HSM Practitioners Guide to Rural Multilane Highways and Urban Suburban Multilane Streets

Prediction of Crash Frequency for Suburban/Urban Multilane Streets

- Session #5

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Learning Outcomes:

- Describe the models to Predict 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.

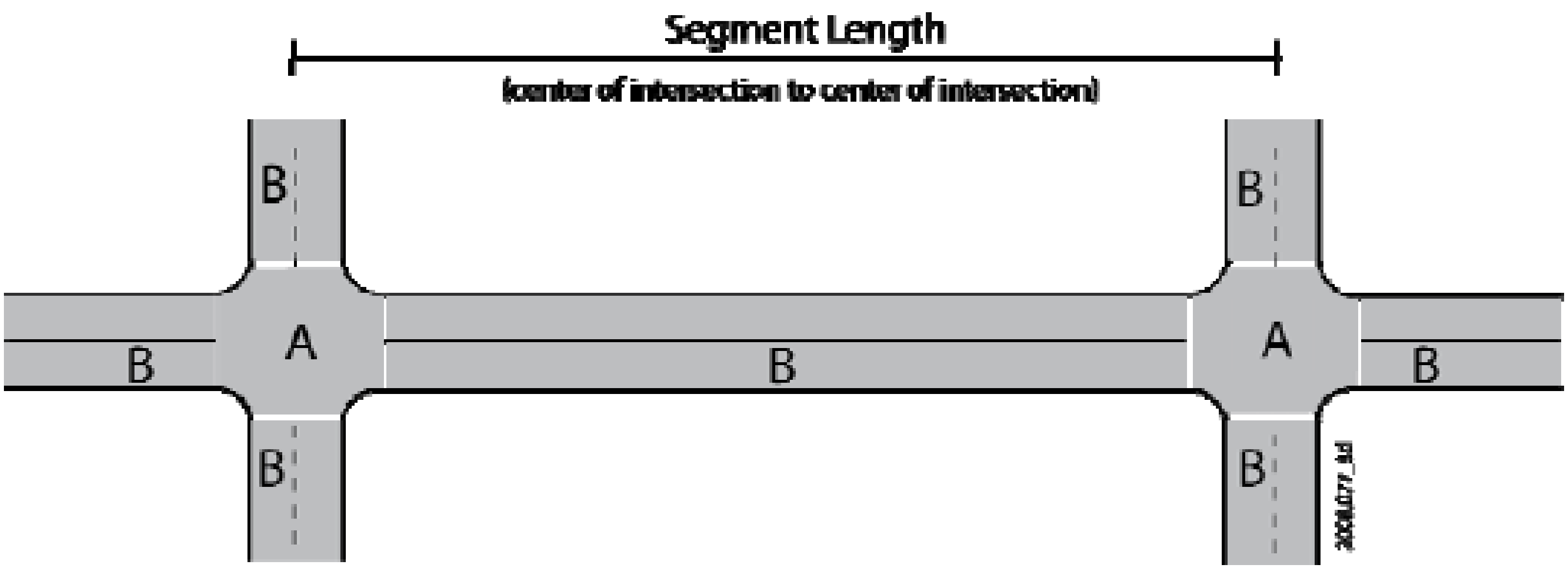
Predicting Crash Frequency of Suburban/Urban Multilane Streets

Separate Prediction Models for:

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

Definition of Segments and Intersections

Exhibit 10-3: Definition of Segments and Intersections



A - All crashes that occur within this region are classified as intersection crashes

B – Crashes in this region may be segment or intersection related, depending on the characteristics of the crash

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):
  - Average daily traffic (ADT) 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:

- Additional info re Median widths for "homogenous sections"

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

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Procedure for safety prediction for a roadway segment:

- Combine base models, CMFs, and calibration factor

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

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

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

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

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

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} = Accident (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 <u>for base conditions</u>
- 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 geograhical area

Combining Safety Predictions for an Entire Series of Segments

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

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

Base Models and Adjustment Factors addresses 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

