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

Site Conditions

Approach	Functional Classification	AADT (veh/day)
DE 42/Seven Hickories Road	Rural Major Collector	7,711
DE 15/Brenford Road	Rural Major Collector	2,171
Seeneytown Road	Rural Local	1,688

Intersection Skew: 90°
Left Turn Lanes: SB Brenford Road
Right Turn Lanes: None
Lighting: SW and SE quadrants
Analysis Year: 2012

Predictive Model for Intersections (Equation 10-3):

$$N_{predicted,int} = N_{SPF,int} \times C_i \times (CMF_{1i} \times CMF_{2i} \times CMF_{3i} \times CMF_{4i})$$

Safety Performance Function for Four-Leg, Stop-Controlled Intersections (Equation 10-9):

$$N_{SPF,4ST} = exp[-8.56 + 0.60 \times ln(AADT_{maj}) + 0.61 \times ln(AADT_{min})]$$

NOTE: Since side streets have two different AADT volumes, use the greater value.

$$N_{SPF,4ST} = exp[-8.56 + 0.60 \times ln(7,711) + 0.61 \times ln(2,171)]$$
$$N_{SPF,4ST} = 4.47\ crashes/year$$

Inclusion of Crash Modification Factors (CMFs):

Skew (Base Condition = 90°):
$$CMF_{1i} = exp(0.0054 \times skew)$$
$$CMF_{1i} = 1.00$$

Left Turn Lanes (Base Condition = None)
NOTE: Left turn lanes on side street approaches have no effect on the CMF, therefore it can be disregarded.

$$CMF_{2i} = 1.00$$

Right Turn Lanes (Base Condition = None)
$$CMF_{3i} = 1.00$$

Lighting (Base Condition = None)

$$CMF_{4i} = 1 - 0.38 \times p_{ni}$$
$$CMF_{4i} = 1 - 0.38 \times 0.244 \quad \textbf{(Table 10-15)}$$
$$CMF_{4i} = 0.91$$

Inclusion of Calibration Factor (C_i):

$$C_i = 1.00$$

NOTE: DelDOT is in the process of formulating local calibration factors. Until a formal set of calibration factors has been issued by the Department, the value of C_i is assumed to be 1.00.

Inclusion in Predictive Model:

$$N_{predicted,int} = 4.47 \times 1.00 \times (1.00 \times 1.00 \times 1.00 \times 0.91)$$

$$\boxed{N_{predicted,int} = 4.06\ crashes/year}$$

Safety Performance Function for Four-Leg, Signalized Intersections (Equation 10-10):

$$N_{SPF,4SG} = exp[-5.13 + 0.60 \times ln(AADT_{maj}) + 0.20 \times ln(AADT_{min})]$$

NOTE: Since side streets have two different AADT volumes, use the greater value.

$$N_{SPF,4SG} = exp[-5.13 + 0.60 \times ln(7,711) + 0.20 \times ln(2,171)]$$
$$N_{SPF,4SG} = 5.91\ crashes/year$$

Inclusion of Crash Modification Factors (CMFs):

Skew (Base Condition = 90°):
$$CMF_{1i} = exp(0.0054 \times skew)$$
$$CMF_{1i} = 1.00$$

Left Turn Lanes (Base Condition = None)
NOTE: Left turn lanes on side street approaches have no effect on the CMF, therefore it can be disregarded.

$$CMF_{2i} = 1.00$$

Right Turn Lanes (Base Condition = None)
$$CMF_{3i} = 1.00$$

Lighting (Base Condition = None)
$$CMF_{4i} = 1 - 0.38 \times p_{ni}$$
$$CMF_{4i} = 1 - 0.38 \times 0.286 \quad \textbf{(Table 10-15)}$$
$$CMF_{4i} = 0.89$$

Inclusion of Calibration Factor (C_i):
$$C_i = 1.00$$

Inclusion in Predictive Model:

$$N_{predicted,int} = 4.47 \times 1.00 \times (1.00 \times 1.00 \times 1.00 \times 0.89)$$

$$\boxed{N_{predicted,int} = 5.26\ crashes/year}$$

Predicted Crash Type Distribution Comparison for All Severities (Table 10-6):

All Severities		Stop-Controlled N = 4.06		Signalized N = 5.26	
	Collision Type	%	# Crashes	%	# Crashes
Single Vehicle Crashes	Animal	1.0%	0.04	0.2%	0.01
	Bicycle	0.1%	0.00	0.1%	0.01
	Pedestrian	0.1%	0.00	0.1%	0.01
	Overturn	0.5%	0.02	0.3%	0.02
	Run Off Road	12.2%	**0.50**	6.4%	**0.34**
	Other	0.8%	0.03	0.5%	0.03
	Total Single Vehicle Crashes	*14.7%*	*0.60*	*7.6%*	*0.40*
Multi-Vehicle Crashes	Angle	43.1%	**1.75**	27.4%	1.44
	Head On	4.0%	0.16	5.4%	0.28
	Rear End	24.2%	0.98	42.6%	**2.24**
	Sideswipe	10.1%	0.41	11.8%	0.62
	Other	3.9%	0.16	5.2%	0.27
	Total Multi-Vehicle Crashes	*85.3%*	*3.46*	*92.4%*	*4.86*
Total Crashes		***100.0%***	***4.06***	***100.0%***	***5.26***

Chapter 14: Crash Modification Factors (CMFs) for Intersections

Crash Summary, 1/1/2012 to 12/31/2012 (0.1-mile along all legs of intersection)
7 Crashes

5 Property Damage Only
2 Personal Injury
0 Fatality

3 Angle
2 Rear End
1 Left Turn
1 Other (Single Vehicle Crash)

Treatment #1: Convert Four-Leg Stop-Controlled Intersection to Four-Leg Signalized Intersection

Table 14-7: Rural Four-Leg

Crash Type	CMF	# Crashes (2012)	Predicted # Crashes per Year
Right Angle	0.23	3	0.7
Left Turn	0.4	1	0.4
Rear End	1.58	2	3.2
All Types	*0.56*	*7*	***3.9***

By using the CMF method for this specific treatment, we can conclude that this intersection will experience approximately 4 crashes per year.

Treatment #2: Convert Four-Leg Stop-Controlled Intersection to Four-Leg, All-Way Stop Intersection

Table 14-5: Rural, Assume all MUTCD warrants met

Crash Type	CMF	# Crashes (2012)	Predicted # Crashes per Year
All Types	*0.52*	*7*	***3.6***

By using the CMF method for this specific treatment, we can conclude that this intersection will experience approximately 4 crashes per year.

Treatment #3: Convert Four-Leg Stop-Controlled Intersection to Modern Roundabout

Table 14-4: Rural, Assume One-Lane

Crash Type	CMF	# Crashes (2012)	Predicted # Crashes per Year
All Types	*0.29*	*7*	***2.0***

By using the CMF method for this specific treatment, we can conclude that this intersection will experience approximately 2 crashes per year.

Crash Rates for Historical Countermeasures

At the intersection of DE 42 (Seven Hickories Road) & DE 15 (Brenford Road)/Seeneytown Road, two historical crash countermeasures have been implemented:

- Lighting on the southeast and southwest quadrants was installed on 1/5/2009.
- Solar-Powered, Flashing Red Beacons were installed on both STOP signs in the northbound and southbound directions on 11/8/2010.

Base Condition	Countermeasure	Study Period	# Years in Study Period	# Crashes in Study Period	Crash Rate (crashes per year)
No Treatment	Install Lighting	1/5/2006 - 1/5/2009	3.00	8	**2.67**
Lighting	Install Flashing Beacons	1/6/2009 - 11/8/2010	1.84	8	**4.35**
Flashing Beacons	Present	11/9/2010 - 7/19/2013	2.70	16	**5.93**

Chapter 12: Predictive Method for Urban and Suburban Arterials

Site Conditions

Approach	Functional Classification	AADT (veh/day)
South Broad Street	Urban Arterial	7,842
East Green Street	Urban Local	2,000
West Green Street	Urban Local	2,000

- Stop-controlled on side streets
- Intersection Skew: 90°
- Left Turn Lanes: All approaches
- Right Turn Lanes: All approaches
- Lighting: All quadrants
- Analysis Year: 2012
- 2 Bus Stops within 1,000 ft of intersection
- No Schools within 1,000 ft of intersection
- No Alcohol Sales Establishments within 1,000 ft of intersection
- Pedestrian Volume (PedVol): 40 Peds/day
- Maximum # of lanes for pedestrian crossing (n_{lanes}): 6

Determine the predicted number of crashes at the existing stop-controlled intersection and a proposed signalized intersection.

Determine the predicted number of crashes at the existing stop-controlled intersection.

Safety Performance Function for Multi-Vehicle Crashes at Four-Leg, Stop-Controlled Intersections

$$N_{bimv,4ST} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \quad \textbf{(Equation 12-21)}$$

NOTE: If side streets have two different AADT volumes, use the greater value.

Use Table 12-10 to find SPF coefficients for 4ST.

$$N_{bimv,4ST} = exp[-8.90 + 0.82 \times ln(7,842) + 0.25 \times ln(2,000)]$$
$$N_{bimv,4ST} = 1.42\ crashes/year$$

If desired, find the number of multi-vehicle crashes based on severity level: Fatal/Injury (FI) and Property Damage Only (PDO). Use Equation 12-21 with appropriate crash severity coefficients from Table 12-10.

Fatal/Injury Crashes

$$N'_{bimv(FI),4ST} = exp[-11.13 + 0.93 \times ln(7,842) + 0.28 \times ln(2,000)]$$
$$N'_{bimv(FI),4ST} = 0.51\ crashes/year$$

Property Damage Only Crashes

$$N'_{bimv(PDO),4ST} = exp[-8.74 + 0.77 \times ln(7,842) + 0.23 \times ln(2,000)]$$
$$N'_{bimv(PDO),4ST} = 0.91\ crashes/year$$

Therefore, in order to assure that $N_{bimv(FI),4ST}$ and $N_{bimv(PDO),4ST}$ sum to $N_{bimv(total),4ST}$,

$$N_{bimv(FI),4ST} = N_{bimv(total),4ST} \times \left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}}\right) \quad \textbf{(Equation 12-22)}$$

$$N_{bimv(FI),4ST} = 1.42 \times \left(\frac{0.51}{0.51 + 0.91}\right)$$
$$N_{bimv(FI),4ST} = 0.51\ crashes/year$$

And thus,

$$N_{bimv(PDO),4ST} = N_{bimv(total),4ST} - N_{bimv(FI),4ST} \quad \textbf{(Equation 12-23)}$$
$$N_{bimv(PDO),4ST} = 1.42 - 0.51$$
$$N_{bimv(PDO),4ST} = 0.91\ crashes/year$$

Safety Performance Function for Single-Vehicle Crashes at Four-Leg, Stop-Controlled Intersections

$$N_{bisv,4ST} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \quad \textbf{(Equation 12-24)}$$

NOTE: If side streets have two different AADT volumes, use the greater value.

Use Table 12-12 to find SPF coefficients for 4ST.

$$N_{bisv,4ST} = exp[-5.33 + 0.33 \times ln(7,842) + 0.12 \times ln(2,000)]$$
$$N_{bisv,4ST} = 0.23\ crashes/year$$

Add results from both crash type totals.

$$N_{SPF,int} = N_{bimv,4ST} + N_{bisv,4ST} \quad \textbf{(Equation 12-7)}$$
$$N_{SPF,int} = 1.42 + 0.23$$
$$N_{SPF,int} = 1.65\ crashes/year$$

If desired, find the number of single-vehicle crashes based on severity level: Fatal/Injury (FI) and Property Damage Only (PDO). Use Equation 12-24 with appropriate crash severity coefficients from Table 12-12.

Fatal/Injury Crashes
***NOTE: No models are available for Fatal/Injury crashes for 4ST. Instead, use:*

$$N_{bisv(FI),4ST} = N_{bisv(total)} \times (f_{bisv}) \quad \textbf{(Equation 12-27)}$$

Where

$$f_{bisv} = \textbf{proportion of fatal \& injury crashes for combined sites} = 0.28 \text{ for } 4ST$$

Therefore,

$$N'_{bisv(FI),4ST} = 0.23 \times (0.28)$$
$$N'_{bisv(FI),4ST} = 0.06\ crashes/year$$

Property Damage Only Crashes
$$N'_{bisv(PDO),4ST} = exp[-7.04 + 0.36 \times ln(7,842) + 0.25 \times ln(2,000)]$$
$$N'_{bisv(PDO),4ST} = 0.16\ crashes/year$$

Therefore, in order to assure that $N_{bisv(FI),4ST}$ and $N_{bisv(PDO),4ST}$ sum to $N_{bisv(total),4ST}$,

$$N_{bisv(FI),4ST} = N_{bisv(total),4ST} \times \left(\frac{N'_{bisv(FI)}}{N'_{bisv(FI)}+N'_{bisv(PDO)}}\right)$$ **(Equation 12-25)**

$$N_{bisv(FI),4ST} = 0.23 \times \left(\frac{0.06}{0.06+0.15}\right)$$
$$N_{bisv(FI),4ST} = 0.07\ crashes/year$$

And thus,

$$N_{bisv(PDO),4ST} = N_{bisv(total),4ST} - N_{bisv(FI),4ST}$$ **(Equation 12-23)**
$$N_{bisv(PDO),4ST} = 0.23 - 0.07$$
$$N_{bisv(PDO),4ST} = 0.16\ crashes/year$$

Inclusion of *Intersection* Crash Modification Factors (CMFs):

Intersection Left Turn Lanes (Table 12-24)
NOTE: Left turn lanes on side street approaches have no effect on the CMF for stop-controlled intersections, therefore these two approaches can be disregarded.

$$CMF_{1i} = 0.53$$

Intersection Left-Turn Phasing (Table 12-25)
Note: This CMF is only applicable to signalized intersections. For unsignalized intersections, use 1.00.

$$CMF_{2i} = 1.00$$

Intersection Right Turn Lanes (Table 12-26)
NOTE: Right turn lanes on side street approaches have no effect on the CMF for stop-controlled intersections, therefore these two approaches can be disregarded.

$$CMF_{3i} = 0.74$$

Right Turn on Red
Note: This CMF is only applicable to signalized intersections. For unsignalized intersections, use 1.00.

$$CMF_{4i} = 1.00$$

Lighting (Table 12-27)

$$CMF_{5i} = 1 - 0.38 \times p_{ni}$$ **(Equation 12-36)**
$$CMF_{5i} = 1 - 0.38 \times (0.229)$$
$$CMF_{5i} = 0.91$$

Red-Light Cameras

Note: This CMF is only applicable to signalized intersections. For unsignalized intersections, use 1.00.

$$CMF_{6i} = 1.00$$

**There are no pedestrian-vehicle CMFs for intersection type 4ST. To determine pedestrian and bicycle crash rates for 4ST, use the following:

$$N_{bi} = N_{SPF,int} \times (CMF_{1i} \times \ldots \times CMF_{6i}) \quad \textbf{(Equation 12-6)}$$
$$N_{bi} = (1.65) \times (0.53) \times (1.00) \times (0.74) \times (1.00) \times (0.91) \times (1.00)$$
$$N_{bi} = 0.59\ crashes/year$$

$$N_{pedi} = N_{bi} \times (f_{pedi}) \quad \textbf{(Equation 12-30)}$$

Use Table 12-16 to determine f_{pedi}

$$N_{pedi} = 0.59 \times (0.022)$$
$$N_{pedi} = 0.01\ crashes/year$$

$$N_{bikei} = N_{pedi} \times (f_{bikei}) \quad \textbf{(Equation 12-31)}$$

Use Table 12-17 to determine f_{bikei}

$$N_{bikei} = 0.01 \times (0.018)$$
$$N_{bikei} = 0.00\ crashes/year$$

Inclusion of Calibration Factor C_i :

$$C_i = 1.00$$

NOTE: DelDOT is in the process of formulating local calibration factors. Until a formal set of calibration factors has been issued by the Department, the value of C_i is assumed to be 1.00.

Inclusion in Predictive Model:

$$N_{predicted,int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \quad \textbf{(Equation 12-5)}$$
$$N_{predicted,int} = 1.00 \times (0.59 + 0.01 + 0.00)$$

$$\boxed{N_{predicted,int} = 0.60\ crashes/year}$$

Determine the predicted number of crashes at the intersection, should a signal be installed.

Safety Performance Function for Multi-Vehicle Crashes at Four-Leg, Signalized Intersections

$$N_{bimv,4SG} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})]$$ **(Equation 12-21)**

NOTE: If side streets have two different AADT volumes, use the greater value.

Use Table 12-10 to find SPF coefficients for 4SG.

$$N_{bimv,4SG} = exp[-10.99 + 1.07 \times ln(7,842) + 0.23 \times ln(2,000)]$$
$$N_{bimv,4SG} = 1.42\ crashes/year$$

If desired, find the number of multi-vehicle crashes based on severity level: Fatal/Injury (FI) and Property Damage Only (PDO). Use Equation 12-21 with appropriate crash severity coefficients from Table 12-10.

Fatal/Injury Crashes
$$N'_{bimv(FI),4SG} = exp[-13.14 + 1.18 \times ln(7,842) + 0.22 \times ln(2,000)]$$
$$N'_{bimv(FI),4SG} = 0.44\ crashes/year$$

Property Damage Only Crashes
$$N'_{bimv(PDO),4SG} = exp[-11.02 + 1.02 \times ln(7,842) + 0.24 \times ln(2,000)]$$
$$N'_{bimv(PDO),4SG} = 0.98\ crashes/year$$

Therefore, in order to assure that $N_{bimv(FI),4SG}$ and $N_{bimv(PDO),4SG}$ sum to $N_{bimv(total),4SG}$,

$$N_{bimv(FI),4SG} = N_{bimv(total),4SG} \times \left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}}\right)$$ **(Equation 12-22)**

$$N_{bimv(FI),4SG} = 1.42 \times \left(\frac{0.44}{0.44 + 0.98}\right)$$
$$N_{bimv(FI),4SG} = 0.44\ crashes/year$$

And thus,

$$N_{bimv(PDO),4SG} = N_{bimv(total),4SG} - N_{bimv(FI),4SG}$$ **(Equation 12-23)**
$$N_{bimv(PDO),4SG} = 1.42 - 0.44$$
$$N_{bimv(PDO),4SG} = 0.98\ crashes/year$$

Safety Performance Function for Single-Vehicle Crashes at Four-Leg, Signalized Intersections

$$N_{bisv,4SG} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})]$$ **(Equation 12-24)**

NOTE: If side streets have two different AADT volumes, use the greater value.

Use Table 12-12 to find SPF coefficients for 4SG.

$$N_{bisv,4SG} = exp[-10.21 + 0.68 \times ln(7,842) + 0.27 \times ln(2,000)]$$
$$N_{bisv,4SG} = 0.13\ crashes/year$$

Add results from both crash types.

$$N_{SPF,int} = N_{bimv,4SG} + N_{bisv,4SG}$$ **(Equation 12-7)**
$$N_{SPF,int} = 1.42 + 0.13$$
$$N_{SPF,int} = 1.55\ crashes/year$$

If desired, find the number of single-vehicle crashes based on severity level: Fatal/Injury (FI) and Property Damage Only (PDO). Use Equation 12-24 with appropriate crash severity coefficients from Table 12-12.

Fatal/Injury Crashes
$$N'_{bisv(FI),4SG} = exp[-9.25 + 0.43 \times ln(7,842) + 0.29 \times ln(2,000)]$$
$$N'_{bisv(FI),4SG} = 0.04\ crashes/year$$

Property Damage Only Crashes
$$N'_{bisv(PDO),4SG} = exp[-11.34 + 0.78 \times ln(7,842) + 0.25 \times ln(2,000)]$$
$$N'_{bisv(PDO),4SG} = 0.09\ crashes/year$$

Therefore, in order to assure that $N_{bisv(FI),4SG}$ and $N_{bisv(PDO),4SG}$ sum to $N_{bisv(total),4SG}$,

$$N_{bisv(FI),4SG} = N_{bisv(total),4SG} \times \left(\frac{N'_{bisv(FI)}}{N'_{bisv(FI)} + N'_{bisv(PDO)}}\right)$$ **(Equation 12-25)**

$$N_{bisv(FI),4SG} = 0.13 \times \left(\frac{0.04}{0.04 + 0.09}\right)$$
$$N_{bisv(FI),4SG} = 0.04\ crashes/year$$

And thus,

$$N_{bisv(PDO),4SG} = N_{bisv(total),4SG} - N_{bisv(FI),4SG}$$ **(Equation 12-23)**

$N_{bisv(PDO),4SG} = 0.13 - 0.04$
$N_{bisv(PDO),4SG} = 0.09\ crashes/year$

Inclusion of *Intersection* Crash Modification Factors (CMFs):

Intersection Left Turn Lanes (Table 12-24)

$CMF_{1i} = 0.66$

Intersection Left-Turn Phasing (Table 12-25)
Note: Protected/Permissive left-turn phasing is assumed for this intersection.

$CMF_{2i} = 0.99$

Intersection Right Turn Lanes (Table 12-26)

$CMF_{3i} = 0.85$

Right Turn on Red
Note: Assume right turns on red are permitted on all approaches.

$CMF_{4i} = 1.00$

Lighting (Table 12-27)

$CMF_{5i} = 1 - 0.38 \times p_{ni}$ **(Equation 12-36)**
$CMF_{5i} = 1 - 0.38 \times (0.235)$
$CMF_{5i} = 0.91$

Red-Light Cameras
Note: Assume no red-light cameras will be in use at this intersection.

$CMF_{6i} = 1.00$

Therefore,

$N_{bi} = N_{SPF,int} \times (CMF_{1i} \times \ldots \times CMF_{6i})$ **(Equation 12-6)**
$N_{bi} = 1.55 \times (0.66 \times 0.99 \times 0.85 \times 1.00 \times 0.91 \times 1.00)$
$N_{bi} = 0.78\ crashes/year$

Inclusion of *Pedestrian* Crash Modification Factors (CMFs):

Bus Stops (Table 12-28)

$$CMF_{1p} = 2.78$$

Schools (Table 12-29)

$$CMF_{2p} = 1.00$$

Alcohol Sales Establishments (Table 12-30)

$$CMF_{3p} = 1.00$$

To determine pedestrian and bicycle crash rates for 4SG, use the following:

$$N_{pedi} = N_{pedbase} \times CMF_{1p} \times CMF_{2p} \times CMF_{3p}$$ **(Equation 12-28)**

Where: **(Equation 12-29, Table 12-14)**

$$N_{pedbase} = exp(a + b \times ln(AADT_{total}) + c \times ln\left(\frac{AADT_{min}}{AADT_{maj}}\right) + d \times ln(PedVol) + e \times n_{lanes}$$

$$N_{pedbase} = exp(-9.53 + 0.40 \times ln(9,842) + 0.26 \times ln\left(\frac{2,000}{7,842}\right) + 0.45 \times ln(40) + 0.04 \times (6)$$
$$N_{pedbase} = 0.01\ crashes/year$$

Therefore,

$$N_{pedi} = 0.01 \times (2.78) \times (1.00) \times (1.00)$$
$$N_{pedi} = 0.04\ crashes/year$$

And therefore,

$$N_{bikei} = N_{bi} \times f_{bikei}$$ **(Equation 12-31)**

Use Table 12-17 to determine f_{bikei}

$$N_{bikei} = 0.78 \times (0.015)$$
$$N_{bikei} = 0.01\ crashes/year$$

Inclusion of Calibration Factor C_i :

$$C_i = 1.00$$

NOTE: DelDOT is in the process of formulating local calibration factors. Until a formal set of calibration factors has been issued by the Department, the value of C_i is assumed to be 1.00.

Inclusion in Predictive Model:

$$N_{predicted,int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \quad \textbf{(Equation 12-5)}$$
$$N_{predicted,int} = 1.00 \times (0.78 + 0.04 + 0.01)$$

$$\boxed{N_{predicted,int} = 0.83\ crashes/year}$$

Final Results:

$$N_{predicted,int,4ST} = 0.60\ crashes/year$$
$$N_{predicted,int,4SG} = 0.83\ crashes/year$$