HSM Practitioners Guide to Urban and Suburban Streets

Prediction of Crash Frequency for Suburban/Urban Streets

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Safe Roads for a Safer Future
Investment in roadway safety saves lives

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Learning Outcomes:

- ► Describe the models to Predict Crash Frequency for Multilane Suburban/Urban Streets
- ►Describe Crash Modification Factors for Multilane Suburban/Urban Streets
- ►Apply Crash Modification Factors (CMF's) to Predicted Crash Frequency for Multilane Suburban/Urban Streets

Defining Urban Multilane Highways

- HSM Methodology applies to arterial four-lane undivided and divided urban and suburban highways.
- Urban and Suburban areas are defined as areas within the urban and urbanized area boundaries established by FHWA. These include all areas with populations of 5,000 or more.
- Some areas beyond the FHWA boundaries may be treated as urban or suburban if the boundaries have not been adjusted to include recent development.
- The boundary dividing rural and urban areas can at times be difficult to determine, especially since most multilane rural highways are located on the outskirts of urban agglomerations.
- These procedures may be used for any multilane road in which the general design features and land use setting are urban or suburban in nature rather than rural.

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

Five Types of Roadway Segments:

- (**2U**) Two-lane undivided arterials
- (**3T**) Three-lane arterials including a center two-way Left Turn Lane
- (**4U**) Four-lane undivided arterials
- (**4D**) Four-lane divided arterials (including a raised or depressed median)
- (**5T**) Five-lane arterials including a center TWLTL

Limitations as to AADT for Urban/Suburban Roadway Models

- 2U: 0 to 32,600 vehicles per day
- 3T : 0 to 32,900 vehicles per day
- 4U: 0 to 40,100 vehicles per day
- 4D: 0 to 66,000 vehicles per day
- 5T: 0 to 53,800 vehicles per day

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Separate Prediction Models for:

- Homogeneous highway segments
- Intersections
  - Sum of Individual Intersection Calculations

Subdividing Roadway Segments

- Before applying the safety prediction methodology to an existing or proposed rural segment facility, the roadway must be divided into analysis units consisting of individual homogeneous roadway segments and intersections.
- A new analysis section begins at each location where the value of one of the following variables changes (alternatively a section is defined as homogenous if none of these variables changes within the section):
  - Annual Average daily traffic (AADT) volume (veh/day)
  - Number of through lanes
  - Presence/Type of a median
  - Presence/Type of Parking
  - Roadside Fixed Object density
  - Presence of Lighting
  - Speed category

Subdividing Roadway Segments

homogeneous roadway segments – Median Width:

Measured Median Width	Rounded Median Width
1-ft to 14-ft	10-ft
15-ft to 24-ft	20-ft
25-ft to 34-ft	30-ft
35-ft to 44-ft	40-ft
45-ft to 54-ft	50-ft
55-ft to 64-ft	60-ft
65-ft to 74-ft	70-ft
75-ft to 84-ft	80-ft
85-ft to 94-ft	90-ft
95 or more	100-ft

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

Five types of Collisions are considered:

1) Multiple-vehicle nondriveway crashes
2) Single-vehicle crashes
3) Multiple-vehicle driveway related crashes
4) Vehicle-pedestrian crashes
5) Vehicle-bicycle collisions

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Procedure for safety prediction for a roadway segment:

►Combine base models, CMFs, and calibration factor

- $N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$
- $N_{br} = N_{spf\ rs}\ (CMF_{1r} \times CMF_{2r} \times \ldots\ CMF_{nr})$
- $N_{predicted\ rs} = (N_{br} + N_{pedr} + N_{biker})\ C_r$

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Where:

- N_{brmv} = Predicted number of multiple-vehicle non-driveway crashes per year for base conditions
- N_{brsv} = Predicted number of single-vehicle collision and non-collision crashes per year for base conditions
- N_{brdwy} = Predicted number of multiple-vehicle driveway related crashes per year

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{br} = N_{spf\ rs} \times (CMF_{1r} \times CMF_{2r} \times .. CMF_{nr})$$

Where:

- **N_{br}** = Predicted number of total roadway segment crashes per year with CMFs applied (excluding ped and bike collisions)
- **$N_{spf\ rs}$** = Predicted number of total roadway segment crashes per year for base conditions
- **CMF_{1r} CMF_{2r}, .. CMF_{nr}** = Crash Modification Factors for roadway segments

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{predicted\ rs} = (N_{br} + N_{pedr} + N_{biker})\, C_r$$

Where:

- $N_{predicted\ rs}$ = Predicted number of total roadway segment crashes per year
- N_{br} = Predicted number of total roadway segment crashes per year with CMFs applied
- N_{pedr} = Predicted number of vehicle-pedestrian collisions per year
- N_{biker} = Predicted number of vehicle-bicycle collisions per year
- C_r = calibration factor for a particular geographical area

Combining Safety Predictions for an Entire Series of Segments

$$N_{total\ predicted} = Sum\ N_{rs} + Sum\ N_{int}$$

Where:

$N_{total\ predicted}$ = Predicted crash frequency for the entire arterial street

N_{rs} = Predicted number of total roadway segment crashes

N_{int} = Predicted number of total intersection-related crashes

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

►No procedure has been developed for application to six-lane undivided (6U) nor for six-lane divided (6D) arterials.

- Until such procedures are developed:

► The procedures for 4U arterials may be applied to 6U arterials and for 4D arterials to 6D arterials.

►These procedures should be applied cautiously to 6U and 6D arterials because this application is not based on data for 6U and 6D arterials.

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Multiple-Vehicle NonDriveway Crashes

$$N_{brmv} = \exp(a + b \ln(AADT) + \ln(L))$$

Where:

AADT = Annual Average Daily Traffic (veh/day)

L = Length of roadway segment (mi)

a & b = regression coefficients (Table 12-3)

Multiple-Vehicle NonDriveway Crashes

$$N_{brmv} = \exp(a + b\ln(AADT) + \ln(L))$$

Table 12-3. SPF Coefficients for Multiple-Vehicle Nondriveway Collisions on Roadway Segments

	Coefficients Used in Equation 12-10	
Road Type	**Intercept (a)**	**AADT (b)**
Total crashes		
2U	–15.22	1.68
3T	–12.40	1.41
4U	–11.63	1.33
4D	–12.34	1.36
5T	–9.70	1.17

Table 12-3. SPF Coefficients for Multiple-Vehicle Nondriveway Collisions on Roadway Segments

Road Type	Coefficients Used in Equation 12-10: Intercept (a)	Coefficients Used in Equation 12-10: AADT (b)	Overdispersion Parameter (k)
Total crashes			
2U	−15.22	1.68	0.84
3T	−12.40	1.41	0.66
4U	−11.63	1.33	1.01
4D	−12.34	1.36	1.32
5T	−9.70	1.17	0.81
Fatal-and-injury crashes			
2U	−16.22	1.66	0.65
3T	−16.45	1.69	0.59
4U	−12.08	1.25	0.99
4D	−12.76	1.28	1.31
5T	−10.47	1.12	0.62
Property-damage-only crashes			
2U	−15.62	1.69	0.87
3T	−11.95	1.33	0.59
4U	−12.53	1.38	1.08
4D	−12.81	1.38	1.34
5T	−9.97	1.17	0.88

Predicting Crash Frequency for a Suburban Street – Example:

<u>4-lane Undivided commercial Suburban Street:</u>

- AADT = 24,000
- Length = 3.6 miles

1st, Calculate Predicted Crash Frequency for Multiple-Vehicle NonDriveway Crashes - use 4U coefficients from Table 12-3

$\mathbf{N_{brmv}} = \exp(a + b\ \ln(AADT) + \ln(L))$

$= \exp(-11.63 + 1.33\ \ln(24{,}000) + \ln(3.6))$

$= \exp(3.065)$

= **21.4** crashes/yr

Safety Performance Function (SPF)

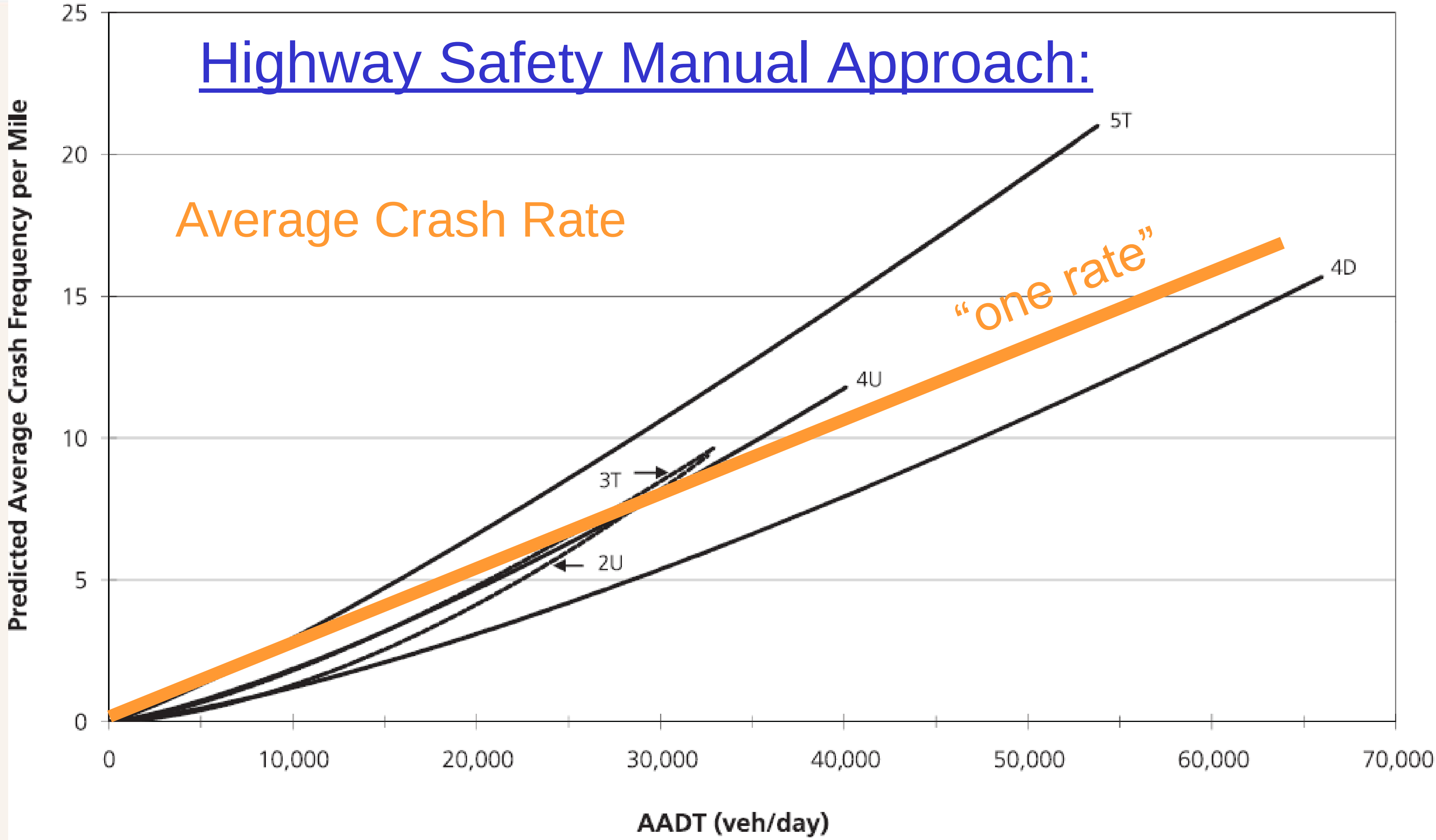

Figure 12-3. Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Table 12-3)

"Is this a Higher Crash Frequency Site?"

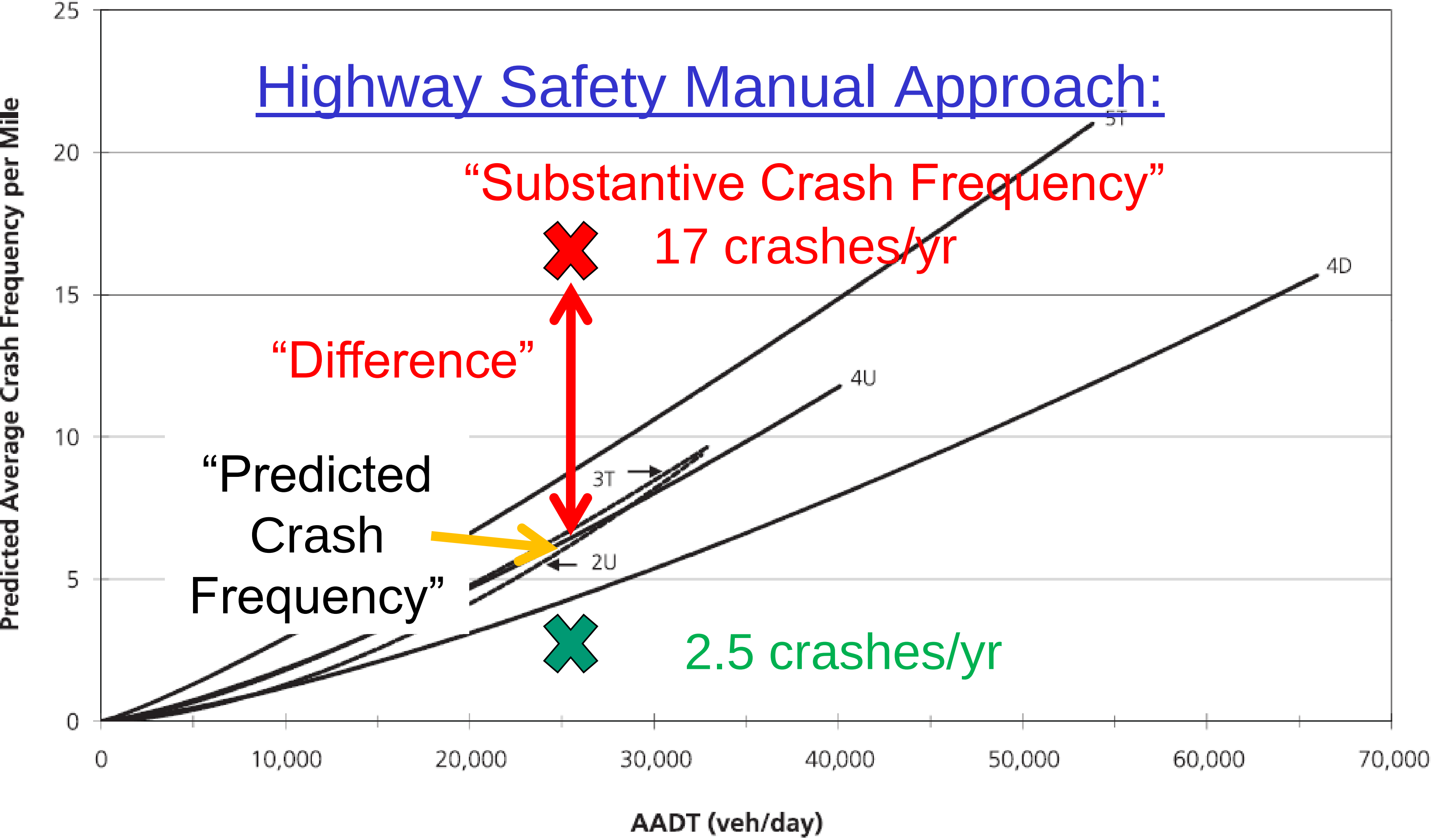

Figure 12-3. Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Table 12-3)

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Single-Vehicle Crashes

$$N_{brsv} = \exp(a + b\ \ln(AADT) + \ln(L))$$

Where:

AADT = Annual Average Daily Traffic (veh/day)

L = Length of roadway segment (mi)

a & b = regression coefficients (Table 12-5)

Single Vehicle NonDriveway Crashes

$$N_{brsv} = \exp(a + b \ln(AADT) + \ln(L))$$

Table 12-5. SPF Coefficients for Single-Vehicle Crashes on Roadway Segments

	Coefficients Used in Equation 12-11	
Road Type	**Intercept (a)**	**AADT (b)**
Total crashes		
2U	–5.47	0.56
3T	–5.74	0.54
4U	–7.99	0.81
4D	–5.05	0.47
5T	–4.82	0.54

Table 12-5. SPF Coefficients for Single-Vehicle Crashes on Roadway Segments

Road Type	Coefficients Used in Equation 12-11: Intercept (a)	Coefficients Used in Equation 12-11: AADT (b)	Overdispersion Parameter (k)
Total crashes			
2U	–5.47	0.56	0.81
3T	–5.74	0.54	1.37
4U	–7.99	0.81	0.91
4D	–5.05	0.47	0.86
5T	–4.82	0.54	0.52
Fatal-and-injury crashes			
2U	–3.96	0.23	0.50
3T	–6.37	0.47	1.06
4U	–7.37	0.61	0.54
4D	–8.71	0.66	0.28
5T	–4.43	0.35	0.36
Property-damage-only crashes			
2U	–6.51	0.64	0.87
3T	–6.29	0.56	1.93
4U	–8.50	0.84	0.97
4D	–5.04	0.45	1.06
5T	–5.83	0.61	0.55

Predicting Crash Frequency for a Suburban Street – Example:

<u>4-lane Undivided commercial Suburban Street:</u>

- AADT = 24,000
- Length = 3.6 miles

\- Predicted Crash Frequency for Single-Vehicle NonDriveway Crashes - use 4U coefficients from Table 12-5

$$\mathbf{N_{brsv}} = \exp(a + b\ \ln(AADT) + \ln(L))$$

$$= \exp(-7.99 + 0.81\ln(24{,}000) + \ln(3.6))$$

$$= \exp(1.46)$$

$$= 4.3 \text{ crashes/yr}$$

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Multiple-Vehicle Driveway Related Crashes

$$N_{brdwy} = SUM\ (n_j\ N_j\ (AADT/15{,}000)^t\ )$$

Where:

- n_j = number of driveways within roadway segment of driveway type j
- N_j = Number of crashes per year for an individual driveway of driveway type j from Table 12-7
- t = coefficient for traffic volume adjustment
- AADT = Annual Average Daily Traffic (veh/day)

Driveway Related Crashes

- 72% of driveway related crashes involve a left turning vehicle – either into, or out of, the driveway

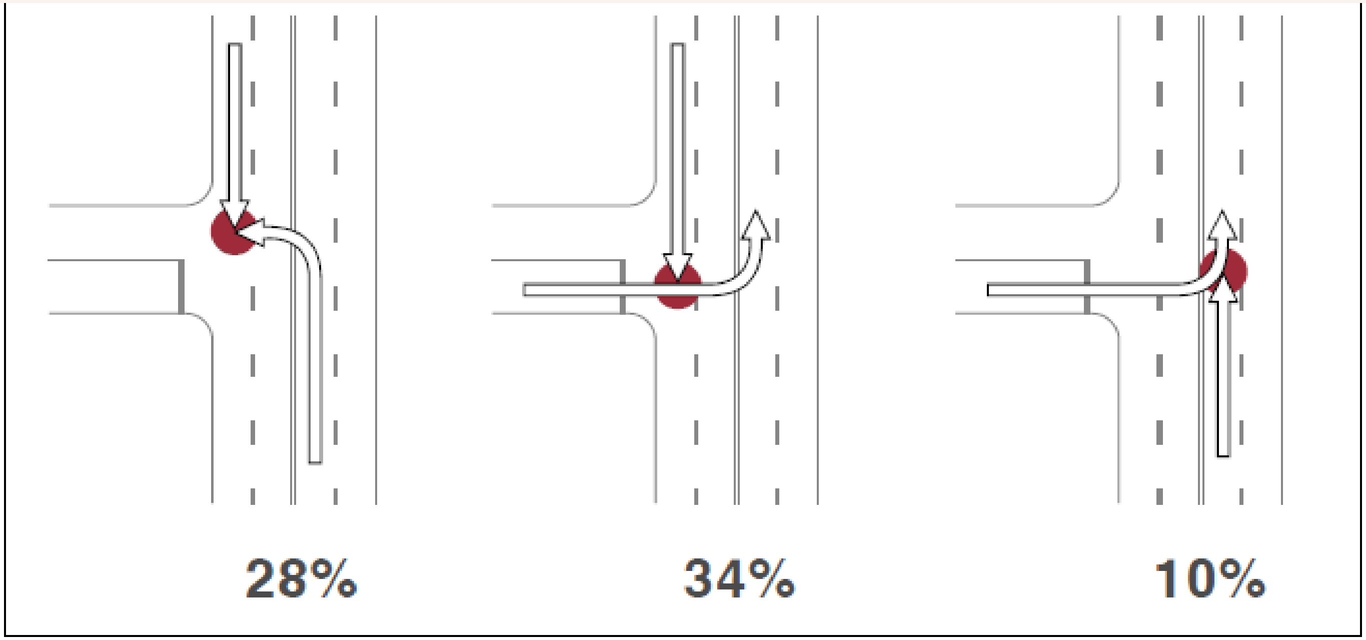

Figure 4: Crash Percentages for Turning Motorists to and from the Driveway

*FHWA-SA-10-002 Access Management in the Vicinity of Intersections

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Multiple-Vehicle Driveway Related Crashes

- ►Major driveways are those that serve 50 or more parking spaces
- ►Minor driveways serve sites with less than 50 parking spaces
- ► Major residential driveways have AADT greater than 900 vpd
- ► Minor residential driveways have "*AADT less than 900 vpd*"

Multiple-Vehicle Driveway Crashes

$$N_{brdwy} = \text{SUM}\left(n_j N_j (AADT/15{,}000)^t\right)$$

Table 12-7. SPF Coefficients for Multiple-Vehicle Driveway Related Collisions

	Coefficients for Specific Roadway Types				
Driveway Type (j)	**2U**	**3T**	**4U**	**4D**	**5T**
Number of Driveway-Related Collisions per Driveway per Year (N_j)					
Major commercial	0.158	0.102	0.182	0.033	0.165
Minor commercial	0.050	0.032	0.058	0.011	0.053
Major industrial/institutional	0.172	0.110	0.198	0.036	0.181
Minor industrial/institutional	0.023	0.015	0.026	0.005	0.024
Major residential	0.083	0.053	0.096	0.018	0.087
Minor residential	0.016	0.010	0.018	0.003	0.016
Other	0.025	0.016	0.029	0.005	0.027
Regression Coefficient for AADT (t)					
All driveways	1.000	1.000	1.172	1.106	1.172

N_j

t

Major driveways are those that serve sites with 50 or more parking spaces.
Minor driveways are those that serve sites with less than 50 parking spaces.

Predicting Crash Frequency for a Suburban Street – Example:

$$N_{brdwy} = SUM\ (n_j\ N_j\ (AADT/15,000)^t\ )$$

4-lane Undivided commercial Suburban Street:

- AADT = 24,000
- Length = 3.6 miles
- 3 major commercial driveways
- 42 minor commercial driveways
- 2 major industrial/institutional driveways
- 5 major residential driveways
- 2 minor residential driveways
- 7 other

❑ 61 total driveways

Predicting Crash Frequency for a Suburban Street – Example:

4-lane Undivided commercial Suburban Street: (Using 4U coefficients from Table 12-7)

$$\mathbf{N_{brdwy}} = \text{SUM}\ (n_j\ N_j\ (\text{AADT}/15{,}000)^t\ )$$
$$= 3 \times 0.182\ (24{,}000/15{,}000)^{1.172}$$
$$+ 42 \times 0.058\ (24{,}000/15{,}000)^{1.172}$$
$$+ 2 \times 0.198\ (24{,}000/15{,}000)^{1.172}$$
$$+ 0 \times 0.026\ (24{,}000/15{,}000)^{1.172}$$
$$+ 5 \times 0.096\ (24{,}000/15{,}000)^{1.172}$$
$$+ 2 \times 0.018\ (24{,}000/15{,}000)^{1.172}$$
$$+ 7 \times 0.029\ (24{,}000/15{,}000)^{1.172}$$

$$= 7.1 \text{ crashes/yr}$$

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Where:

$N_{spf\ rs}$ = Predicted number of total roadway segment crashes per year for base conditions for suburban 4-Lane Undivided (4U) of 24,000 AADT for 3.6 miles

N_{brmv} = 21.4

N_{brsv} = 4.3

N_{brdwy} = 7.1

$\mathbf{N_{spf\ rs} = 21.4 + 4.3 + 7.1 = 32.8}$ crashes per year

Applying Severity Index to Urban Suburban Multilane Streets

Example: Suburban Four Lane Undivided Segment (4U) street of 24,000 AADT for 3.6 miles;

Fatal and Injury crashes are 15 of 40 total crashes

a. Compute the actual Severity Index (SI)

$$SI_{4sg} = \frac{\text{Fatal + Injury Crashes}}{\text{Total Crashes}} = 15/40 = \mathbf{0.375}$$

Applying Severity Index to Urban Suburban Multilane Streets

Table 12-3. SPF Coefficients for Multiple-Vehicle Nondriveway Collisions on Roadway Segments

	Coefficients Used in Equation 12-10		
Road Type	Intercept (a)	AADT (b)	Overdispersion Parameter (k)
Fatal-and-injury crashes			
2U	−16.22	1.66	0.65
3T	−16.45	1.69	0.59
4U	−12.08	1.25	0.99
4D	−12.76	1.28	1.31
5T	−10.47	1.12	0.62

b. Compute Predicted Fatal + Injury Crashes

$$N_{brmv} = \exp(-12.08 + 1.25 \ln(24{,}000) + \ln(3.6))$$
$$= 6.1$$

Applying Severity Index to Urban Suburban Multilane Streets

Table 12-5. SPF Coefficients for Single-Vehicle Crashes on Roadway Segments

Road Type	Coefficients Used in Equation 12-11: Intercept (a)	Coefficients Used in Equation 12-11: AADT (b)	Overdispersion Parameter (k)
Fatal-and-injury crashes			
2U	–3.96	0.23	0.50
3T	–6.37	0.47	1.06
4U	–7.37	0.61	0.54
4D	–8.71	0.66	0.28
5T	–4.43	0.35	0.36

b. Compute Predicted Fatal + Injury Crashes

$$N_{brsv} = \exp(-7.37 + 0.61 \ln(24{,}000) + \ln(3.6))$$

$$= 1.1$$

Applying Severity Index to Urban Suburban Multilane Streets

Table 12-7. SPF Coefficients for Multiple-Vehicle Driveway Related Collisions

Driveway Type (j)	Coefficients for Specific Roadway Types: 2U	3T	4U	4D	5T
Proportion of Fatal-and-Injury Crashes (f_{dwy})					
All driveways	0.323	0.243	0.342	0.284	0.269

b. Compute Predicted Fatal + Injury Crashes

$$N_{brdwy} = N_{brdwy} \times \text{Coefficient} = 7.1 \times 0.342$$

$$= 2.4 \text{ crashes per year}$$

Applying Severity Index to Urban Suburban Multilane Intersections

Example: Suburban Four Lane Undivided Segment (4U) street of 24,000 ADT for 3.6 miles; Fatal and Injury crashes are 15 of 40 total crashes

a. Compute the actual Severity Index (SI)

$$SI = \frac{\text{Fatal + Injury Crashes}}{\text{Total Crashes}} = 15/40 = \mathbf{0.375}$$

b. Compute the Predicted Severity Index (SI)

$$SI = \frac{\text{Fatal + Injury Crashes}}{\text{Total Crashes}} = (6.1+1.1+2.4)/32.8$$

$$= \mathbf{0.293}$$

► **Actual Severity is greater than Predicted Severity**

Applying CMF's for Conditions other than "Base"

- Next Step is:

$$N_{br} = N_{spf\ rs}(CMF_{1r} \times CMF_{2r} \times .. \ CMF_{nr})$$

Where:

- ► **N_{br}** = Predicted number of total roadway segment crashes per year with CMFs applied
- ► **$N_{spf\ rs}$** = Predicted number of total roadway segment crashes per year for base conditions
- ► CMF_{1r} CMF_{2r}, .. CMF_{nr} = Crash modification factors for roadway segments

Chapter 12 Base Conditions for Urban/Suburban Roadways

	Base Condition	Measurement	CMF
Roadway Segments	On Street Parking	None	1.00
	Roadside Fixed Objects	None	1.00
	Median Width	15 ft	1.00
	Lighting	None	1.00
	Automated Speed Enforcement	None	1.00
Multiple Vehicle and Single Vehicle Crashes at Intersections	Left Turn Lanes	None	1.00
	Left Turn Signal Phasing	Permissive	1.00
	Right Turn Lanes	None	1.00
	Right Turn on Red	Permitted	1.00
	Lighting	None	1.00
	Red Light Cameras	None	1.00
Vehicle-Ped Crashes at Signalized Intersections	Bus Stops	None	1.00
	Schools	None	1.00
	Alcohol Sales Establishment	None	1.00

Applying CMF's for Conditions other than "Base"

Table 12-18. Summary of CMFs in Chapter 12 and the Corresponding SPFs

Applicable SPF	CMF	CMF Description
Roadway Segments	CMF_{1r}	On-Street Parking
	CMF_{2r}	Roadside Fixed Objects
	CMF_{3r}	Median Width
	CMF_{4r}	Lighting
	CMF_{5r}	Automated Speed Enforcement

CMF for Curb Parking on Urban Streets

$$CMF_{1r} = 1 + P_{pk} * (f_{pk} - 1.0)$$

Table 12-19. Values of f_{pk} Used in Determining the Crash Modification Factor for On-Street Parking

	Type of Parking and Land Use			
	Parallel Parking		Angle Parking	
Road Type	Residential/Other	Commercial or Industrial/Institutional	Residential/Other	Commercial or Industrial/Institutional
2U	1.465	2.074	3.428	4.853
3T	1.465	2.074	3.428	4.853
4U	1.100	1.709	2.574	3.999
4D	1.100	1.709	2.574	3.999
5T	1.100	1.709	2.574	3.999

Where:

P_{pk} = Proportion of curb length with parking, = $(0.5L_{pk}/L)$

L_{pk} = curb length with on-street parking, both sides (mi) combined

f_{pk} = factor from Table 12-19

CMF for Curb Parking on Urban Streets

Example: For 4-Ln Urban commercial street (4U), *angle* parking *one* side 3.12 miles of 3.6 mile length, commercial area:

$$CMF_{1r} = 1 + P_{pk} (f_{pk} - 1.0)$$

$$CMF_{1r} = 1 + (0.50 (L_{pk}/L) 1) \times (f_{pk} - 1)$$

$$= 1 + (0.50 (3.12/3.6) 1) \times (3.999 - 1)$$

$$= 1 + (0.50(0.867)) \times 2.999$$

$$= 1 + (0.43 \times 2.999)$$

= 2.30

CMF for Curb Parking Urban Streets: Example

For 4-Ln Urban commercial street (4U), *parallel* parking *both* sides 3.12 miles of 3.6 mile length, commercial area:

$$CMF_{1r} = 1 + P_{pk}\,(f_{pk} - 1.0)$$

$$CMF_{1r} = 1 + (0.50(3.12/3.6)2) \times (1.709 - 1))$$

$$= 1 + (0.5(0.867)2) \times 0.709$$

$$= 1 + (0.867 \times 0.709)$$

$$= \mathbf{1.614}$$

CMF for Roadside Fixed Objects

$$CMF_{2r} = f_{offset} * D_{fo} * p_{fo} + (1 - p_{fo})$$

Where:

f_{offset} = fixed object offset factor from Table 12-20

D_{fo} = fixed object density (fixed objects/mi)

p_{fo} = fixed-object collisions as a proportion of total crashes, Table 12-21

► Only point objects that are 4inches or more in diameter and do not have a breakaway design are considered.

► Point objects that are within 70 feet of each other longitudinally are considered as a single object

CMF for Roadside Fixed Objects

Table 12-20. Fixed-Object Offset Factor

Offset to Fixed Objects (O_{fo}) (ft)	Fixed-Object Offset Factor (f_{offset})
2	0.232
5	0.133
10	0.087
15	0.068
20	0.057
25	0.049
30	0.044

Example: For 4-Ln Urban undivided street (4U) with power poles at 2 ft offset

$f_{offset} = 0.232$

$p_{fo} = 0.037$

► Offset is measured from edge of travel way

Table 12-21. Proportion of Fixed-Object Collisions

Road Type	Proportion of Fixed-Object Collisions (p_{fo})
2U	0.059
3T	0.034
4U	0.037
4D	0.036
5T	0.016

CMF for Roadside Fixed Objects: Example

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with power poles on *one* side on 150 foot spacing 2 feet from edge of travel way:

$$CMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1 - p_{fo})$$

$$= 0.232\ (5280/150)(1)(0.037) + (1 - 0.037)$$

$$= 0.232 \times 35.2 \times 0.037 + (0.963)$$

$$= 0.302 + 0.963$$

$$= \mathbf{1.265}$$

CMF for Roadside Fixed Objects: Example

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with power poles on *both* sides on 150 foot spacing 2 feet from edge of travel way:

$$\mathbf{CMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1 - p_{fo})}$$

$$= 0.232\,(5280/150)(2)(0.037))+(1 - 0.037)$$

$$= 0.232 \times 70.4 \times 0.037 + (0.963)$$

$$= \mathbf{1.567}$$

CMF_{3r} for Median Width – Urban/Suburban Multilane Streets

Table 12-22. CMFs for Median Widths on Divided Roadway Segments without a Median Barrier (CMF_{3r})

Median Width (ft)	CMF
10	1.01
15	1.00
20	0.99
30	0.98
40	0.97
50	0.96
60	0.95
70	0.94
80	0.93
90	0.93
100	0.92

- This CMF applies only to divided roadway segments with traversable medians without barrier.
- The effect of traffic barriers on safety would be expected to be a function of barrier type and offset, rather than the median width; however, the effects of these factors on safety have not been quantified. Until better information is available, an CMF value of 1.00 is used for medians with traffic barriers.

CMF for Lighting

$$CMF_{4r} = 1 - (p_{nr} \times (1.0 - 0.72\, p_{inr} - 0.83\, p_{pnr}))$$

Where:

p_{inr} = proportion of total nighttime crashes for unlighted roadway segments that involve a nonfatal injury

p_{pnr} = proportion of total nighttime crashes for unlighted roadway segments that involve PDO crashes only

p_{nr} = proportion of total crashes for unlighted roadway segments that occur at night

CMF for Lighting

$$CMF_{4r} = 1 - [p_{nr} \times (1.0 - 0.72\, p_{inr} - 0.83\, p_{pnr})]$$

Table 12-23. Nighttime Crash Proportions for Unlighted Roadway Segments

	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
Roadway Segment Type	Fatal and Injury p_{inr}	PDO p_{pnr}	p_{nr}
2U	0.424	0.576	0.316
3T	0.429	0.571	0.304
4U	0.517	0.483	0.365
4D	0.364	0.636	0.410
5T	0.432	0.568	0.274

- These are default values for nighttime crash proportions; replace with local information
- If light installation increases the density of roadside fixed objects, adjust CMF_{2r}

CMF for Lighting: Example

For 4-Ln Urban undivided commercial curbed street (4U) with power poles on 150 foot spacing 2 feet from edge of travel way on one-side– Add Lighting

$$CMF_{3r} = 1- [p_{nr} \times (1.0 – 0.72\, p_{inr} – 0.83\, p_{pnr})]$$

$$= 1- [0.365 \times (1.0 – 0.72 (0.517) – 0.83 \times 0.483)]$$

$$= \mathbf{0.917}$$

- Lighting adds light poles at 160 foot spacing on one side (the other side) set back 2 feet from back of curb

► Recompute CMF_{2r}

CMF for Roadside Fixed Objects: Example

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with power poles on *one* side on 150 foot spacing 2 feet from edge of travel way + street lighting on other side on 160 foot spacing 2 feet from edge of travel way:

$$\mathbf{CMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1 - p_{fo})}$$

$= 0.232((5280/150)(1)+ (5280/160)(1))(0.037) + (1 – 0.037)$

$= 0.232 \times (35.2+33.0) \times 0.037+ (0.963)$

$= 0.232 \times 68.2 \times 0.037 + 0.963$

$= 0.585 + 0.963 =$ **1.548**

CMF for Automated Speed Enforcement

CMF_{5r} is:

1.00 for no automated speed enforcement;

0.95 for automated speed enforcement

Applying Crash Modification Factors to Prediction of Crash Frequency for Urban/Suburban Roadway Segments

$$N_{br} = N_{spf\ rs} \ (CMF_{1r} \times CMF_{2r} \ldots\ldots CMF_{nr})$$

Where:

N_{br} = Predicted number of total roadway segment crashes per year with effects of conditions other than base conditions

Applying Crash Modification Factors to Prediction of Crash Frequency for Urban/Suburban Roadway Segments

Example:

- Commercial on-street parallel parking both sides
- Roadside Fixed Objects (power poles on *1* side 150 ft spacing + non-breakaway light poles@160’ other side)
- Traversible 15 foot wide median Lighting
- Lighting ible 15 foot wide median
- No speed enforcement

CMF_{1r} = 1.613

CMF_{2r} = 1.548

CMF_{3r} = 1.00
CMF_{4r} = 0.917
CMF_{5r} = 1.00

$$N_{br} = N_{spf\ rs}\ (CMF_{1r} \times CMF_{2r} \times \ldots . CMF_{nr})$$

$$= \mathbf{32.8}\ (1.613 \times 1.548 \times 1.00 \times 0.917 \times 1.00)$$

$$= \mathbf{75.1} \text{ crashes per year}$$

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

$$N_{predicted\ rs} = (N_{br} + N_{pedr} + N_{biker})\ C_r$$

Where:

- $N_{predicted\ rs}$ = predicted average crash frequency of an
- individual roadway segment for the selected year
- N_{br} = predicted average crash frequency of an individual roadway segment excluding vehicle-pedestrian and vehicle-bicycle crashes
- N_{pedr} = predicted average crash frequency of vehicle-pedestrian crashes for an individual roadway segment
- N_{biker} = predicted average crash frequency of vehicle-bicycle crashes for an individual roadway segment
- C_r = calibration factor for roadway segments of a specific type developed for use for a particular geographical area

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

$$N_{pedr} = N_{br} \times f_{pedr}$$

Table 12-8. Pedestrian Crash Adjustment Factor for Roadway Segments

	Pedestrian Crash Adjustment Factor (fpedr)	
Road Type	**Posted Speed 30 mph or Lower**	**Posted Speed Greater than 30 mph**
2U	0.036	0.005
3T	0.041	0.013
4U	0.022	0.009
4D	0.067	0.019
5T	0.030	0.023

Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All pedestrian collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as property-damage-only crashes.

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

From continued Example:

4-Ln Undivided

40 mph

Table 12-8. Pedestrian Crash Adjustment Factor for Roadway Segments

	Pedestrian Crash Adjustment Factor (fpedr)	
Road Type	**Posted Speed 30 mph or Lower**	**Posted Speed Greater than 30 mph**
2U	0.036	0.005
3T	0.041	0.013
4U	0.022	0.009
4D	0.067	0.019
5T	0.030	0.023

Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All pedestrian collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as property-damage-only crashes.

$$N_{pedr} = N_{br} \times f_{pedr}$$

= **75.1** crashes per year x **0.009**

= **0.68** crashes per year

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

$$N_{biker} = N_{br} \times f_{biker}$$

Table 12-9. Bicycle Crash Adjustment Factors for Roadway Segments

	Bicycle Crash Adjustment Factor (f_{biker})	
Road type	**Posted Speed 30 mph or Lower**	**Posted Speed Greater than 30 mph**
2U	0.018	0.004
3T	0.027	0.007
4U	0.011	0.002
4D	0.013	0.005
5T	0.050	0.012

Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All bicycle collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as property-damage-only crashes.

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

Table 12-9. Bicycle Crash Adjustment Factors for Roadway Segments

	Bicycle Crash Adjustment Factor (f_{biker})	
Road type	**Posted Speed 30 mph or Lower**	**Posted Speed Greater than 30 mph**
2U	0.018	0.004
3T	0.027	0.007
4U	0.011	0.002
4D	0.013	0.005
5T	0.050	0.012

Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All bicycle collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as property-damage-only crashes.

From continued Example:

4-Ln Undivided

40 mph = high speed

$$N_{biker} = N_{br} \times f_{biker}$$

= 75.1 crashes per year x 0.002

= 0.15 crashes per year

Predicting Crash Frequency for Peds + Bikes on Urban/Suburban Streets

Combining Segment, Ped and Bike crashes:

$$N_{predicted\ rs} = (N_{br} + N_{pedr} + N_{biker})\ C_r$$

$$N_{predicted\ rs} = (75.1 + 0.68 + 0.15)\ x\ 1$$

$$= 75.9 \text{ crashes per year}$$

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Learning Outcomes:

- ► Described the models to Predict Crash Frequency for Multilane Suburban/Urban Streets
- ►Described Crash Modification Factors for Multilane Suburban/Urban Streets
- ►Applied Crash Modification Factors (CMF’s) to Predicted Crash Frequency for Multilane Suburban/Urban Streets

Introduction and Background

Questions and Discussion: