.

If the error of the CMF is available, the calculation of an appropriate confidence interval is used to determine the range of statistical application due to the error. The selected CMF for this project includes an unadjusted standard error of 0.09.

Confidence intervals can vary, but they are essentially a range represented by a certain number of standard deviations away from the mean. Through the HSM lens, the CMF represents the mean, and the error represents the standard deviation. For this project, a 95% confidence interval was selected because it captures a reasonably large anticipated application of the CMF; the CMF with its error is anticipated to be true 95% of the time. Note that other confidence intervals may be appropriate for other projects or other CMFs. A 95% confidence interval is approximately 2 standard deviations away from the mean in the positive direction and the negative direction, representing an upper and lower limit – ±2.

Calculation of the 95% confidence interval follows:

95% Confidence Interval = CMF ± 2 (Error)

95% Confidence Interval (Upper Limit) = 0.4 + 2(0.09) = 0.58

95% Confidence Interval (Lower Limit) = 0.4 – 2(0.09) = 0.22

95% Confidence Interval = 0.22 – 0.58

A CMF is statistically significant if its value with its applicable error applied with the selected confidence interval does not pass through 1.0. For example, CMF ID 1719 includes a CMF value of 0.65 with a 0.2 unadjusted standard error. Calculating the applicable CMF range at the 95% confidence interval results in a range of 0.25 – 1.05. Since the range passes through 1.0, this is not a statistically significant CMF for use quantitatively. This range indicates the CMF's effects to be a decrease in collisions or an increase in collisions. For project application, it would be difficult to discern if this CMF would increase or decrease collisions.

Applying the CMF's confidence interval to a completed Part C Analysis is a simple multiplication of the CMF to the upper and lower limits which results in the range of the CMF's effects on the predicted vehicle-bicycle collisions:

The updated total = total predicted fatal & injury vehicle-bicycle collision frequency for the proposed conditions x CMF (lower limit) and CMF (upper limit)

= 0.03 collisions/year x 0.22 = 0.01

= 0.03 collisions/year x 0.58 = 0.02

The updated total predicted F&I vehicle-bicycle collision frequency for the proposed conditions with a bike lane installed (per CMF ID 7841) = 0.01 – 0.02. The updated total demonstrates a reduction in F&I vehicle-bicycle collisions, which is a favorable result for the project and, more importantly, the public.

An updated segment-to-segment and collision-type to collision-type comparison of the F&I annual collision frequency is shown below in Table 5. Several reasonable assumptions were made, which were concurred with by the District HSM SMEs, and documented to appropriately apply the HSM to this project, including a possibly improved pedestrian safety performance, despite the HSM prediction, due to a proposed increase in physical separation between motorized users and pedestrians.

In total, per the documented assumptions, namely the anticipated safety effects of increased separation from the sidewalk and the choice of the CMF, and a completed HSM analysis, this project would result in an overall reduction in F&I collisions for the proposed conditions. Implementing this project would support Director's Policy 36:

Road User Safety[9], which outlines Caltrans' goal to prioritize the reduction of F&I collisions to zero by 2050.

Table 5 – Updated Predicted Safety Performance Comparison of the F&I Collisions for the Existing vs Proposed Conditions (with applicable Part D CMFs)[10]

Segment #	Collision Type	Predicted F&I Collision Frequency for Existing Conditions (collision/year)	Predicted F&I Collision Frequency for Proposed Conditions (collision/year)
1	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.06
	Multiple-vehicle driveway-related	0.06	0.03
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
2	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.06
	Multiple-vehicle driveway-related	0.06	0.03
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
3	Single vehicle	0.02	0.02
	Multiple-vehicle non-driveway	0.07	0.05
	Multiple-vehicle driveway-related	0.07	0.04
	Vehicle-Bicycle	0.01	0.01
	Vehicle-Pedestrian	0.01	0.02
4	Single vehicle	0.01	0.01
	Multiple-vehicle non-driveway	0.04	0.03
	Multiple-vehicle driveway-related	0.01	0.00
	Vehicle-Bicycle	0.00	0.00
	Vehicle-Pedestrian	0.00	0.01
Totals	Vehicles Only	**0.51**	**0.36**
Totals	Vehicle-Bicycle	**0.03**	**0.01 – 0.02**
Totals	Vehicle-Pedestrian	**0.03**	**0.07**

---

[9] https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/policy/dp_36-a11y.pdf

[10] The HSM considers all vehicle-bicycle and vehicle-pedestrian predicted collisions as F&I collisions only.