AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

AASHTO

THE VOICE OF TRANSPORTATION

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ERRATA for *Highway Safety Manual*

February 2012

Dear Customer:

Recently, we were made aware of some technical revisions that need to be applied to the *Highway Safety Manual*, 1st Edition.

Please replace the existing text with the corrected text to ensure that your edition is both accurate and current. Users who purchased the CD-ROM do **not** need to make the revisions noted in bold. Corrections that were included in the June 2011 errata are in blue ink.

AASHTO staff sincerely apologizes for any inconvenience.

Errata to *Highway Safety Manual*, 1st Edition

Page	Existing Text	Corrected Text
Volume 1		
3-17	The term $e^{(-0.4865)}$ is used in Equation 3-4.	Change the term to $e^{(-0.312)}$.
3-21	Answer to Example 1: "Using Equation 3-7, expected crashes . . ."	Change to "Using Equation 3-3 and a calibration factor = 1.0, expected crashes . . ."
3-21	Answer to Example 2: Using Equation 3.8 . . .	Change the answer to "Using Equation 3.7 . . ."
3-33	2nd to last equation on page began with $\hat{\mu}_{\text{Year 4}} = (5+7-11+9)/(0.87+0.71+0.64+1) = 32/3.22 = 9.94$ estimate of crashes for the last year:	Change to the following: $\hat{\mu}_{\text{Year 4}} = (5+7+11+9)/(0.87+0.71+0.64+1) = 32/3.22 = 9.94$ estimate of crashes for the last year:
4-17	The Coefficient of Variation for Segment B1 is shown as $CV_{B1} = \frac{\sqrt{7.7}}{5.7} = 0.53$.	The denominator should be 5.2: $CV_{B1} = \frac{\sqrt{7.7}}{5.2} = 0.53$
4-35	In the table showing Ranking Based on RSI, the Average RSI Cost for Intersection 6 is \$48,900.	The Average RSI cost for Intersection 6 should be \$42,800.
4-42	The calculation of crash frequency variance shown in the table in Step 3 indicates the variance for Signal is 10.5 and the variance for TWSC is 18.8.	The variance for Signal should be 13.75, and the variance for TWSC should be 10.5.
4-46	In Table 4-10, the heading for last column is "Average 3-Year Expected..."	Change this heading to "Average 3-Year Predicted . . ."
4-46	Eq. 4-16 is incorrect.	Replace Eq. 4-16 with the following: $\sigma = \sqrt{kN^2_{\text{predicted}}}$
4-60	In Eq. 4-26, the last item under "where" is $N_{\text{predicted},1(FI)}$.	Change this item to $N_{\text{predicted},n(FI)}$.
7-7	In Section 7.4.3.4, item 1-a-ii is shown as $(P/F,i,y) = (1 + i)(-y)$.	Change this item to $(P/F,i,y) = (1 + i)^{(-y)}$.
7-14	Table 12 is referenced in the last paragraph.	Change the reference to Table 7-5.
7-17	In Step 4, Eq. 7-13 is shown as: $AM_{(\text{total})} = AM_{(PDO)} \times AM_{(FI)}$.	Change Eq. 7-13 to $AM_{(\text{total})} = AM_{(PDO)} + AM_{(FI)}$.
7-18	Following Eq. 7-14, at the end of second line of the where list, the $(P/F,i,y)$ is calculated as $(1 + i) - y$.	Change this calculation to $(1 + i)^{(-y)}$.
7-19	In Table 7-10, Columns 2 and 4 need to be revised, as does the heading for Column 2.	Substitute Table 7-10 with the attached revised table.

Errata to *Highway Safety Manual*, 1st Edition

Page	Existing Text	Corrected Text
7-19	The first line under Results states, "The estimated present value monetary benefit of installing a roundabout at Intersection 2 is $33,437,850."	Change the amount to $5,675,500.
9-8	Step 2 of Figure 9-2 states, "Calculate the predicted crash frequency for each site summed over the entire before period."	Change "predicted" to "expected."
9-21	**Eq. A-10 is referenced in the last column in the table under Step 6.**	**Change the reference to Eq. 9A.1-11.**
9-41	Eq. 9A.2-16 is shown as Safety Effectiveness = 100 × (1 − *R*).	Change this equation to Safety Effectiveness = 100 × (1 − *OR*).
Volume 2		
C-14	After Figure C-3, a heading was inadvertently omitted.	Add the heading "C.6.3 Safety Performance Functions (SPFs)" immediately following Figure C-3.
C-14	**The term $e^{(-0.4865)}$ is used in Eq. C-4.**	**Change the term to $e^{(-0.312)}$.**
C-15	C.6.3 Crash Modification Factors (CMFs)	Renumber the heading as "C.6.4 Crash Modification Factors (CMFs)."
C-18	C.6.4 Calibration of Safety Performance Functions to Local Conditions	Renumber the heading as "C.6.5 Calibration of Safety Performance Functions to Local Conditions."
C-18	C.6.5 Weighting Using the Empirical Bayes Method	Renumber the heading as "C.6.6 Weighting Using the Empirical Bayes Method."
10-23	**The 3rd row about (CMF_{3r}) in Table 10-7 references Table 10-7.**	**Change this reference to Equation 10-13.**
10-23	The 6th row about (CMF_{6r}) in Table 10-7 references Table 10-11.	Change this reference to Equation 10-17.
10-25	**The calculation 0.98 + 6.875 is used in an equation within the last row in Table 10-9.**	**Change the calculation to 0.98 – 6.875.**
10-42	A 1,2000-ft horizontal curve radius is used in the 5th bullet under the heading The Facts.	Change the horizontal curve radius to 1,200 ft.
11-10	The second sentence of Step 12 reads, "Otherwise, proceed to Step 14."	Change "Step 14" to "Step 13."
11-31	Paragraph 1, line 7 refers to Table 13-9.	Change this reference to Table 13-13.

Page	Existing Text	Corrected Text
11-33	Eq. 11-18 is shown as $CMF_{1i} = \frac{0.016 \times skew}{(0.98 + 0.16 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{1i} = \frac{0.016 \times skew}{(0.98 + 0.016 \times skew)} + 1.0$
11-33	Eq. 11-19 is shown as $CMF_{1i} = \frac{0.017 \times skew}{(0.52 + 0.17 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{1i} = \frac{0.017 \times skew}{(0.52 + 0.017 \times skew)} + 1.0$
11-34	Eq. 11-20 is shown as $CMF_{1i} = \frac{0.053 \times skew}{(1.43 + 0.53 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{1i} = \frac{0.053 \times skew}{(1.43 + 0.053 \times skew)} + 1.0$
11-34	Eq. 11-21 is shown as $CMF_{1i} = \frac{0.048 \times skew}{(0.72 + 0.48 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{1i} = \frac{0.048 \times skew}{(0.72 + 0.048 \times skew)} + 1.0$
11-50	Step 10, Intersection Skew Angle calculates CMF_{1i} as follows: $CMF_{1i} = \frac{0.016 \times skew}{(0.98 + 0.16 \times skew)} + 1.0$ $CMF_{1i} = \frac{0.016 \times 30}{(0.98 + 0.16 \times 30)} + 1.0 = 1.08$	Change this calculation to $CMF_{1i} = \frac{0.016 \times skew}{(0.98 + 0.016 \times skew)} + 1.0$ $CMF_{1i} = \frac{0.016 \times 30}{(0.98 + 0.016 \times 30)} + 1.0 = 1.33$
11-50	The final calculation in Step 10 is $CMF_{comb} = 1.08 \times 0.56 \times 0.90 = 0.54$.	Change this calculation to $CMF_{comb} = 1.33 \times 0.56 \times 0.90 = 0.67$.
11-50	Step 11, Calculation of Predicted Average Crash Frequency, indicates the results are = 0.928 × 1.50 × (0.54) = 0.752 crashes/year.	Change these results to = 0.928 × 1.50 × (0.67) = 0.933 crashes/year.
11-52	Column 2 of the table for Worksheet SP3B lists CMF for Intersection Skew Angle for the Total Crash Severity Level in Row 1 as 1.08 and the Fatal and Injury Crash Severity Level in Row 2 as 1.09.	Change the CMF for Intersection Skew Angle for the Total Crash Severity Level to 1.33 and the Fatal and Injury Crash Severity Level to 1.50.
11-52	Column 6 of the table for Worksheet SP3B lists Combined CMF for the Total Crash Severity Level in Row 1 as 0.54 and the Fatal and Injury Crash Severity Level in Row 2 as 0.44.	Change the Combined CMF in Column 6 to 0.67 for the Total Crash Severity Level in Row 1 and to 0.61 for the Fatal and Injury Crash Severity Level in Row 2.
11-52	Column 5 of the Worksheet SP3C show the values for Combined CMFs are 0.54 for Total Crash Severity Level in Row 1, 0.44 for Fatal and Injury Crash Severity Level in Row 2, and 0.44 for Fatal and Injury Crash Severity Level in Row 3.	Change these values to 0.67, 0.61, and 0.61, respectively.

Page	Existing Text	Corrected Text
11-52	Column 7 of the Worksheet SP3C show the values for Predicted Crash Frequency are 0.752 for Total Crash Severity Level in Row 1, 0.286 for Fatal and Injury Crash Severity Level in Row 2, 0.178 for Fatal and Injury Crash Severity Level in Row 3, and 0.466 for Property Damage Only in Row 4.	Change these values to 0.933, 0.396, 0.247, and 0.537, respectively.
11-53	The values in Columns 3, 5, 7, and 9 in the table for Worksheet SP3D are incorrect.	Substitute the table for Worksheet SP3D with the attached revised table.
11-53	In the table for Worksheet SP3E, the values for Predicted Average Crash Frequency listed in Column 2 are 0.752, 0.286, 0.178, 0.466 crashes/year.	Change these values to 0.933, 0.396, 0.247, and 0.537, respectively.
11-55	The values in Columns 2, 3, 4, 7, and 8 for Intersections shown in Worksheet SP4A are incorrect.	Substitute the table for Worksheet SP4A with the attached revised table.
11-55	The final calculation for Intersection 1 is shown as $w = \frac{1}{1+0.460\times(0.752)} = 0.743$.	Change this calculation to $w = \frac{1}{1+0.460\times(0.933)} = 0.700$.
11-56	Under the subheading Column 8—Expected Average Crash Frequency, the calculation for Intersection 1 is shown as follows: $N_{expected} = 0.743 \times 0.752 + (1 - 0.743) \times 3 = 1.330$.	Change this calculation to $N_{expected} = 0.700 \times 0.933 + (1 - 0.700) \times 3 = 1.554$.
11-56	The values and the reference to Worksheet 3A in the table for Worksheet SP4B are incorrect.	Substitute the table for Worksheet SP4B with the attached revised table.
11-58	The headings and values shown in the tables for Worksheet SP5A and SP5A Continued are incorrect.	Substitute the tables for Worksheet SP5A and SP5A Continued with the attached revised table.
11-59	The calculation for w_0 in Column 9 is shown as $= \frac{1}{1+\frac{1.968}{4.347}}$ $= 0.688$	Change the calculation to $= \frac{1}{1+\frac{2.109}{4.528}}$ $= 0.682$
11-59	The calculation for N_0 in Column 10 is shown as $= 0.688 \times 4.347 + (1 - 0.688) \times 9 = 5.799$.	Change the calculation to $0.682 \times 4.528 + (1 - 0.682) \times 9 = 5.950$.

Page	Existing Text	Corrected Text
11-59	The calculation for w_1 in Column 11 is shown as $= \frac{1}{1+\frac{2.009}{4.347}}$ $= 0.684$	Change this calculation to $= \frac{1}{1+\frac{2.076}{4.528}}$ $= 0.686$
11-59	The calculation for N_1 in Column 12 is shown as $= 0.684 \times 4.347 + (1 - 0.684) \times 9 = 5.817$.	Change this calculation to $= 0.686 \times 4.528 + (1 - 0.686) \times 9 = 5.932$.
11-59	The calculation for $N_{expected/comb}$ in Column 13 is shown as $= \frac{5.799 + 5.817}{2}$ $= 5.808$	Change this calculation to $= \frac{5.950 + 5.932}{2}$ $= 5.941$
11-60	The values shown in the table for Worksheet SP5B are incorrect.	Substitute the table for Worksheet SP5B with the attached revised table.
11-61	The first sentence in the section on Results reads, "The predicted average crash frequency for the proposed four-lane facility project is 4.4 crashes per year, and the predicted crash reduction for the project is 8.1 crashes per year."	Change the numbers to 4.5 crashes per year for the predicted average crash frequency and 7.8 crashes per year for the predicted crash reduction.
11-61	The values in Table 11-26 are incorrect.	Substitute Table 11-26 with the attached revised table.
12-12	The second sentence of Step 12 reads, "Otherwise, proceed to Step 14."	Change "Step 14" to "Step 13."
12-43	Paragraph 1, line 2 of Section 12.7.2 refers to CMF_{4i}.	Change CMF_{4i} to CMF_{6i}.
12-86	Paragraph 1, Line 1 of the section on Results refers to "the unsignalized intersection in Sample Problem 4."	Change "unsignalized" to "signalized."
12-114	Column head (7) of *Worksheet 2C Continued* refers to Worksheet SP4B.	Change the reference to Worksheet 2B.
12-115	Column head (7) of *Worksheet 2E Continued* refers to Worksheet SP4B.	Change the reference to Worksheet 2B.
A-5	In Table A-2, the row for Presence of Lighting for Chapter 11 shows the "X" in the Required column.	The "X" should be in the Desirable column.
A-5	In Table A-2, the row for Sideslope for Chapter 11 shows the "X" not aligned in the Required column.	The "X" should be in the Required column.

Page	Existing Text	Corrected Text
A-6	In Table A-2, the row for Presence of Lighting for Chapter 11 reads "Need actual datad."	The final d should be deleted so that the text reads "Need actual data."
A-6	In Table A-2, the row for Intersection Skew Angle for Chapter 11 does not have a superscript.	Insert a superscript "d" to indicate a cross reference to table note d. The text should read, "Assume no skew^{d}".
A-7	In Table A-2, Pedestrian Volume for Chapter 12 refers to "Estimate with Table 12-21."	Change the cross reference to Table 12-15.
A-8	The first line of Example Calibration Factor Calculation refers to Equation 10-18.	Change the cross reference to Equation 10-10.
A-8	In the calculation for predicted crash frequency, the sample indicates that $N_{bibase} = e^{(-5.73 + 0.60 \times \ln(4000) + 0.20 \times \ln(2000))} = 2.152$ crashes/year	The correct values should be $N_{bibase} = e^{(-5.13 + 0.60 \times \ln(4000) + 0.20 \times \ln(2000))} = 3.922$ crashes/year
A-8	In the paragraph following the N_{bibase} calculation, the first sentence states, "The intersection has a left-turn lane on the major road, for which CMF_{1i} is 0.67, and a right-turn lane on one approach, a feature for which CMF_{2i} is 0.98."	Change this text to read, "The intersection has a left-turn lane on the major road, for which CMF_{1i} is 0.82, and a right-turn lane on one approach, a feature for which CMF_{2i} is 0.96."
A-8	The calculation for predicted average crash frequency is recorded as "2.152 × 0.67 × 0.98 × 3 = 4.240 crashes in three years, shown in Column 9."	The correct values for this calculation are actually "3.922 × 0.82 × 0.96 × 3 = 9.262 crashes in three years, shown in Column 9."
A-8	The final paragraph on page A-8 indicates, ". . . The sum of the observed crash frequencies in Column 10 (43) is divided by the sum of the predicted average crash frequencies in Column 9 (45.594) to obtain the calibration factor, C_i, equal to 0.943. It is recommended that calibrations factors be rounded to two decimal places, so calibration factor equal to 0.94 should be used . . ."	These sentences of the paragraph should read, ". . .The sum of the observed crash frequencies in Column 10 (43) is divided by the sum of the predicted average crash frequencies in Column 9 (87.928) to obtain the calibration factor, C_i, equal to 0.489. It is recommended that calibrations factors be rounded to two decimal places, so calibration factor equal to 0.49 should be used . . ."
A-9	The values in Columns 3, 5, 7, and 9 of Table Ex-1 are incorrect.	Substitute the table for Table Ex-1 with the attached revised table.
Volume 3		
D-3	A sentence for Row "T" in Table D-1 was omitted.	Add "A list of these treatments is presented in the appendices to each chapter" as the final sentence in this row.
D-5	Item 2 in Section D.4.4, Application of CMFs to Estimate Crash Frequency, refers to "an expected number of crashes."	Change this phrase to "a predicted number of crashes."

Page	Existing Text	Corrected Text
13-22	There is no specific table referenced in the first sentence of the first paragraph to Section 13.5.2.2.	Reference Table 13-21.
13-24	Table 13-2 is referenced in the 2nd paragraph to Section 13.5.2.4.	Change the reference to Table 13-23.
13-35	Table 13-411 is referenced in the 2nd paragraph to Section 13.8.2.7.	Change the reference to Table 13-41.
13-48	Table 13-54 is missing a row for installing pedestrian-activated flashing yellow beacons with overhead signs. In addition, the treatment to provide pedestrian overpasses and underpasses has a trend for urban arterials.	Replace Table 13-54 with the attached revision. Change bars indicate rows that have been revised.
14-10	Exhibit 14-8 is referenced in the last paragraph.	Change the reference to Table 14-4.
14-19	Eq. 14-3 is shown as $CMF = \frac{0.016 \times skew}{(0.98 + 0.16 \times skew)} + 1.0$	Change the denominator as follows: $CMF = \frac{0.016 \times skew}{(0.98 + 0.016 \times skew)} + 1.0$
14-19	Eq. 14-4 is shown as $CMF = \frac{0.053 \times skew}{(1.43 + 0.53 \times skew)} + 1.0$	Change the denominator as follows: $CMF = \frac{0.053 \times skew}{(1.43 + 0.053 \times skew)} + 1.0$
14-20	Eq. 14-5 is shown as $CMF_{kab} = \frac{0.017 \times skew}{(0.52 + 0.17 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{kab} = \frac{0.017 \times skew}{(0.52 + 0.017 \times skew)} + 1.0$
14-20	Eq. 14-6 is shown as $CMF_{kab} = \frac{0.048 \times skew}{(0.72 + 0.48 \times skew)} + 1.0$	Change the denominator as follows: $CMF_{kab} = \frac{0.048 \times skew}{(0.72 + 0.048 \times skew)} + 1.0$
14-42	Exhibit 14-38 is referenced in the 3rd paragraph to Section 14.7.2.8.	Change the reference to Table 14-28.
14-52	The final sentence of Section 14A.5.1.8 reads, "The LPI provides pedestrians an opportunity to begin crossing without concern for turning vehicles (assuming right-on-red is <u>permitted</u>)."	This sentence should read, "The LPI provides pedestrians an opportunity to begin crossing without concern for turning vehicles (assuming right-on-red is <u>prohibited</u>)."
15-4	There are unknown crash effects for modifying ramp type or configuration and for providing pedestrian facilities on ramp terminals.	Replace Table 15-1 with the attached revision. The two rows referring to modifying ramp type or configuration and to providing pedestrian facilities on ramp terminals have been deleted.

Page	Existing Text	Corrected Text
15-11	A bulleted item is missing under Section 15A.3.1, Ramp Roadways.	Add the following bulleted item: ■ Modify ramp type or configuration.
15-12	A bulleted item is missing under Section 15A.3.1, Bicyclists and Pedestrians.	Add the following bulleted item: ■ Provide pedestrian facilities on ramp terminals.
16-6	Exhibit 16-5 is referenced in the 2nd sentence to Section 16.4.2.1.	Change the reference to Figure 16-1.
16-6	Figure 16-1 is referenced in the 3rd sentence to Section 16.4.2.1.	Change the reference to Figure 16-2.
17-5	There are unknown crash effects for mitigating aggressive driving through engineering and for implementing older driver education and retesting programs.	Replace Table 17-4 with the attached revision. The two rows referring to mitigating aggressive driving through engineering and to implementing older driver education and retesting programs have been deleted.
17-14	A subsection is missing under Section 17A.4.1.	Add the following subsection and text after the 3rd paragraph to subsection 17A.4.1.6: 17A.4.1.7. Conduct Enforcement to Reduce Red-Light Running Automated enforcement for red-light running, combined with appropriate enabling legislation, potentially reduces crashes.
17-14 to 17-16	As a result of adding a subsection that was missing under Section 17A.4.1, renumber the remaining subsections.	Renumber as follows: ■ Section 17A.4.1.7 as Section 17A.4.1.8 ■ Section 17A.4.1.8 as Section 17A.4.1.9 ■ Section 17A.4.1.9 as Section 17A.4.1.10 ■ Section 17A.4.1.10 as Section 17A.4.1.11 ■ Section 17A.4.1.11 as Section 17A.4.1.12
Throughout	Some equations using natural logarithm were inadvertently typeset with "In" instead of "ln".	Please replace the "In" with "ln" in these equations.

Table 7-10 summarizes the results of converting the annual values to present values.

Table 7-10. Converting Annual Values to Present Values

Year in service life (y)	($P/F,i,y$)	$AM_{(total)}$	Present Value
1	0.96	\$682,480	\$656,230
2	0.92	\$682,480	\$630,990
3	0.89	\$682,480	\$606,720
4	0.85	\$698,300	\$596,910
5	0.82	\$698,300	\$573,950
6	0.79	\$698,300	\$551,880
7	0.76	\$714,120	\$542,670
8	0.73	\$714,120	\$521,800
9	0.70	\$714,120	\$501,730
10	0.68	\$729,200	\$492,620
Total			\$5,675,500

The total present value of the benefits of installing a roundabout at Intersection 2 is the sum of the present value for each year of the service life. The sum is shown above in Table 7-10.

Results

The estimated present value monetary benefit of installing a roundabout at Intersection 2 is \$5,675,500.

The roadway agency estimates the cost of installing the roundabout at Intersection 2 is \$2,000,000.

If this analysis were intended to determine whether the project is cost-effective, the magnitude of the monetary benefit provides support for the project. If the monetary benefit of change in crashes at this site were to be compared to other sites the BCR could be calculated and used to compare this project to other projects in order to identify the most economically efficient project.

7.10. REFERENCES

(1) AASHTO. *A Manual of User Benefit Analysis for Highways*, 2nd Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2003.

(2) Council, F. M., E. Zaloshnja, T. Miller, and B. Persaud. *Crash Cost Estimates by Maximum Police Reported Injury Severity within Selected Crash Geometries*. Publication No. FHWA-HRT-05-051. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, October 2005.

(3) Harwood, D. W. et al. *Safety Analyst: Software Tools for Safety Management of Specific Highway Sites Task M Functional Specification for Module 3*. Economic Appraisal and Priority Ranking GSA Contract No. GS-23F-0379K Task No. DTFH61-01-F-00096. Midwest Research Institute for FHWA. November 2003. More information available from http://www.safetyanalyst.org.

Using the default proportions, the predicted average crash frequency by collision type in Columns 3 (Total), 5 (Fatal and Injury, FI), 7 (Fatal and Injury, not including "possible injury"), and 9 (Property Damage Only, PDO).

These proportions may be used to separate the predicted average crash frequency (from Column 7, Worksheet SP3C) by crash severity and collision type.

Worksheet SP3D. Crashes by Severity Level and Collision Type for Rural Multilane Highway Intersections

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Collision Type	Proportion of Collision Type $_{(total)}$	$N_{predicted\ int\ (total)}$ (crashes/year)	Proportion of Collision Type $_{(FI)}$	$N_{predicted\ int\ (FI)}$ (crashes/year)	Proportion of Collision Type $_{(FI^a)}$	$N_{predicted\ int\ (FI^a)}$ (crashes/year)	Proportion of Collision Type (PDO)	$N_{predicted\ int\ (PDO)}$ (crashes/year)
	from Table 11-9	$(7)_{total}$ from Worksheet SP3C	from Table 11-9	$(7)_{FI}$ from Worksheet SP3C	from Table 11-9	$(7)_{FI^a}$ from Worksheet SP3C	from Table 11-9	$(7)_{PDO}$ from Worksheet SP3C
Total	1.000	0.933	1.000	0.396	1.000	0.247	1.000	0.537
		$(2)*(3)_{total}$		$(4)*(5)_{FI}$		$(6)*(7)_{FI^a}$		$(8)*(9)_{PDO}$
Head-on collision	0.029	0.027	0.043	0.017	0.052	0.013	0.020	0.011
Sideswipe collision	0.133	0.124	0.058	0.023	0.057	0.014	0.179	0.096
Rear-end collision	0.289	0.270	0.247	0.098	0.142	0.035	0.315	0.169
Angle collision	0.263	0.245	0.369	0.146	0.381	0.094	0.198	0.106
Single-vehicle collision	0.234	0.218	0.219	0.087	0.284	0.070	0.244	0.131
Other collision	0.052	0.049	0.064	0.025	0.084	0.021	0.044	0.024

[a] Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

Worksheet SP3E—Summary Results for Rural Multilane Highway Intersections

Worksheet SP3E presents a summary of the results.

Worksheet SP3E. Summary Results for Rural Multilane Highway Intersections

(1)	(2)
	Predicted Average Crash Frequency (crashes/year)
Crash Severity Level	(7) from Worksheet SP3C
Total	0.933
Fatal and injury (FI)	0.396
Fatal and injury[a] (FI[a])	0.247
Property damage only (PDO)	0.537

[a] Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

Worksheet SP4A. Predicted and Observed Crashes by Severity and Site Type Using the Site-Specific EB Method for Rural Two-Lane, Two-Way Roads and Multilane Highways

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Predicted Average Crash Frequency (crashes/year)			Observed Crashes, $N_{observed}$		Weighted Adjustment, w	Expected Average Crash Frequency, $N_{expected}$
Site Type	$N_{predicted\ (total)}$	$N_{predicted\ (FI)}$	$N_{predicted\ (PDO)}$	(crashes/year)	Overdispersion Parameter, k	Equation A-5	Equation A-4
Roadway Segments							
Segment 1	3.306	1.726	1.580	4	0.142	0.681	3.527
Segment 2	0.289	0.177	0.112	2	1.873	0.649	0.890
Intersections							
Intersection 1	0.933	0.396	0.537	3	0.460	0.700	1.554
Combined (Sum of Column)	4.528	2.299	2.229	9	—	—	5.971

Column 7—Weighted Adjustment

The weighted adjustment, w, to be placed on the predictive model estimate is calculated using Equation A-5 as follows:

$$w = \frac{1}{1 + k \times \left(\sum_{\substack{\text{all study}\\\text{years}}} N_{predicted} \right)}$$

Segment 1

$$w = \frac{1}{1 + 0.142 \times (3.306)} = 0.681$$

Segment 2

$$w = \frac{1}{1 + 1.873 \times (0.289)} = 0.649$$

Intersection 1

$$w = \frac{1}{1 + 0.460 \times (0.933)} = 0.700$$

Column 8—Expected Average Crash Frequency

The estimate of expected average crash frequency, $N_{expected}$, is calculated using Equation A-4 as follows:

$$N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$$

Segment 1: $N_{expected} = 0.681 \times 3.306 + (1 - 0.681) \times 4 = 3.527$

Segment 2: $N_{expected} = 0.649 \times 0.289 + (1 - 0.649) \times 2 = 0.890$

Intersection 1: $N_{expected} = 0.743 \times 0.752 + (1 - 0.743) \times 3 = 1.330$

Worksheet SP4B—Site-Specific EB Method Summary Results for Rural Two-Lane, Two-Way Roads and Multilane Highways

Worksheet SP4B presents a summary of the results. The expected average crash frequency by severity level is calculated by applying the proportion of predicted average crash frequency by severity level to the total expected average crash frequency (Column 3).

Worksheet SP4B. Site-Specific EB Method Summary Results for Rural Two-Lane, Two-Way Roads and Multilane Highways

(1)	(2)	(3)
Crash Severity Level	$N_{predicted}$	$N_{expected}$
Total	$(2)_{comb}$ from Worksheet SP4A	$(8)_{comb}$ from Worksheet SP4A
	4.528	6.0
Fatal and injury (FI)	$(3)_{comb}$ from Worksheet SP4A	$(3)_{total}*(2)_{FI}/(2)_{total}$
	2.299	3.0
Property damage only (PDO)	$(4)_{comb}$ from Worksheet SP4A	$(3)_{total}*(2)_{PDO}/(2)_{total}$
	2.229	3.0

11.12.5. Sample Problem 5

The Project

A project of interest consists of three sites: a rural four-lane divided highway segment, a rural four-lane undivided highway segment, and a three-leg intersection with minor-road stop control. (This project is a compilation of roadway segments and intersections from Sample Problems 1, 2, and 3.)

The Question

What is the expected average crash frequency of the project for a particular year incorporating both the predicted crash frequencies from Sample Problems 1, 2, and 3 and the observed crash frequencies using the **project-level EB Method?**

The Facts

- 2 roadway segments (4D segment, 4U segment)
- 1 intersection (3ST intersection)
- 9 observed crashes (but no information is available to attribute specific crashes to specific sites within the project)

Worksheet SP5A. Predicted and Observed Crashes by Severity and Site Type Using the Project-Level EB Method for Rural Two-Lane, Two-Way Roads and Multilane Highways

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Predicted Average Crash Frequency (crashes/year)	Observed Crashes, $N_{observed}$ (crashes/year)				
Site Type	$N_{predicted\ (total)}$	$N_{predicted\ (FI)}$	$N_{predicted\ (PDO)}$	N_{w0}	Overdispersion Parameter, k	Equation A-8 (6)* (2)²
Roadway Segments						
Segment 1	3.306	1.726	1.580	4	0.142	1.552
Segment 2	0.289	0.177	0.112	2	1.873	0.156
Intersections						
Intersection 1	0.933	0.396	0.537	3	0.460	0.400
Combined (sum of column)	4.528	2.299	2.229	9	—	2.109

Note: $N_{predicted\ w0}$ = Predicted number of total crashes assuming that crash frequencies are statistically independent

Worksheet SP5A. Continued

(1)	(8)	(9)	(10)	(11)	(12)	(13)
Site Type	N_{w1}	w_0	N_0	w_1	N_1	
Equation A-9 sqrt((6)*(2))	Equation A-10	Equation A-11	Equation A-12	Equation A-13	Equation A-14	$N_{expected/comb}$
Roadway Segments						
Segment 1	0.685	—	—	—	—	—
Segment 2	0.736	—	—	—	—	—
Intersections						
Intersection 1	0.655	—	—	—	—	—
Combined (Sum of Column)	2.076	0.682	5.95	0.686	5.932	5.941

Note: $N_{predicted\ w0}$ = Predicted number of total crashes assuming that crash frequencies are statistically independent

$$N_{\text{predicted } w0} = \sum_{j=1}^{5} k_{rmj} N_{rmj}^2 + \sum_{j=1}^{5} k_{rsj} N_{rsj}^2 + \sum_{j=1}^{5} k_{rdj} N_{rdj}^2 + \sum_{j=1}^{4} k_{imj} N_{imj}^2 + \sum_{j=1}^{4} k_{isj} N_{isj}^2 \tag{A-8}$$

$N_{predicted\ w1}$ = Predicted number of total crashes assuming that crash frequencies are perfectly correlated

$$N_{\text{predicted } w1} = \sum_{j=1}^{5} \sqrt{k_{rmj} N_{rmj}} + \sum_{j=1}^{5} \sqrt{k_{rsj} N_{rsj}} + \sum_{j=1}^{5} \sqrt{k_{rdj} N_{rdj}} + \sum_{j=1}^{4} \sqrt{k_{imj} N_{imj}} + \sum_{j=1}^{4} \sqrt{k_{isj} N_{isj}} \tag{A-9}$$

Worksheet SP5B—Project-Level EB Method Summary Results for Rural Two-Lane, Two-Way Roads and Multilane Highways

Worksheet SP5B presents a summary of the results. The expected average crash frequency by severity level is calculated by applying the proportion of predicted average crash frequency by severity level to the total expected average crash frequency (Column 3).

Worksheet SP5B. Project-Level EB Method Summary Results for Rural Two-Lane, Two-Way Roads and Multilane Highways

(1)	(2)	(3)
Crash Severity Level	$N_{predicted}$	$N_{expected}$
Total	$(2)_{comb}$ from Worksheet SP5A	$(13)_{comb}$ from Worksheet SP5A
	4.528	5.9
Fatal and injury (FI)	$(3)_{comb}$ from Worksheet SP5A	$(3)_{total}*(2)_{FI}/(2)_{total}$
	2.299	3.0
Property damage only (PDO)	$(4)_{comb}$ from Worksheet SP5A	$(3)_{total}*(2)_{PDO}/(2)_{total}$
	2.229	2.9

11.12.6. Sample Problem 6

The Project

An existing rural two-lane roadway is proposed for widening to a four-lane highway facility. One portion of the project is planned as a four-lane divided highway, while another portion is planned as a four-lane undivided highway. There is one three-leg stop-controlled intersection located within the project limits.

The Question

What is the expected average crash frequency of the proposed rural four-lane highway facility for a particular year, and what crash reduction is expected in comparison to the existing rural two-lane highway facility?

The Facts

- Existing rural two-lane roadway facility with two roadway segments and one intersection equivalent to the facilities in Chapter 10's Sample Problems 1, 2, and 3.
- Proposed rural four-lane highway facility with two roadway segments and one intersection equivalent to the facilities in Sample Problems 1, 2, and 3 presented in this chapter.

Outline of Solution

Sample Problem 6 applies the Project Estimation Method 1 presented in Section C.7 (i.e., the expected average crash frequency for existing conditions is compared to the predicted average crash frequency of proposed conditions). The expected average crash frequency for the existing rural two-lane roadway can be represented by the results from applying the site-specific EB Method in Chapter 10's Sample Problem 5. The predicted average crash frequency for the proposed four-lane facility can be determined from the results of Sample Problems 1, 2, and 3 in this chapter. In this case, Sample Problems 1 through 3 are considered to represent a proposed facility rather than an existing facility; therefore, there is no observed crash frequency data, and the EB Method is not applicable.

Results

The predicted average crash frequency for the proposed four-lane facility project is 4.5 crashes per year, and the predicted crash reduction from the project is 7.8 crashes per year. Table 11-26 presents a summary of the results.

Table 11-26. Summary of Results for Sample Problem 6

Site	Expected Average Crash Frequency for the Existing Condition (crashes/year)[a]	Predicted Average Crash Frequency for the Proposed Condition (crashes/year)[b]	Predicted Crash Reduction from Project Implementation (crashes/year)
Segment 1	8.02	3.3	4.7
Segment 2	1.34	0.3	1.1
Intersection 1	2.94	0.9	2.0
Total	12.3	4.5	7.8

[a] From Sample Problems 5 in Chapter 10
[b] From Sample Problems 1 through 3 in Chapter 11

11.13. REFERENCES

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Table Ex-1. Example of Calibration Factor Computation

1	2	3	4	5	6	7	8	9	10
$AADT_{maj}$	$AADT_{min}$	SPF Prediction	Intersection Approaches with Left-Turn Lanes	CMF_{1i}	Intersection Approaches with Right-Turn Lane	CMF_{2i}	Years of Data	Predicted Average Crash Frequency	Observed Crash Frequency
4000	2000	3.922	1	0.82	1	0.96	3	9.262	4
3000	1500	3.116	0	1.00	2	0.92	2	5.733	5
5000	3400	4.986	0	1.00	2	0.92	3	13.761	10
6500	3000	5.692	0	1.00	2	0.92	3	15.709	5
3600	2300	3.786	1	0.82	1	0.96	3	8.941	2
4600	4500	5.016	0	1.00	2	0.92	3	13.844	8
5700	3300	5.362	1	0.82	1	0.96	3	12.662	5
6800	1500	5.091	1	0.82	1	0.96	2	8.015	4
							Sum	87.928	43
							Calibration Factor (C_i)		0.489

A.1.2. Development of Jurisdiction-Specific Safety Performance Functions for Use in the Part C Predictive Method

Satisfactory results from the Part C predictive method can be obtained by calibrating the predictive model for each facility type, as explained in Appendix A.1.1. However, some users may prefer to develop jurisdiction-specific SPFs using their agency's own data, and this is likely to enhance the reliability of the Part C predictive method. While there is no requirement that this be done, HSM users are welcome to use local data to develop their own SPFs, or if they wish, replace some SPFs with jurisdiction-specific models and retain other SPFs from the Part C chapters. Within the first two to three years after a jurisdiction-specific SPF is developed, calibration of the jurisdiction-specific SPF using the procedure presented in Appendix A.1.1 may not be necessary, particularly if other default values in the Part C models are replaced with locally-derived values, as explained in Appendix A.1.3.

If jurisdiction-specific SPFs are used in the Part C predictive method, they need to be developed with methods that are statistically valid and developed in such a manner that they fit into the applicable Part C predictive method. The following guidelines for development of jurisdiction-specific SPFs that are acceptable for use in Part C include:

- In preparing the crash data to be used for development of jurisdiction-specific SPFs, crashes are assigned to roadway segments and intersections following the definitions explained in Appendix A.2.3 and illustrated in Figure A-1.
- The jurisdiction-specific SPF should be developed with a statistical technique such as negative binomial regression that accounts for the overdispersion typically found in crash data and quantifies an overdispersion parameter so that the model's predictions can be combined with observed crash frequency data using the EB Method.
- The jurisdiction-specific SPF should use the same base conditions as the corresponding SPF in Part C or should be capable of being converted to those base conditions.
- The jurisdiction-specific SPF should include the effects of the following traffic volumes: average annual daily traffic volume for roadway segment and major- and minor-road average annual daily traffic volumes for intersections.
- The jurisdiction-specific SPF for any roadway segment facility type should have a functional form in which predicted average crash frequency is directly proportional to segment length.

Table 13-54. Summary of Roadway Treatments for Pedestrians and Bicyclists

HSM Section	Treatment	Rural Two-Lane Road	Rural Multilane Highway	Freeway	Expressway	Urban Arterial	Suburban Arterial
Appendix 13A.9.1.1	Provide a sidewalk or shoulder	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.2	Install raised pedestrian crosswalks	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.3	Install pedestrian-activated flashing yellow beacons with overhead signs	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.4	Install pedestrian-activated flashing yellow beacons with overhead signs and advance pavement markings	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.5	Install overhead electronic signs with pedestrian-activated crosswalk flashing beacons	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.6	Reduce posted speed limit through school zones during school times	T	T	N/A	N/A	T	T
Appendix 13A.9.1.7	Provide pedestrian overpasses and underpasses	—	—	N/A	N/A	T	T
Appendix 13A.9.1.8	Mark crosswalks at uncontrolled locations, intersection or mid-block	—	N/A	N/A	N/A	T	T
Appendix 13A.9.1.9	Use alternative crosswalk markings at mid-block locations	—	N/A	N/A	N/A	T	T
Appendix 13A.9.1.10	Use alternative crosswalk devices at mid-block locations	—	N/A	N/A	N/A	T	T
Appendix 13A.9.1.11	Provide a raised median or refuge island at marked and unmarked crosswalks	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.12	Provide a raised or flush median or center two-way left-turn lane at marked and unmarked crosswalks	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.13	Install pedestrian refuge islands or split pedestrian crossovers	N/A	N/A	N/A	N/A	T	T
Appendix 13A.9.1.14	Widen median	N/A	—	N/A	N/A	T	T
Appendix 13A.9.1.15	Provide dedicated bicycle lanes (BLs)	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.16	Provide wide curb lanes (WCLs)	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.17	Provide shared bus/bicycle lanes	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.18	Re-stripe roadway to provide bicycle lane	N/A	N/A	N/A	N/A	T	—
Appendix 13A.9.1.19	Pave highway shoulders for bicycles	T	T	N/A	N/A	N/A	—
Appendix 13A.9.1.20	Provide separate bicycle facilities	N/A	N/A	N/A	N/A	T	—

NOTE: T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 13A.

N/A = Indicates that the treatment is not applicable to the corresponding setting.

15.4. CRASH EFFECTS OF INTERCHANGE DESIGN ELEMENTS

15.4.1. Background and Availability of CMFs

Table 15-1 lists common treatments related to interchange design and the CMFs available in this edition of the HSM. Table 15-1 also contains the section number where each CMF can be found.

Table 15-1. Treatments Related to Interchange Design

HSM Section	Treatment	Trumpet	One Quadrant	Diamond	Single Point Urban	Partial Cloverleaf	Full Cloverleaf	Directional
15.4.2.1	Convert intersection to grade-separated interchange	✓	✓	✓	✓	✓	✓	✓
15.4.2.2	Design interchange with crossroad above freeway	✓	—	✓	—	✓	✓	—
15.4.2.3	Modify speed change lane design	✓	✓	✓	✓	✓	✓	✓
15.4.2.4	Modify two-lane-change merge/diverge area to one-lane-change	✓	✓	✓	✓	✓	✓	✓
Appendix 15A.2.2.1	Redesign interchange to modify interchange configuration	T	T	T	T	T	T	T
Appendix 15A.2.2.2	Modify interchange spacing	T	T	T	T	T	T	T
Appendix 15A.2.2.3	Provide right-hand exit and entrance ramps	T	T	T	T	T	T	T
Appendix 15A.2.2.4	Increase horizontal curve radius of ramp roadway	T	T	T	T	T	T	T
Appendix 15A.2.2.5	Increase lane width of ramp roadway	T	T	T	T	T	T	T
Appendix 15A.2.2.6	Increase length of weaving areas between adjacent entrance and exit ramps	T	T	T	T	T	T	T
Appendix 15A.2.2.7	Redesign interchange to provide collector-distributor roads	T	T	T	T	T	T	T
Appendix 15A.2.2.8	Provide bicycle facilities at interchange ramp terminals	T	T	T	T	T	T	T

NOTE: ✓ = Indicates that a CMF is available for this treatment.
T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 15A.
— = Indicates that a CMF is not available and a crash trend is not known.

islation, and enforcement levels. Road-use culture evolves as individuals influence society and as society influences individuals. Additional information regarding road-use culture can be found in Appendix 17A.

Table 17-4 summarizes treatments related to road-use culture and the corresponding CMFs available. The treatments summarized below encompass engineering, enforcement, and education.

Table 17-4. Road-Use Culture Network Considerations and Treatments

HSM Section	Treatment	Urban	Suburban	Rural
17.5.2.1	Install automated speed enforcement	✓	—	✓
17.5.2.2	Install changeable speed warning signs	✓	✓	✓
Appendix 17A.4.1.1	Deploy mobile patrol vehicles	T	T	T
Appendix 17A.4.1.2	Deploy stationary patrol vehicles	T	T	T
Appendix 17A.4.1.3	Deploy aerial enforcement	T	T	T
Appendix 17A.4.1.4	Deploy radar and laser speed monitoring equipment	T	T	T
Appendix 17A.4.1.5	Install drone radar	T	T	T
Appendix 17A.4.1.6	Modify posted speed limit	T	T	T
Appendix 17A.4.1.7	Conduct enforcement to reduce red-light running	T	T	T
Appendix 17A.4.1.8	Conduct enforcement to reduce impaired driving	T	T	T
Appendix 17A.4.1.9	Conduct enforcement to increase seat belt and helmet use	T	T	T
Appendix 17A.4.1.10	Implement network-wide engineering consistency	T	T	T
Appendix 17A.4.1.11	Conduct public education campaigns	T	T	T
Appendix 17A.4.1.12	Implement young drivers and graduated driver licensing programs	T	T	T

NOTE: ✓ = Indicates that a CMF is available for the treatment.
T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 17A.
— = Indicates that a CMF is not available and a trend is not known.

17.5.2. Road Use Culture Network Consideration Treatments with CMFs

17.5.2.1. Install Automated Speed Enforcement

Automated enforcement systems use video or photographic identification in conjunction with radar or lasers to detect speeding drivers. The systems automatically record vehicle registrations without needing police officers at the scene.

The crash effects of installing automated speed enforcement in urban or rural areas on all road types are shown in Table 17-5 (1,3,5,7,9,12). The base condition for this CMF (i.e., the condition in which the CMF = 1.00) is the absence of automated speed enforcement.