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

Multiple-Vehicle NonDriveway Crashes

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

Where:

ADT = Annual Average Daily Traffic (veh/day)

L = Length of roadway segment (mi)

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

Multiple-Vehicle NonDriveway Crashes

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

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:

4-lane Undivided commercial Suburban Street:

- ADT = 24,000
- Length = 3.6 miles

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

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

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

$$= \exp(3.065)$$

$$= 21.4 \text{ crashes/yr}$$

Safety Performance Function (SPF)

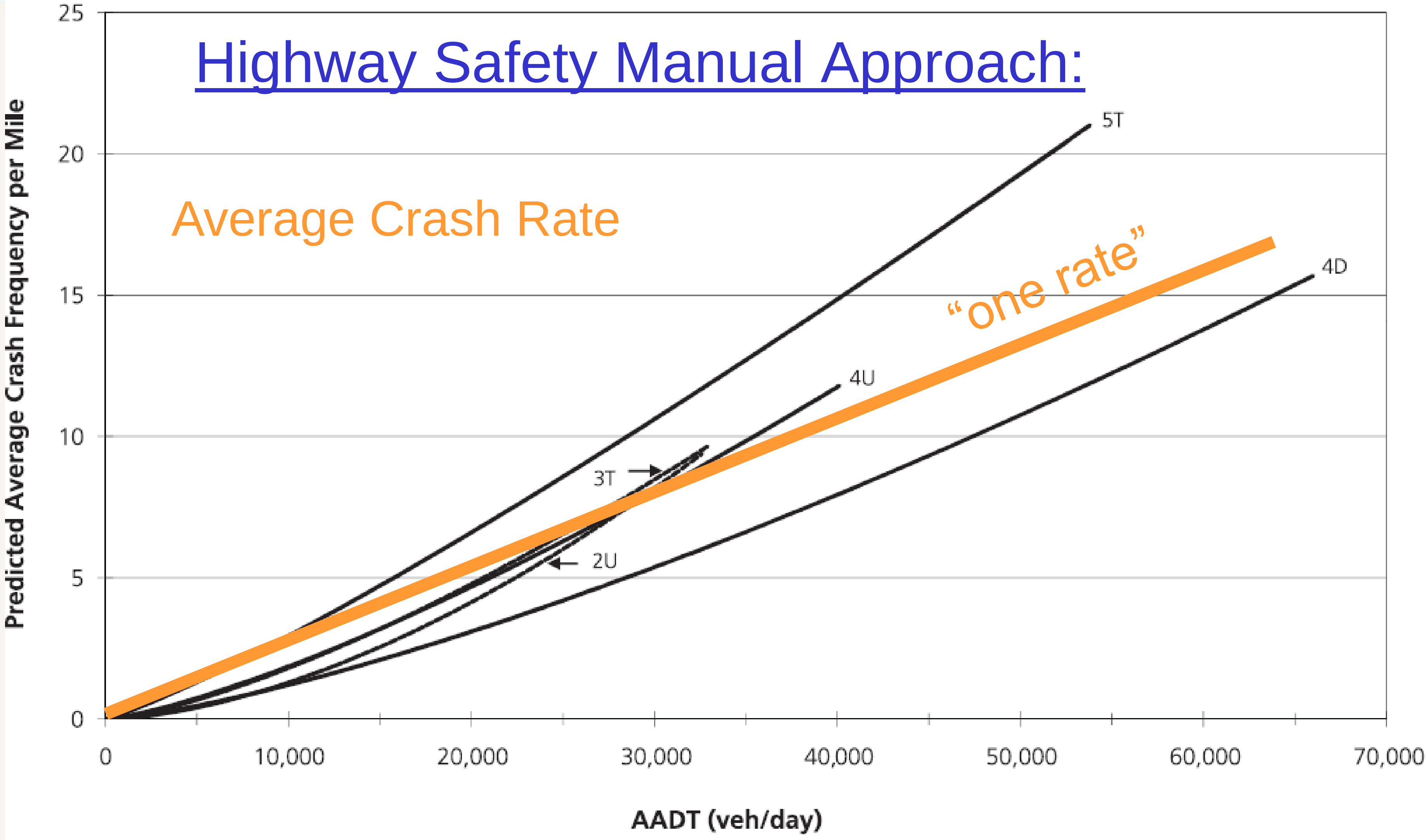


Figure 12-3. Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Table 12-3)

"Is this a Higher Crash Frequency Site?"

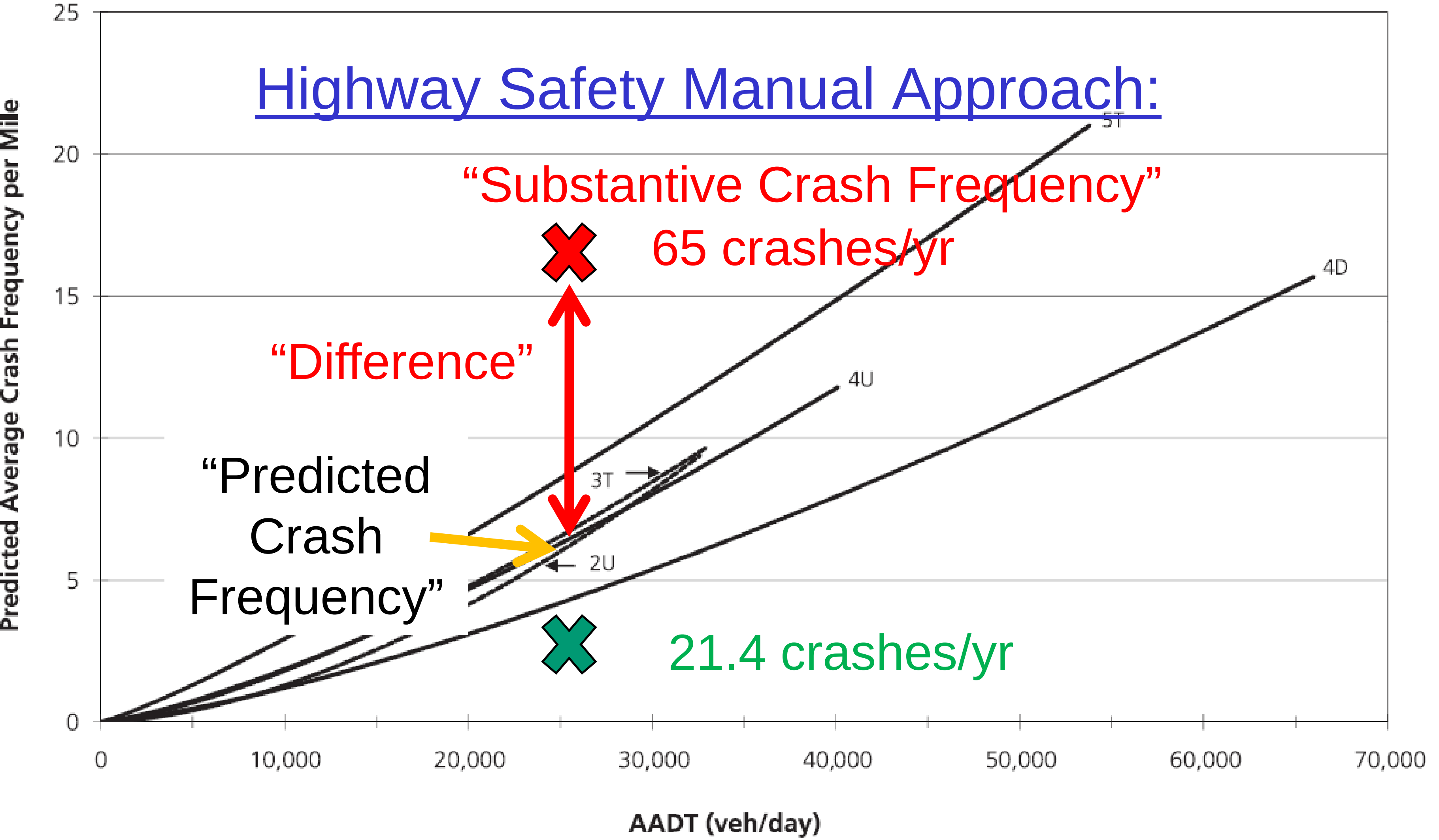


Figure 12-3. Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Table 12-3)

Predicting Crash Frequency for a Suburban Street – Exercise:

4-lane Divided Suburban Street:

- ADT = 24,000
- Length = 3.6 miles

- Predicted Crash Frequency for Multilane NonDriveway crashes – Use 4D coefficients

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

$$= \exp(-12.34 + 1.36 \ln(24{,}000) + \ln(3.6))$$

$$= \ ? \quad \text{crashes per year}$$

Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

Single Vehicle Crashes:

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

Where:

ADT = Annual Average Daily Traffic (veh/day)

L = Length of roadway segment (mi)

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

Single Vehicle NonDriveway Crashes

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

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>

- ❑ ADT = 24,000
- ❑ Length = 3.6 miles

\- Predicted Crash Frequency for Single-Vehicle NonDriveway Crashes - use 4U coefficients

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

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

$$= \exp(1.46)$$

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

Predicting Crash Frequency for a Suburban Street – Exercise:

<u>4-lane Divided Suburban Street:</u>

- ADT = 24,000
- Length = 3.6 miles

2nd, Calculate Predicted Crash Frequency for Single-Vehicle NonDriveway crashes – Use 4D

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

$$N_{brsv} = ?$$

a) 2.6 crashes per year
b) 4.2 crashes per year
c) 8.4 crashes per year
d) 12.6 crashes per year

Safety Performance Function (SPF)

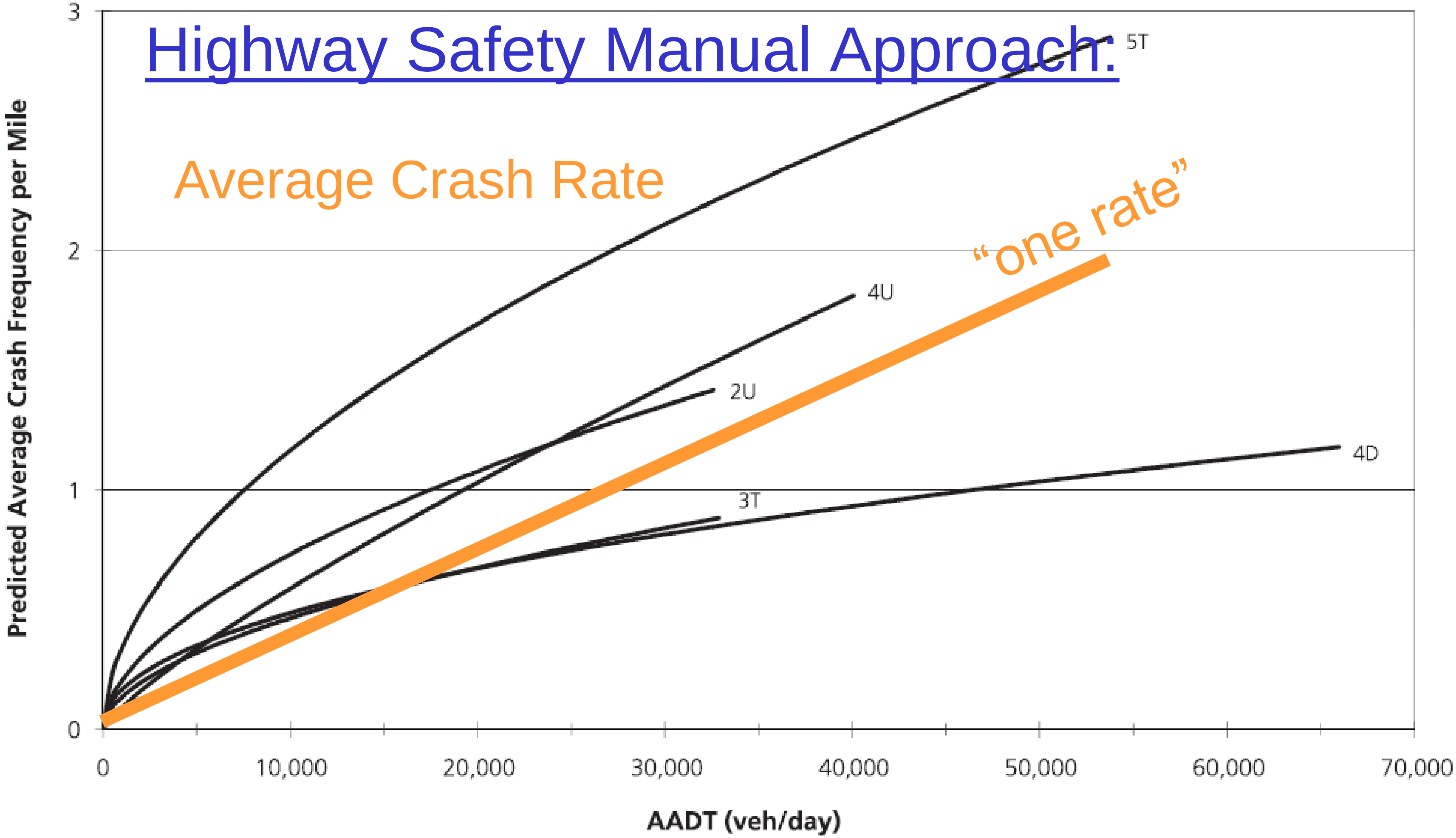


Figure 12-4. Graphical Form of the SPF for Single-Vehicle Crashes (from Equation 12-13 and Table 12-5)

"Is this a Higher Crash Frequency Site?"

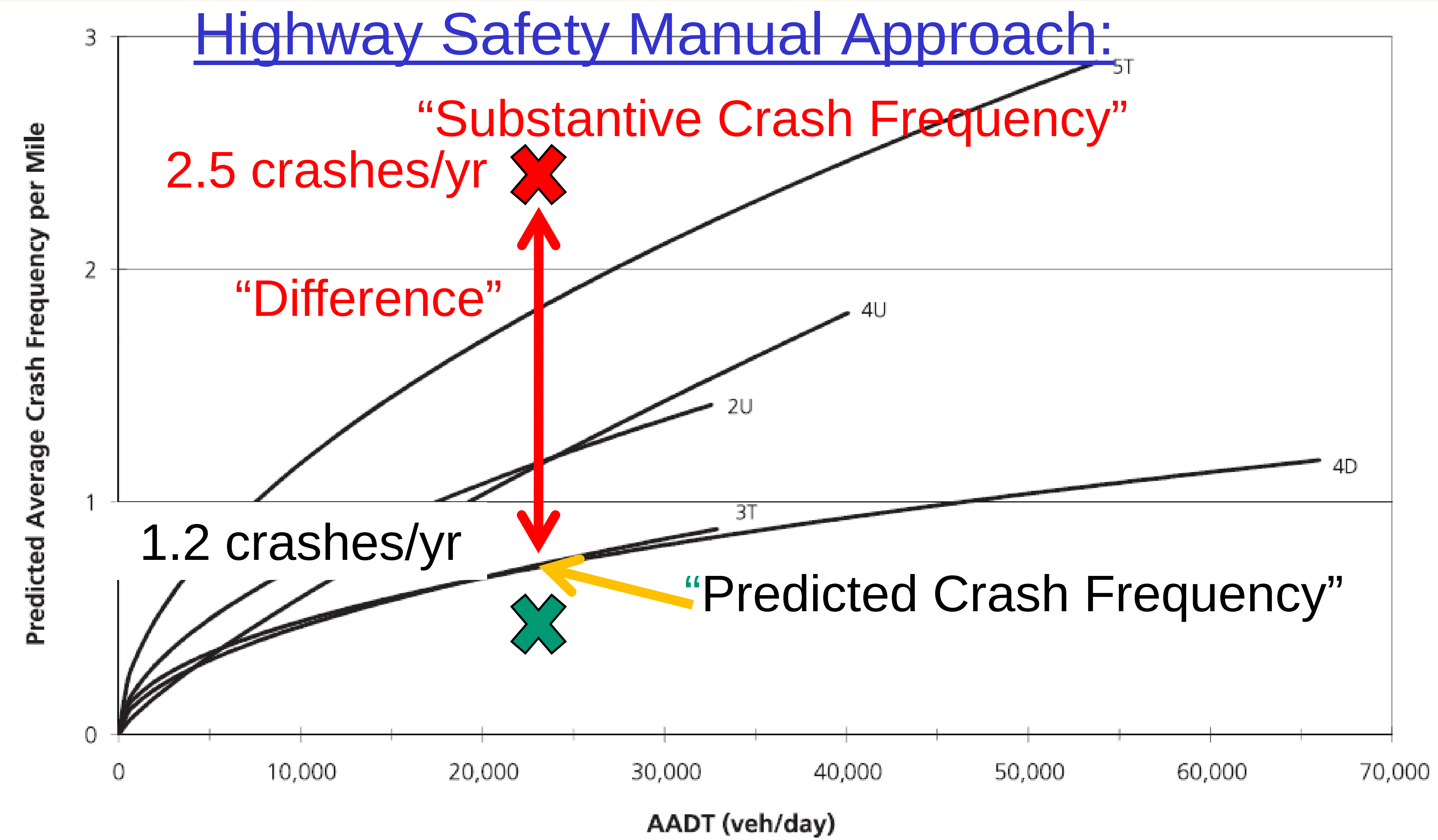


Figure 12-4. Graphical Form of the SPF for Single-Vehicle Crashes (from Equation 12-13 and Table 12-5)

Driveway Related Crashes

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

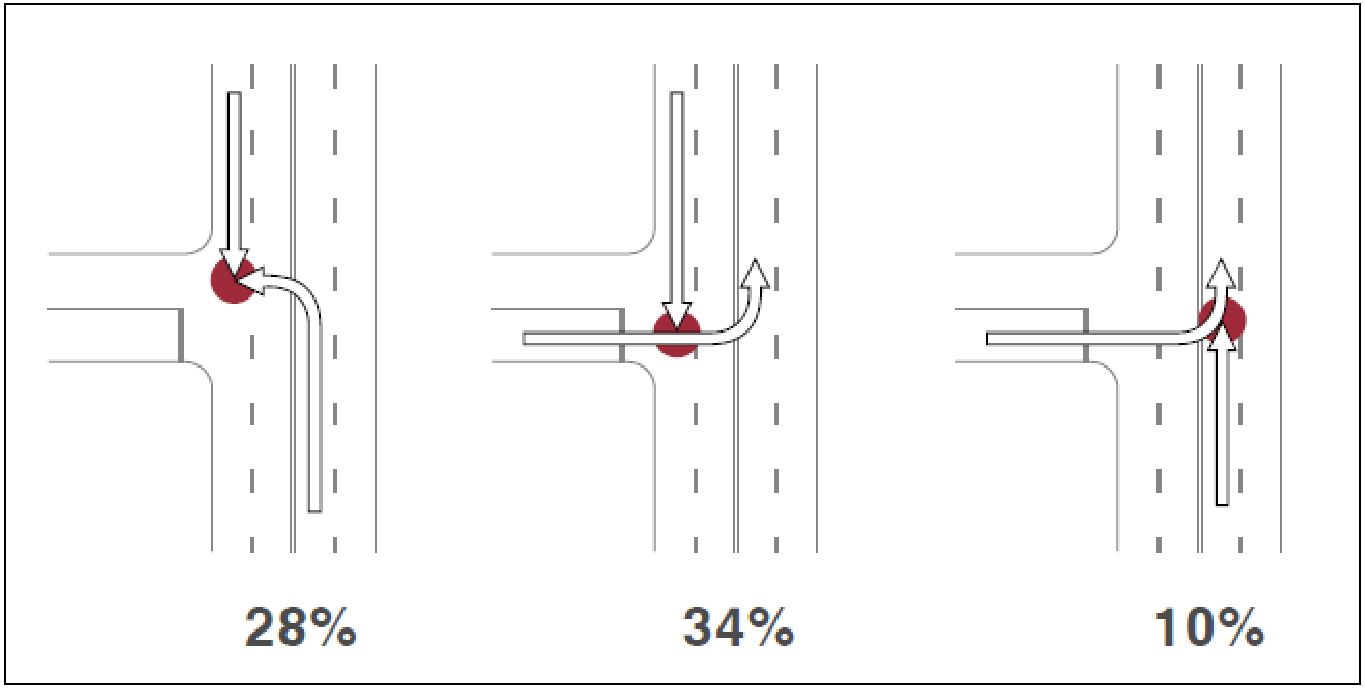


Figure 4: Crash Percentages for Turning Motorists to and from the Driveway

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 ADT greater than 900 vpd
- ► Minor residential driveways have "*ADT less than 900 vpd*"

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Multiple-Vehicle Driveway Related Crashes

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

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 Exhibit 12-7
- t = coefficient for traffic volume adjustment
- ADT = Average Daily Traffic (veh/day)

Multiple-Vehicle Driveway Crashes

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

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

Driveway Type (j)	Coefficients for Specific Roadway Types				
	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

Predicting Crash Frequency for a Suburban Street – Example:

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

4-lane Undivided commercial Suburban Street:

- ADT = 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:

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

$$= 3 \times 0.182\ (24{,}000/15{,}000)^{1.172}$$
$$+ 42 \times 0.058\ (24{,}000/15{,}000)^{1.172}$$
$$+ 2 \times 0.198\ (24{,}000/15{,}000)^{1.172}$$
$$+ 0 \times 0.026\ {*}24{,}000/15{,}000)^{1.172}$$
$$+ 5 \times 0.096\ (24{,}000/15{,}000)^{1.172}$$
$$+ 2 \times 0.018\ (24{,}000/15{,}000)^{1.172}$$
$$+ 7 \times 0.029\ (24{,}000/15{,}000)^{1.172}$$

= 7.1 crashes/yr

Predicting Crash Frequency for a Suburban Street – Exercise:

4-lane Divided (Commercial) Suburban Street:

- ❑ ADT = 24,000
- ❑ Length = 3.6 miles
- ❑ same driveways as in the example just provided - Use 4D coefficients

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

$= ?$

a) 28.8 crashes per year

b) 36.3 crashes per year

c) 1.3 crashes per year

d) 3.63 crashes per year

Predicting Crash Frequency of Suburban/Urban Multilane Streets

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

Where:

N_{brbase} = Predicted number of total roadway segment crashes per year for <u>base conditions</u> for suburban 4-Lane Undivided (4U) of 24,000 ADT for 3.6 miles

N_{brmv} = 21.4

N_{brsv} = 4.3

N_{brdwy} = 7.1

$N_{spf\ rs}$ **= 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 ADT 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

Road Type	Coefficients Used in Equation 12-10: Intercept (a)	Coefficients Used in Equation 12-10: 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)	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

	Coefficients for Specific Roadway Types				
Driveway Type (j)	**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

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Learning Outcomes:

- Described the models to Predict Crash Frequency for Multilane Suburban/Urban Streets

Predicting Crash Frequency of Suburban/Urban Multilane Streets

Questions and Discussion: