

PART C— PREDICTIVE METHOD

CHAPTER 12— PREDICTIVE METHOD FOR URBAN AND SUBURBAN ARTERIALS

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Chapter 12 presents the predictive method for urban and suburban arterials.

1 **CHAPTER 12 URBAN AND SUBURBAN ARTERIALS**

2 **12.1. INTRODUCTION**

3 This chapter presents the predictive method for urban and suburban arterial
4 facilities. A general introduction to the Highway Safety Manual (HSM) predictive
5 method is provided in the *Part C Introduction and Applications Guidance*.

6 The predictive method for urban or suburban arterial facilities provides a
7 structured methodology to estimate the expected average crash frequency, crash
8 severity and collision types for facilities with known characteristics. All types of
9 crashes involving vehicles of all types, bicycles, and pedestrians are included, with
10 the exception of crashes between bicycles and pedestrians. The predictive method
11 can be applied to existing sites, design alternatives to existing sites, new sites or for
12 alternative traffic volume projections. An estimate can be made for crash frequency in
13 a period of time that occurred in the past (i.e., what did or would have occurred) or
14 in the future (i.e., what is expected to occur). The development of the SPFs in Chapter
15 12 is documented by Harwood et al.(1). The AMFs used in this chapter have been
16 reviewed and updated by Harkey et al.(2) and in related work by Srinivasan et al.(3)
17 The SPF coefficients, default collision type distributions, and default nighttime
18 accident proportions have been adjusted to a consistent basis by Srinivasan et al.(4).

19 This chapter presents the following information about the predictive method for
20 urban and suburban arterial facilities:

- 21 ■ A concise overview of the predictive method.
- 22 ■ The definitions of the facility types included in Chapter 12, and site types for
23 which predictive models have been developed for Chapter 12.
- 24 ■ The steps of the predictive method in graphical and descriptive forms.
- 25 ■ Details for dividing an urban or suburban arterial facility into individual
26 sites, consisting of intersections and roadway segments.
- 27 ■ Safety Performance Functions (SPFs) for urban and suburban arterials.
- 28 ■ Accident Modification Factors (AMFs) applicable to the SPFs in Chapter 12.
- 29 ■ Guidance for applying the Chapter 12 predictive method, and limitations of
30 the predictive method specific to Chapter 12.
- 31 ■ Sample problems illustrating the application of the Chapter 12 predictive
32 method for urban and suburban arterials.

33 **12.2. OVERVIEW OF THE PREDICTIVE METHOD**

34 The predictive method provides an 18 step procedure to estimate the “expected
35 average crash frequency”, $N_{expected}$ (by total crashes, crash severity or collision type) of
36 a roadway network, facility or site. In the predictive method the roadway is divided
37 into individual sites, which are homogenous roadway segments and intersections. A
38 facility consists of a contiguous set of individual intersections and roadway
39 segments, referred to as “sites.” Different facility types are determined by
40 surrounding land use, roadway cross-section, and degree of access. For each facility
41 type, a number of different site types may exist, such as divided and undivided

42 roadway segments, and unsignalized and signalized intersections. A roadway
43 network consists of a number of contiguous facilities.

44 The method is used to estimate the expected average crash frequency of an
45 individual site, with the cumulative sum of all sites used as the estimate for an entire
46 facility or network. The estimate is for a given time period of interest (in years)
47 during which the geometric design and traffic control features are unchanged and
48 traffic volumes (AADT) are known or forecasted. The estimate relies on estimates
49 made using predictive models which are combined with observed crash data using
50 the Empirical Bayes (EB) Method.

51 The predictive models used within the Chapter 12 predictive method are
52 described in detail in Section 12.3.

53 The predictive models used in Chapter 12 to predict average crash frequency
54 $N_{predicted}$, are of the general form shown in Equation 12-1.

Section 12.6 provides the
predictive models in
Chapter 12.

55
$$N_{predicted} = (N_{spf\ x} \times (AMF_{1x} \times AMF_{2x} \times \dots \times AMF_{yx}) + N_{pedx} + N_{bikex}) \times C_x \quad (12-1)$$

56 Where,

57 $N_{predicted}$ = predicted average crash frequency for a specific year on site
58 type x ;

59 $N_{spf\ x}$ = predicted average crash frequency determined for base
60 conditions of the SPF developed for site type x ;

61 N_{pedx} = predicted average number of vehicle-pedestrian collisions
62 per year for site type x ;

63 N_{bikex} = predicted average number of vehicle-bicycle collisions per
64 year for site type x ;

65 AMF_{yx} = Accident Modification Factors specific to site type x and
66 specific geometric design and traffic control features y ;

67 C_x = calibration factor to adjust SPF for local conditions for site
68 type x .

69 The predictive models in Chapter 12 provide estimates of the crash severity and
70 collision type distributions for roadway segments and intersections. The SPFs in
71 Chapter 12 address two general crash severity levels: fatal-and-injury and property-
72 damage-only crashes. Fatal-and-injury crashes include crashes involving all levels of
73 injury severity including fatalities, incapacitating injuries, nonincapacitating injuries,
74 and possible injuries. The relative proportions of crashes for the two severity levels
75 are determined from separate SPFs for each severity level. The default estimates of
76 the crash severity and crash type distributions are provided with the SPFs for
77 roadway segments and intersections in Section 12.6.

78 **12.3. URBAN AND SUBURBAN ARTERIALS – DEFINITIONS AND**
79 **PREDICTIVE MODELS IN CHAPTER 12**

80 This section provides the definitions of the facility and site types included in
81 Chapter 12, and the predictive models for each of the site types included in Chapter
82 12. These predictive models are applied following the steps of the predictive method
83 presented in Section 12.4.

84 12.3.1. Definition of Chapter 12 Facility Types

85 The predictive method in Chapter 12 addresses the following urban and
86 suburban arterial facilities: two- and four-lane undivided facilities, four-lane divided
87 facilities, and three- and five-lane facilities with center two-way left-turn lanes.
88 Divided arterials are nonfreeway facilities (i.e., facilities without full control of
89 access) that have lanes in the two directions of travel separated by a raised or
90 depressed median. Such facilities may have occasional grade-separated interchanges,
91 but these are not the primary form of access. The predictive models do not apply to
92 any section of an arterial within the limits of an interchange which has free-flow
93 ramp terminals on the arterial of interest. Arterials with a flush separator (i.e., a
94 painted median) between the lanes in the two directions of travel are considered
95 undivided facilities, not divided facilities. Separate prediction models are provided
96 for arterials with a flush separator that serves as a center two-way left-turn lane.
97 Chapter 12 does not address arterial facilities with six or more lanes.

98 The terms “highway” and “road” are used interchangeably in this chapter and
99 apply to all urban and suburban arterials independent of official state or local
100 highway designation.

101 Classifying an area as urban, suburban or rural is subject to the roadway
102 characteristics, surrounding population and land uses and is at the user’s discretion.
103 In the HSM, the definition of “urban” and “rural” areas is based on Federal Highway
104 Administration (FHWA) guidelines which classify “urban” areas as places inside
105 urban boundaries where the population is greater than 5,000 persons. “Rural” areas
106 are defined as places outside urban areas with populations greater than 5,000
107 persons. The HSM uses the term “suburban” to refer to outlying portions of an
108 urban area; the predictive method does not distinguish between urban and suburban
109 portions of a developed area. The term “arterial” refers to facilities that meet the
110 FHWA definition of “roads serving major traffic movements (high-speed, high
111 volume) for travel between major points.”⁽⁵⁾

112 Exhibit 12-1 identifies the specific site types on urban and suburban arterial
113 highways that have predictive models. In Chapter 12, separate SPFs are used for each
114 individual site to predict multiple-vehicle nondriveway collisions, single-vehicle
115 collisions, driveway-related collisions, vehicle-pedestrian collisions, and vehicle-
116 bicycle collisions for both roadway segments and intersections. These are combined
117 to predict the total average crash frequency at an individual site.

118 **Exhibit 12-1: Urban and Suburban Arterial Site Type SPFs included in Chapter 12**

Site Type	Site Types with SPFs in Chapter 12
Roadway Segments	Two-lane undivided arterials (2U)
	Three-lane arterials including a center two-way left-turn lane(TWLTL) (3T)
	Four-lane undivided arterials (4U)
	Four-lane divided arterials (i.e., including a raised or depressed median) (4D)
	Five-lane arterials including a center TWLTL (5T)
Intersections	Unsignalized three-leg intersection (Stop control on minor-road approaches) (3ST)
	Signalized three-leg intersections (3SG)
	Unsignalized four-leg intersection (Stop control on minor-road approaches) (4ST)
	Signalized four-leg intersection (4SG)

119

120 These specific site types are defined as follows:

- 121 ■ Two-lane undivided arterial (2U) – a roadway consisting of two lanes with a
122 continuous cross-section providing two directions of travel in which the
123 lanes are not physically separated by either distance or a barrier.
- 124 ■ Three-lane arterials (3T) - a roadway consisting of three lanes with a
125 continuous cross-section providing two directions of travel in which center
126 lane is a two-way left turn lane (TWLTL).
- 127 ■ Four-lane undivided arterials (4U) – a roadway consisting of four lanes with
128 a continuous cross-section providing two directions of travel in which the
129 lanes are not physically separated by either distance or a barrier.
- 130 ■ Four-lane divided arterials (i.e., including a raised or depressed median)
131 (4D) – a roadway consisting of two lanes with a continuous cross-section
132 providing two directions of travel in which the lanes are physically
133 separated by either distance or a barrier.
- 134 ■ Five-lane arterials including a center TWLTL (5T) - a roadway consisting of
135 five lanes with a continuous cross-section providing two directions of travel
136 in which the center lane is a two-way left-turn lane (TWLTL).
- 137 ■ Three-leg intersection with STOP control (3ST) – an intersection of a urban or
138 suburban arterial and a minor road. A STOP sign is provided on the minor
139 road approach to the intersection only.
- 140 ■ Four-leg intersection with STOP control (4ST) – an intersection of a urban or
141 suburban arterial and two minor roads. A STOP sign is provided on both the
142 minor road approaches to the intersection.

This section defines urban and suburban arterial site types.

- 143 ■ Four-leg signalized intersection (4SG) - an intersection of a urban or
144 suburban arterial and two minor roads. Signalized control is provided at the
145 intersection by traffic lights.
- 146 ■ Three-leg signalized intersection (3SG) - an intersection of a urban or
147 suburban arterial and one minor road. Signalized control is provided at the
148 intersection by traffic lights.

149 **12.3.2. Predictive Models for Urban and Suburban Arterial Roadway**
150 **Segments**

151 The predictive models can be used to estimate total average crashes (i.e., all crash
152 severities and collision types) or can be used to predict average frequency of specific
153 crash severity types or specific collision types. The predictive model for an individual
154 roadway segment or intersection combines the SPF, AMFs, and a calibration factor.
155 Chapter 12 contains separate predictive models for roadway segments and for
156 intersections.

157 The predictive models for roadway segments estimate the predicted average
158 crash frequency of non-intersection-related crashes. Non-intersection-related crashes
159 may include crashes that occur within the limits of an intersection but are not related
160 to the intersection. The roadway segment predictive models estimate crashes that
161 would occur regardless of the presence of the intersection.

In contrast to the chapter
10 and 11 predictive
method, in chapter 12
roadway segment crash
frequency is estimated as
the sum of three
components: N_{br} , N_{pedr} , and
 N_{biker} .

162 The predictive models for roadway segments are presented in Equations 12-2
163 and 12-3 below.

164
$$N_{predicted\ rs} = C_r \times (N_{br} + N_{pedr} + N_{biker}) \quad (12-2)$$

165
$$N_{br} = N_{spf\ rs} \times (AMF_{1r} \times AMF_{2r} \times \dots \times AMF_{nr}) \quad (12-3)$$

166 Where,

167 $N_{predicted\ rs}$ = predicted average crash frequency of an individual roadway
168 segment for the selected year;

169 N_{br} = predicted average crash frequency of an individual roadway
170 segment (excluding vehicle-pedestrian and vehicle-bicycle
171 collisions);

172 $N_{spf\ rs}$ = predicted total average crash frequency of an individual
173 roadway segment for base conditions (excluding vehicle-
174 pedestrian and vehicle-bicycle collisions);

175 N_{pedr} = predicted average crash frequency of vehicle-pedestrian
176 collisions for an individual roadway segment;

177 N_{biker} = predicted average crash frequency of vehicle-bicycle
178 collisions for an individual roadway segment;

179 $AMF_{1r} \dots AMF_{nr}$ = Accident Modification Factors for roadway segments;

180 C_r = calibration factor for roadway segments of a specific type
181 developed for use for a particular geographical area.

182 Equation 12-2 shows that roadway segment crash frequency is estimated as the
183 sum of three components: N_{br} , N_{pedr} , and N_{biker} . The following equation shows that the

184 SPF portion of N_{br} , designated as $N_{spf\ rs}$, is further separated into three components by
 185 collision type shown in Equation 12-4:

186
$$N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brdwy} \quad (12-4)$$

187 Where,

188 N_{brmv} = predicted average crash frequency of multiple-vehicle
 189 nondriveway collisions for base conditions;

190 N_{brsv} = predicted average crash frequency of single-vehicle crashes
 191 for base conditions; and

192 N_{brdwy} = predicted average crash frequency of multiple-vehicle
 193 driveway-related collisions.

194 Thus, the SPFs and adjustment factors are applied to determine five components:
 195 N_{brmv} , N_{brsv} , N_{brdwy} , N_{pedr} , and N_{biker} , which together provide a prediction of total
 196 average crash frequency for a roadway segment.

197 Equations 12-2 through 12-4 are applied to estimate roadway segment crash
 198 frequencies for all crash severity levels combined (i.e., total crashes) or for fatal-and-
 199 injury or property-damage-only crashes.

200 **12.3.3. Predictive Models for Urban and Suburban Arterial**
 201 **Intersections**

202 The predictive models for intersections estimate the predicted total average crash
 203 frequency including those crashes that occur within the limits of an intersection and
 204 are a result of the presence of the intersection. The predictive model for an urban or
 205 suburban arterial intersection is given by:

206
$$N_{predicted\ int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \quad (12-5)$$

207
$$N_{bi} = N_{spf\ int} \times (AMF_{1i} \times AMF_{2i} \times \dots \times AMF_{6i}) \quad (12-6)$$

208 Where,

209 N_{int} = predicted average crash frequency of an intersection for the
 210 selected year;

211 N_{bi} = predicted average crash frequency of an intersection
 212 (excluding vehicle-pedestrian and vehicle-bicycle collisions);

213 $N_{spf\ int}$ = predicted total average crash frequency of intersection-
 214 related crashes for base conditions (excluding vehicle-
 215 pedestrian and vehicle-bicycle collisions);

216 N_{pedi} = predicted average crash frequency of vehicle-pedestrian
 217 collisions;

218 N_{bikei} = predicted average crash frequency of vehicle-bicycle
 219 collisions;

220 $AMF_{1i} \dots AMF_{6i}$ = Accident Modification Factors for intersections;

221 C_i = calibration factor for intersections developed for use for a
 222 particular geographical area.

223 The AMFs shown in Equation 12-6 do not apply to vehicle-pedestrian and
 224 vehicle-bicycle collisions. A separate set of AMFs that apply to vehicle-pedestrian
 225 collisions at signalized intersections is presented in Section 12.7.

226 Equation 12-5 shows that the intersection crash frequency is estimated as the sum
 227 of three components: N_{bi} , N_{pedi} , and N_{bikei} . The following equation shows that the SPF
 228 portion of N_{bi} , designated as $N_{spf\ int}$, is further separated into two components by
 229 collision type:

$$230 \quad N_{spf\ int} = N_{bimv} + N_{bisv} \quad (12-7)$$

231 Where,

232 N_{bimv} = predicted average number of multiple-vehicle collisions for
 233 base conditions, and

234 N_{bisv} = predicted average number of single-vehicle collisions for base
 235 conditions.

The SPFs for urban and
 suburban arterial highways
 are presented in Section
 12.6.

236 Thus, the SPFs and adjustment factors are applied to determine four components
 237 of total intersection average crash frequency: N_{bimv} , N_{bisv} , N_{pedi} , and N_{bikei} .

238 The SPFs for urban and suburban arterial highways are presented in Section 12.6.
 239 The associated AMFs for each of the SPFs are presented in Section 12.7, and
 240 summarized in Exhibit 12-35. Only the specific AMFs associated with each SPF are
 241 applicable to an SPF (as these AMFs have base conditions which are identical to the
 242 base conditions). The calibration factors, C_r and C_i are determined in the *Part C*
 243 Appendix A.1.1. Due to continual change in the crash frequency and severity
 244 distributions with time, the value of the calibration factors may change for the
 245 selected year of the study period.

246 **12.4. PREDICTIVE METHOD STEPS FOR URBAN AND SUBURBAN**
 247 **ARTERIALS**

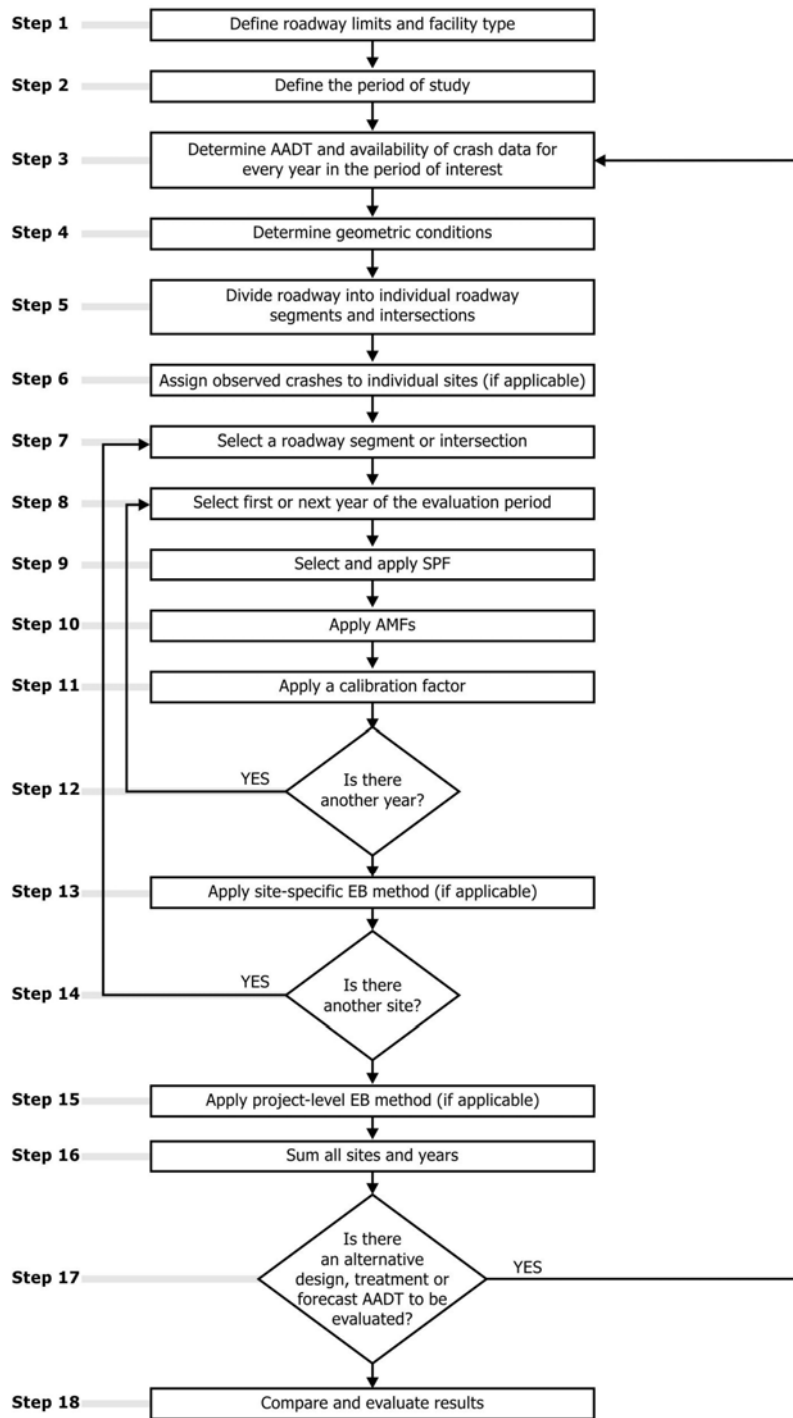
The predictive method is
 described in detail in the
 Part C Introduction and
 Applications Guide.

248 The predictive method for urban and suburban arterials is shown in Exhibit 12-2.
 249 Applying the predictive method yields an estimate of the expected average crash
 250 frequency (and/or crash severity and collision types) for an urban or suburban
 251 arterial facility. The components of the predictive models in Chapter 12 are
 252 determined and applied in Steps 9, 10 and 11 of the predictive method. The
 253 information to apply each step is provided in the following sections and in the *Part C*
 254 Appendix. In some situations, certain steps will not require any action. For example,
 255 a new facility will not have observed crash data and therefore steps relating to the EB
 256 Method require no action.

257 There are 18 steps in the predictive method. In some situations certain steps will
 258 not be needed because data is not available or the step is not applicable to the
 259 situation at hand. In other situations, steps may be repeated if an estimate is desired
 260 for several sites or for a period of several years. In addition, the predictive method
 261 can be repeated as necessary to undertake crash estimation for each alternative
 262 design, traffic volume scenario or proposed treatment option (within the same period
 263 to allow for comparison).

264 The following explains the details of each step of the method as applied to urban
 265 and suburban arterials.

266 Exhibit 12-2: The HSM Predictive Method



267
268

This section describes each step of the predictive method in the context of urban and suburban arterials.

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Step 1 - Define the limits of the roadway and facility types in the study network, facility or site for which the expected average crash frequency, severity and collision types are to be estimated.

The predictive method can be undertaken for a roadway network, a facility, or an individual site. A site is either an intersection or a homogeneous roadway segment. Sites may consist of a number of types, such as signalized and unsignalized intersections. The definitions of urban and suburban arterials, intersections and roadway segments and the specific site types included in Chapter 12 are provided in Section 12-3.

The predictive method can be undertaken for an existing roadway, a design alternative for an existing, or a new roadway (which may be either unconstructed or yet to experience enough traffic to have observed crash data).

The limits of the roadway of interest will depend on the nature of the study. The study may be limited to only one specific site or a group of contiguous sites. Alternatively, the predictive method can be applied to a very long corridor for the purposes of network screening which is discussed in *Chapter 4*.

Step 2 - Define the period of interest.

The predictive method can be undertaken for either a past period or a future period. All periods are measured in years. Years of interest will be determined by the availability of observed or forecast AADTs, observed crash data and geometric design data. Whether the predictive method is used for a past or future period depends upon the purpose of the study. The period of study may be:

A past period (based on observed AADTs) for:

- An existing roadway network, facility or site. If observed crash data are available, the period of study is the period of time for which the observed crash data are available and for which (during that period) the site geometric design features, traffic control features and traffic volumes are known.
- An existing roadway network, facility or site for which alternative geometric design features or traffic control features are proposed (for near term conditions).

A future period (based on forecast AADTs) for:

- An existing roadway network, facility or site for a future period where forecast traffic volumes are available.
- An existing roadway network, facility or site for which alternative geometric design or traffic control features are proposed for implementation in the future.
- A new roadway network, facility or site that does not currently exist, but is proposed for construction during some future period.

307 **Step 3 – For the study period, determine the availability of annual average**
308 **daily traffic volumes, pedestrian crossing volumes and, for an existing roadway**
309 **network, the availability of observed crash data (to determine whether the EB**
310 **Method is applicable).**

311 *Determining Traffic Volumes*

312 The SPFs used in Step 9 (and some AMFs in Step 10), include AADT volumes
313 (vehicles per day) as a variable. For a past period the AADT may be determined by
314 automated recording or estimated by a sample survey. For a future period the AADT
315 may be a forecast estimate based on appropriate land use planning and traffic
316 volume forecasting models, or based on the assumption that current traffic volumes
317 will remain relatively constant.

318 For each roadway segment, the AADT is the average daily two-way 24 hour
319 traffic volume on that roadway segment in each year of the period to be evaluated
320 selected in Step 8.

321 For each intersection, two values are required in each predictive model. These
322 are: the two-way AADT of the major street, $AADT_{maj}$ and the two-way AADT of the
323 minor street, $AADT_{min}$.

324 $AADT_{maj}$ and $AADT_{min}$ are determined as follows: if the AADTs on the two
325 major-road legs of an intersection differ, the larger of the two AADT values is used
326 for the intersection. If the AADTs on the two minor road legs of a four-leg
327 intersection differ, the larger of the AADTs for the two minor road legs is used. For a
328 three-leg intersection, the AADT of the single minor road leg is used. If AADTs are
329 available for every roadway segment along a facility, the major-road AADTs for
330 intersection legs can be determined without additional data.

331 In many cases, it is expected that AADT data will not be available for all years of
332 the evaluation period. In that case, an estimate of AADT for each year of the
333 evaluation period is interpolated or extrapolated as appropriate. If there is not an
334 established procedure for doing this, the following may be applied within the
335 predictive method to estimate the AADTs for years for which data are not available.

- 336 ■ If AADT data are available for only a single year, that same value is assumed
337 to apply to all years of the before period;
- 338 ■ If two or more years of AADT data are available, the AADTs for intervening
339 years are computed by interpolation;
- 340 ■ The AADTs for years before the first year for which data are available are
341 assumed to be equal to the AADT for that first year;
- 342 ■ The AADTs for years after the last year for which data are available are
343 assumed to be equal to the last year.

344 If the EB Method is used (discussed below) AADT data are needed for each year
345 of the period for which observed crash frequency data are available. If the EB Method
346 will not be used, AADT data for the appropriate time period—past, present, or
347 future—determined in Step 2 are used.

348 For signalized intersections, the pedestrian volumes crossing each intersection
349 leg are determined for each year of the period to be evaluated. The pedestrian
350 crossing volumes for each leg of the intersection are then summed to determine the
351 total pedestrian crossing volume for the intersection. Where pedestrian volume
352 counts are not available, they may be estimated using the guidance presented in
353 Exhibit 12-32. Where pedestrian volume counts are not available for each year, they

The EB Method and criteria to determine whether the EB Method is applicable are presented in Section A.2.1 in the Appendix to Part C.

354 may be interpolated or extrapolated in the same manner as explained above for
355 AADT data.

356 *Determining Availability of Observed Crash Data*

357 Where an existing site or alternative conditions for an existing site are being
358 considered, the EB Method is used. The EB Method is only applicable when reliable
359 observed crash data are available for the specific study roadway network, facility, or
360 site. Observed data may be obtained directly from the jurisdiction’s accident report
361 system. At least two years of observed crash frequency data are desirable to apply the
362 EB Method. The EB Method and criteria to determine whether the EB Method is
363 applicable are presented in Section A.2.1 in the Appendix to *Part C*.

364 The EB Method can be applied at the site-specific level (i.e., observed crashes are
365 assigned to specific intersections or roadway segments in Step 6) or at the project
366 level (i.e., observed crashes are assigned to a facility as a whole). The site-specific EB
367 Method is applied in Step 13. Alternatively, if observed crash data are available but
368 can not be assigned to individual roadway segments and intersections, the project
369 level EB Method is applied (in Step 15).

370 If observed crash frequency data are not available, then Steps 6, 13, and 15 of the
371 predictive method are not conducted. In this case the estimate of expected average
372 crash frequency is limited to using a predictive model (i.e. the predictive average
373 crash frequency).

374 **Step 4 - Determine geometric design features, traffic control features and site**
375 **characteristics for all sites in the study network.**

376 In order to determine the relevant data needs and avoid unnecessary collection
377 of data, it is necessary to understand the base conditions and AMFs in Step 9 and
378 Step 10. The base conditions are defined in Section 12.6.1 for roadway segments and
379 in Section 12.6.2 for intersections.

380 The following geometric design and traffic control features are used to determine
381 whether the site specific conditions vary from the base conditions and therefore
382 whether an AMF is applicable:

- 383 ▪ Length of roadway segment (miles)
- 384 ▪ AADT (vehicles per day)
- 385 ▪ Number of through lanes
- 386 ▪ Presence/type of median (undivided, divided by raised or depressed
387 median, center TWLTL)
- 388 ▪ Presence/type of on-street parking (parallel vs. angle; one side vs. both sides
389 of street)
- 390 ▪ Number of driveways for each driveway type (major commercial, minor
391 commercial; major industrial/institutional; minor industrial/institutional;
392 major residential; minor residential; other)
- 393 ▪ Roadside fixed object density (fixed objects/mile, only obstacles 4-in or more
394 in diameter that do not have a breakaway design are counted)
- 395 ▪ Average offset to roadside fixed objects from edge of traveled way (feet)
- 396 ▪ Presence/absence of roadway lighting

- 397 ▪ Speed category (based on actual traffic speed or posted speed limit)
- 398 ▪ Presence of automated speed enforcement
- 399 For all intersections within the study area, the following geometric and traffic
- 400 control features are identified:
- 401 ▪ Number of intersection legs (3 or 4)
- 402 ▪ Type of traffic control (minor-road STOP or signal)
- 403 ▪ Number of approaches with intersection left turn lane (all approaches, 0, 1, 2,
- 404 3, or 4 for signalized intersection; only major approaches, 0, 1, or 2, for Stop-
- 405 controlled intersections)
- 406 ▪ Number of major-road approaches with left-turn signal phasing (0, 1, or 2)
- 407 (signalized intersections only) and type of left-turn signal phasing
- 408 (permissive, protected/permissive, permissive/protected, or protected)
- 409 ▪ Number of approaches with intersection right turn lane (all approaches, 0, 1,
- 410 2, 3, or 4 for signalized intersection; only major approaches, 0, 1, or 2, for
- 411 Stop-controlled intersections)
- 412 ▪ Number of approaches with right-turn-on-red operation prohibited (0, 1, 2,
- 413 3, or 4) (signalized intersections only)
- 414 ▪ Presence/absence of intersection lighting
- 415 ▪ Maximum number of traffic lanes to be crossed by a pedestrian in any
- 416 crossing maneuver at the intersection considering the presence of refuge
- 417 islands (for signalized intersections only)
- 418 ▪ Proportions of nighttime crashes for unlighted intersections (by total, fatal,
- 419 non-fatal injury and property damage only)
- 420 For signalized intersections, land use and demographic data used in the
- 421 estimation of vehicle-pedestrian collisions include:
- 422 ▪ Number of bus stops within 1,000 feet of the intersection
- 423 ▪ Presence of schools within 1,000 feet of the intersection
- 424 ▪ Number of alcohol sales establishments within 1,000 feet of the intersection
- 425 ▪ Presence of Red Light Camera
- 426 ▪ Number of approaches on which right turn on red is allowed

427 **Step 5 – Divide the roadway network or facility into individual homogenous**
 428 **roadway segments and intersections, which are referred to as sites.**

429 Using the information from Step 1 and Step 4, the roadway is divided into
 430 individual sites, consisting of individual homogenous roadway segments and
 431 intersections. The definitions and methodology for dividing the roadway into
 432 individual intersections and homogenous roadway segments for use with the
 433 Chapter 12 predictive models are provided in Section 12.5. When dividing roadway

434 facilities into small homogenous roadway segments, limiting the segment length to a
435 minimum of 0.10 miles will decrease data collection and management efforts.

436 **Step 6 – Assign observed crashes to the individual sites (if applicable).**

437 Step 6 only applies if it was determined in Step 3 that the site-specific EB Method
438 was applicable. If the site-specific EB Method is not applicable, proceed to Step 7. In
439 Step 3, the availability of observed data and whether the data could be assigned to
440 specific locations was determined. The specific criteria for assigning accidents to
441 individual roadway segments or intersections are presented in Section A.2.3 of the
442 Appendix to *Part C*.

443 Crashes that occur at an intersection or on an intersection leg, and are related to
444 the presence of an intersection, are assigned to the intersection and used in the EB
445 Method together with the predicted average crash frequency for the intersection.
446 Crashes that occur between intersections and are not related to the presence of an
447 intersection are assigned to the roadway segment on which they occur; such crashes
448 are used in the EB Method together with the predicted average crash frequency for
449 the roadway segment.

450 **Step 7 – Select the first or next individual site in the study network. If there
451 are no more sites to be evaluated, proceed to Step 15.**

452 In Step 5 the roadway network within the study limits has been divided into a
453 number of individual homogenous sites (intersections and roadway segments).

454 The outcome of the HSM Predictive Method is the expected average crash
455 frequency of the entire study network, which is the sum of the all of the individual
456 sites, for each year in the study. Note that this value will be the total number of
457 crashes expected to occur over all sites during the period of interest. If a crash
458 frequency is desired, the total can be divided by the number of years in the period of
459 interest.

460 The estimation for each site (roadway segments or intersection) is conducted one
461 at a time. Steps 8 through 14, described below, are repeated for each site.

462 **Step 8 – For the selected site, select the first or next year in the period of
463 interest. If there are no more years to be evaluated for that site, proceed to
464 Step 14**

465 Steps 8 through 14 are repeated for each site in the study and for each year in the
466 study period.

467 The individual years of the evaluation period may have to be analyzed one year
468 at a time for any particular roadway segment or intersection because SPFs and some
469 AMFs (e.g., lane and shoulder widths) are dependent on AADT, which may change
470 from year to year.

471 **Step 9 – For the selected site, determine and apply the appropriate Safety
472 Performance Function (SPF) for the site's facility type, and traffic control
473 features.**

474 Steps 9 through 13, described below, are repeated for each year of the evaluation
475 period as part of the evaluation of any particular roadway segment or intersection.
476 The predictive models in Chapter 12 follow the general form shown in Equation 12-1.
477 Each predictive model consists of a SPF, which is adjusted to site specific conditions
478 using AMFs (in Step 10) and adjusted to local jurisdiction conditions (in Step 11)
479 using a calibration factor (C). The SPFs, AMFs and calibration factor obtained in
480 Steps 9, 10, and 11 are applied to calculate the predicted average crash frequency for

481 the selected year of the selected site. The SPFs available for urban and suburban
482 arterials are presented in Section 12.6

483 The SPF (which is a regression model based on observed crash data for a set of
484 similar sites) determines the predicted average crash frequency for a site with the
485 same base conditions (i.e., a specific set of geometric design and traffic control
486 features). The base conditions for each SPF are specified in Section 12.6. A detailed
487 explanation and overview of the SPFs in *Part C* is provided in Section C.6.3 of the *Part*
488 *C Introduction and Applications Guidance*.

489 The SPFs developed for Chapter 12 are summarized in Exhibit 12-4 in Section
490 12.6. For the selected site, determine the appropriate SPF for the site type
491 (intersection or roadway segment) and the geometric and traffic control features
492 (undivided roadway, divided roadway, stop-controlled intersection, signalized
493 intersection). The SPF for the selected site is calculated using the AADT determined
494 in Step 3 (AADT_{maj} and AADT_{min} for intersections) for the selected year.

495 Each SPF determined in Step 9 is provided with default distributions of crash
496 severity and collision type (presented in section 12.6). These default distributions can
497 benefit from being updated based on local data as part of the calibration process
498 presented in Appendix A.1.1.

499 **Step 10 – Multiply the result obtained in Step 9 by the appropriate AMFs to**
500 **adjust base conditions to site specific geometric design and traffic control**
501 **features**

502 In order to account for differences between the base conditions (Section 12.6) and
503 the specific conditions of the site, AMFs are used to adjust the SPF estimate. An
504 overview of AMFs and guidance for their use is provided in Section C.6.4 of the *Part*
505 *C Introduction and Applications Guidance*, including the limitations of current
506 knowledge related to the effects of simultaneous application of multiple AMFs. In
507 using multiple AMFs, engineering judgment is required to assess the
508 interrelationships and/or independence of individual elements or treatments being
509 considered for implementation within the same project.

510 All AMFs used in Chapter 12 have the same base conditions as the SPFs used in
511 Chapter 12 (i.e., when the specific site has the same condition as the SPF base
512 condition, the AMF value for that condition is 1.00). Only the AMFs presented in
513 Section 12.7 may be used as part of the Chapter 12 predictive method. Exhibit 12-35
514 indicates which AMFs are applicable to the SPFs in Section 12.6.

515 The AMFs for roadway segments are those described in Section 12.7.1. These
516 AMFs are applied as shown in Equation 12-3.

517 The AMFs for intersections are those described in Section 12.7.2, which apply to
518 both signalized and STOP-controlled intersections, and in Section 12.7.3, which apply
519 to signalized intersections only. These AMFs are applied as shown in Equations 12-6
520 and 12-28.

521 In Chapter 12, the multiple- and single-vehicle base crashes determined in Step 9
522 and the AMFs values calculated in Step 10 are then used to estimate the vehicle-
523 pedestrian and vehicle-bicycle base crashes for roadway segments and intersections
524 (present in Section 12.6.1 and 12.6.2 respectively).

525 **Step 11 – Multiply the result obtained in Step 10 by the appropriate calibration**
526 **factor.**

527 The SPFs used in the predictive method have each been developed with data
528 from specific jurisdictions and time periods. Calibration to local conditions will

A detailed explanation and
overview of the SPFs in Part
C is provided in Section
C.6.3 of the Part C
Introduction and
Applications Guide.

Detailed guidance for the development of calibration factors is included in Part C Appendix A.1.1.

529 account for these differences. A calibration factor (C_r for roadway segments or C_i for
530 intersections) is applied to each SPF in the predictive method. An overview of the use
531 of calibration factors is provided in the *Part C Introduction and Applications Guidance*
532 Section C.6.5. Detailed guidance for the development of calibration factors is
533 included in *Part C Appendix A.1.1*.

534 Steps 9, 10, and 11 together implement the predictive models in Equations 12-2
535 through 12-7 to determine predicted average crash frequency.

536 **Step 12 – If there is another year to be evaluated in the study period for the**
537 **selected site, return to Step 8. Otherwise, proceed to Step 14.**

538 This step creates a loop through Steps 8 to 12 that is repeated for each year of the
539 evaluation period for the selected site.

540 **Step 13 – Apply site-specific EB Method (if applicable).**

541 Whether the site-specific EB Method is applicable is determined in Step 3. The
542 site-specific EB Method combines the Chapter 12 predictive model estimate of
543 predicted average crash frequency, $N_{predicted}$ with the observed crash frequency of the
544 specific site, $N_{observed}$. This provides a more statistically reliable estimate of the
545 expected average crash frequency of the selected site.

546 In order to apply the site-specific EB Method, in addition to the material in *Part C*
547 Appendix A.2.4 the overdispersion parameter, k , for the is also used. The
548 overdispersion parameter provides an indication of the statistical reliability of the
549 SPF. The closer the overdispersion parameter is to zero, the more statistically reliable
550 the SPF. This parameter is used in the site-specific EB Method to provide a weighting
551 to $N_{predicted}$ and $N_{observed}$. Overdispersion parameters are provided for each SPF in
552 Section 12.6.

553 *Apply the site-specific EB Method to a future time period, if appropriate.*

554 The estimated expected average crash frequency obtained above applies to the
555 time period in the past for which the observed crash data were obtained. Section
556 A.2.6 in the Appendix to *Part C* provides a method to convert the estimate of
557 expected average crash frequency for a past time period to a future time period. In
558 doing this, consideration is given to significant changes in geometric or roadway
559 characteristics cause by the treatments considered for future time period.

560 **Step 14 –If there is another site to be evaluated, return to 7, otherwise,**
561 **proceed to Step 15.**

562 This step creates a loop through Steps 7 to 13 that is repeated for each roadway
563 segment or intersection within the facility.

564 **Step 15 – Apply the project level EB Method (if the site-specific EB Method is**
565 **not applicable).**

566 This step is only applicable to existing conditions when observed crash data are
567 available, but can not be accurately assigned to specific sites (e.g., the crash report
568 may identify crashes as occurring between two intersections, but is not accurate to
569 determine a precise location on the segment). Detailed description of the project level
570 EB Method is provided in *Part C Appendix A.2.5*.

571 **Step 16 – Sum all sites and years in the study to estimate total crash**
 572 **frequency.**

573 The total estimated number of crashes within the network or facility limits
 574 during a study period of n years is calculated using Equation 12-8:

$$575 \quad N_{total} = \sum_{\substack{\text{all} \\ \text{roadway} \\ \text{segments}}} N_{rs} + \sum_{\substack{\text{all} \\ \text{intersections}}} N_{int} \quad (12-8)$$

576 Where,

577 N_{total} = total expected number of crashes within the limits of a rural
 578 two-lane two-way road facility for the period of interest. Or,
 579 the sum of the expected average crash frequency for each
 580 year for each site within the defined roadway limits within
 581 the study period;

582 N_{rs} = expected average crash frequency for a roadway segment
 583 using the predictive method for one specific year; and

584 N_{int} = expected average crash frequency for an intersection using
 585 the predictive method for one specific year.

586 Equation 12-8 represents the total expected number of crashes estimated to occur
 587 during the study period. Equation 12-9 is used to estimate the total expected average
 588 crash frequency within the network or facility limits during the study period.

$$589 \quad N_{total\ average} = \frac{N_{total}}{n} \quad (12-9)$$

590 Where,

591 $N_{total\ average}$ = total expected average crash frequency estimated to occur
 592 within the defined network or facility limits during the study
 593 period;

594 n = number of years in the study period.

595 **Step 17 – Determine if there is an alternative design, treatment or forecast**
 596 **AADT to be evaluated.**

597 Steps 3 through 16 of the predictive method are repeated as appropriate for the
 598 same roadway limits but for alternative conditions, treatments, periods of interest or
 599 forecast AADTs.

600 **Step 18 – Evaluate and compare results.**

601 The predictive method is used to provide a statistically reliable estimate of the
 602 expected average crash frequency within defined network or facility limits over a
 603 given period of time, for given geometric design and traffic control features and
 604 known or estimated AADT. In addition to estimating total crashes, the estimate can
 605 be made for different crash severity types and different collision types. Default
 606 distributions of crash severity and collision type are provided with each SPF in
 607 Section 12.6. These default distributions can benefit from being updated based on
 608 local data as part of the calibration process presented in *Part C* Appendix A.1.1.

609 **12.5. ROADWAY SEGMENTS AND INTERSECTIONS**

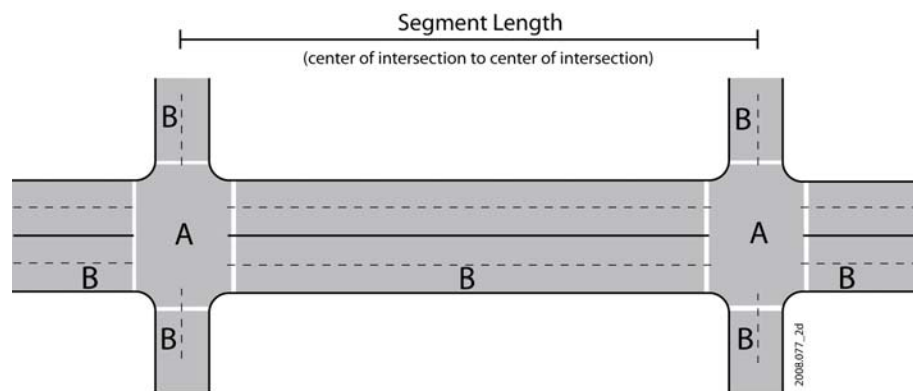
610 Section 12.4 provides an explanation of the predictive method. Sections 12.5
 611 through 12.8 provide the specific detail necessary to apply the predictive method
 612 steps. Detail regarding the procedure for determining a calibration factor to apply in
 613 Step 11 is provided in the *Part C* Appendix A.1. Detail regarding the EB Method,
 614 which is applied in Steps 6, 13, and 15, is provided in the *Part C* Appendix A.2.

615 In Step 5 of the predictive method, the roadway within the defined limits is
 616 divided into individual sites, which are homogenous roadway segments and
 617 intersections. A facility consists of a contiguous set of individual intersections and
 618 roadway segments, referred to as "sites." A roadway network consists of a number of
 619 contiguous facilities. Predictive models have been developed to estimate crash
 620 frequencies separately for roadway segments and intersections. The definitions of
 621 roadway segments and intersections presented below are the same as those used in
 622 the FHWA Interactive Highway Safety Design Model (IHSDM) ⁽⁴⁾.

623 Roadway segments begin at the center of an intersection and end at either the
 624 center of the next intersection, or where there is a change from one homogeneous
 625 roadway segment to another homogenous segment. The roadway segment model
 626 estimates the frequency of roadway-segment-related crashes which occur in Region B
 627 in Exhibit 12-3. When a roadway segment begins or ends at an intersection, the
 628 length of the roadway segment is measured from the center of the intersection.

629 Chapter 12 provides predictive models for stop-controlled (three- and four-leg)
 630 and signalized (three- and four-leg) intersections. The intersection models estimate
 631 the predicted average frequency of crashes that occur within the limits of an
 632 intersection (Region A of Exhibit 12-3) and intersection-related crashes that occur on
 633 the intersection legs (Region B in Exhibit 12-3).

634 **Exhibit 12-3: Definition of Roadway 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.

635
 636 The segmentation process produces a set of roadway segments of varying length,
 637 each of which is homogeneous with respect to characteristics such as traffic volumes
 638 and key roadway design characteristics and traffic control features. Exhibit 12-3
 639 shows the segment length, *L*, for a single homogenous roadway segment occurring
 640 between two intersections. However, several homogenous roadway segments can
 641 occur between two intersections. A new (unique) homogeneous segment begins at

642 the center of each intersection and where there is a change in at least one of the
 643 following characteristics of the roadway:

- 644 ▪ Annual average daily traffic volume (AADT) (vehicles/day)
- 645 ▪ Number of through lanes
- 646 ▪ Presence/type of median

647 The following rounded widths for medians without barriers are
 648 recommended before determining “homogeneous” segments:

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

- 649
- 650 ▪ Presence/type of on-street parking
- 651 ▪ Roadside fixed object density
- 652 ▪ Presence of lighting
- 653 ▪ Speed category (based on actual traffic speed or posted speed limit)

654 In addition, each individual intersection is treated as a separate site, for which
 655 the intersection-related crashes are estimated using the predictive method.

656 There is no minimum roadway segment length, *L*, for application of the
 657 predictive models for roadway segments. When dividing roadway facilities into
 658 small homogenous roadway segments, limiting the segment length to a minimum of
 659 0.10 miles will minimize calculation efforts and not affect results.

660 In order to apply the site-specific EB Method, observed crashes are assigned to
 661 the individual roadway segments and intersections. Observed crashes that occur
 662 between intersections are classified as either intersection-related or roadway
 663 segment-related. The methodology for assigning crashes to roadway segments and
 664 intersections for use in the site-specific EB Method is presented in Section A.2.3 in the
 665 Appendix to *Part C*. In applying the EB Method for urban and suburban arterials,
 666 whenever the predicted average crash frequency for a specific roadway segment
 667 during the multiyear study period is less than 1/*k* (the inverse of the overdispersion
 668 parameter for the relevant SPF), consideration should be given to combining adjacent
 669 roadway segments and applying the project-level EB Method. This guideline for the
 670 minimum crash frequency for a roadway segment applies only to Chapter 12 which

The methodology for assigning crashes to roadway segments and intersections for use in the site-specific EB Method is presented in Section A.2.3 in the Appendix to Part C.

671 uses fixed-value overdispersion parameters. It is not needed in *Chapter 10* or *Chapter*
 672 *11* which use length-dependent overdispersion parameters.

673 **12.6. SAFETY PERFORMANCE FUNCTIONS FOR BASE CONDITIONS**

674 In Step 9 of the predictive method, the appropriate Safety Performance Functions
 675 (SPFs) are used to predict crash frequencies for specific base conditions. SPFs are
 676 regression models for estimating the predicted average crash frequency of individual
 677 roadway segments or intersections. Each SPF in the predictive method was
 678 developed with observed accident data for a set of similar sites. The SPFs, like all
 679 regression models, estimates the value of a dependent variable as a function of a set
 680 of independent variables. In the SPFs developed for the HSM, the dependent variable
 681 estimated is the predicted average crash frequency for a roadway segment or
 682 intersection under base conditions, and the independent variables are the AADTs of
 683 the roadway segment or intersection legs (and, for roadway segments, the length of
 684 the roadway segment).

685 The predicted crash frequencies for base conditions obtained with the SPFs are
 686 used in the predictive models in Equations 12-2 through 12-7. A detailed discussion
 687 of SPFs and their use in the HSM is presented in *Chapter 3* Section 3.5.2 and the *Part C*
 688 *Introduction and Applications Guidance* Section C.6.3.

689 Each SPF also has an associated overdispersion parameter, k. The overdispersion
 690 parameter provides an indication of the statistical reliability of the SPF. The closer the
 691 overdispersion parameter is to zero, the more statistically reliable the SPF. This
 692 parameter is used in the EB Method discussed in the *Part C* Appendix. The SPFs in
 693 *Chapter 12* are summarized in Exhibit 12-4.

694 **Exhibit 12-4: Safety Performance Functions included in Chapter 12**

Chapter 12 SPFs for Urban and Suburban Arterials	SPF Components by Collision type	SPF Equations and Exhibits
Roadway segments	multiple-vehicle nondriveway collisions	Equation 12-10, 12-11, 12-12, Exhibits 12-5, 12-6, 12-7
	single-vehicle crashes	Equations 12-13, 12-14, 12-15, Exhibits 12-8, 12-9, 12-10
	multiple-vehicle driveway-related collisions	Equations 12-16, 12-17, 12-18, Exhibits 12-11, 12-12, 12-13, 12-14, 12-15, 12-16
	vehicle-pedestrian collisions	Equation 12-19 Exhibit 12-17
	vehicle-bicycle collisions	Equation 12-20, Exhibit 12-18
Intersections	multiple-vehicle collisions	Equations 12-21, 12-22, 12-23, Exhibit 12-19, 12-20, 12-21, 12-22, 12-23, 12-24
	single-vehicle crashes	Equations 12-24, 12-25, 12-26, 12-27, Exhibit 12-25, 12-26, 12-27, 12-28, 12-29, 12-30
	vehicle-pedestrian collisions	Equations 12-28, 12-29, 12-30, Exhibits 12-31, 12-32, 12-33
	vehicle-bicycle collisions	Equation 12-31, Exhibit 12-34

695

696 Some highway agencies may have performed statistically-sound studies to
 697 develop their own jurisdiction-specific SPFs derived from local conditions and crash
 698 experience. These models may be substituted for models presented in this chapter.
 699 Criteria for the development of SPFs for use in the predictive method are addressed
 700 in the calibration procedure presented in the Appendix to *Part C*.

701 **12.6.1. Safety Performance Functions for Urban and Suburban Arterial** 702 **Roadway Segments**

703 The predictive model for predicting average crash frequency on a particular
 704 urban or suburban arterial roadway segment was presented in Equation 12-2. The
 705 effect of traffic volume (AADT) on crash frequency is incorporated through the SPF,
 706 while the effects of geometric design and traffic control features are incorporated
 707 through the AMFs. The SPF for urban and suburban arterial roadway segments is
 708 presented in this section. Urban and suburban arterial roadway segments are defined
 709 in Section 12.3.

710 SPFs and adjustment factors are provided for five types of roadway segments on
 711 urban and suburban arterials:

- 712 ▪ Two-lane undivided arterials (2U)
- 713 ▪ Three-lane arterials including a center two-way left-turn lane (TWLTL) (3T)
- 714 ▪ Four-lane undivided arterials (4U)
- 715 ▪ Four-lane divided arterials (i.e., including a raised or depressed median)
 716 (4D)
- 717 ▪ Five-lane arterials including a center TWLTL (5T)

718 Guidance on the estimation of traffic volumes for roadway segments for use in
 719 the SPFs is presented in Step 3 of the predictive method described in Section 12.4.
 720 The SPFs for roadway segments on urban and suburban arterials are applicable to the
 721 following AADT ranges:

- 722 ▪ 2U: 0 to 32,600 vehicles per day
- 723 ▪ 3T : 0 to 32,900 vehicles per day
- 724 ▪ 4U: 0 to 40,100 vehicles per day
- 725 ▪ 4D: 0 to 66,000 vehicles per day
- 726 ▪ 5T: 0 to 53,800 vehicles per day

727 Application to sites with AADTs substantially outside these ranges may not
 728 provide reliable results.

729 Other types of roadway segments may be found on urban and suburban arterials
 730 but are not addressed by the predictive model in Chapter 12.

731 The procedure addresses five types of collisions. The corresponding Equations
 732 and Exhibits are indicated in Exhibit 12-4 above:

- 733 ▪ multiple-vehicle nondriveway collisions
- 734 ▪ single-vehicle crashes

The traffic volume boundary conditions for the chapter 12 roadway segment SPFs are presented here.

- 735 ■ multiple-vehicle driveway-related collisions
- 736 ■ vehicle-pedestrian collisions
- 737 ■ vehicle-bicycle collisions

738 The predictive model for estimating average crash frequency on roadway
 739 segments is shown in Equations 12-2 through 12-4. The effect of traffic volume on
 740 predicted crash frequency is incorporated through the SPFs, while the effects of
 741 geometric design and traffic control features are incorporated through the AMFs.
 742 SPFs are provided for multiple-vehicle nondrivable collisions and single-vehicle
 743 crashes. Adjustment factors are provided for multi-vehicle driveway-related, vehicle-
 744 pedestrian, and vehicle-bicycle collisions.

This section presents the SPFs and adjustment factors for multiple-vehicle nondrivable collisions.

745 **Multiple-Vehicle Nondrivable Collisions**

746 The SPF for multiple-vehicle nondrivable collisions is applied as follows:

747
$$N_{brmv} = \exp (a + b \times \ln(AADT) + \ln(L)) \quad (12-10)$$

748 Where,

749 AADT = average daily traffic volume (vehicles/day) on roadway
 750 segment;

751 L = length of roadway segment (mi); and

752 a, b = regression coefficients.

753 Exhibit 12-5 presents the values of the coefficients a and b used in applying
 754 Equation 12-10. The overdispersion parameter, k, is also presented in Exhibit 12-5.

755 **Exhibit 12-5: SPF Coefficients for Multiple-Vehicle Nondrivable Collisions on Roadway**
 756 **Segments**

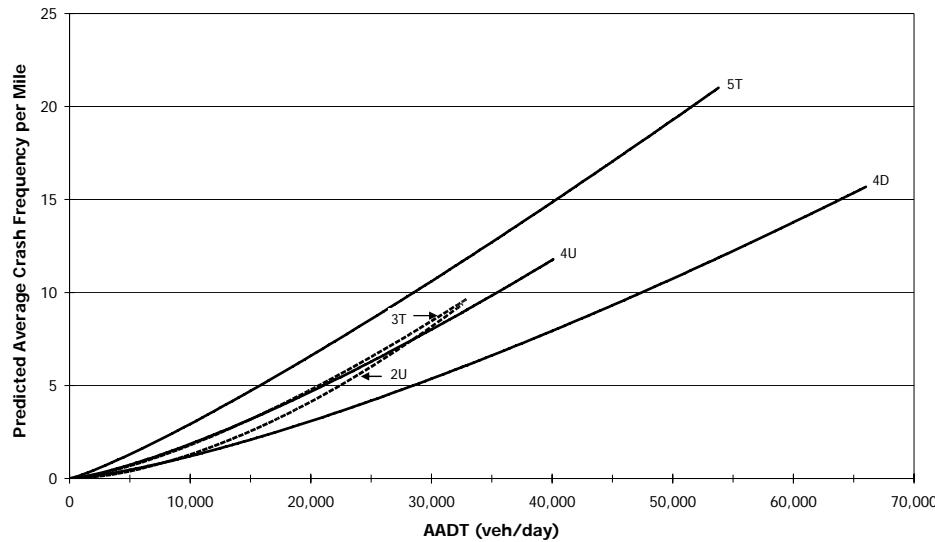
Road type	Coefficients used in Equation 12-10		Overdispersion parameter (k)
	Intercept (a)	AADT (b)	
Total crashes			
2U	-15.22	1.68	0.84
3T	-12.40	1.41	0.66
4U	-11.63	1.33	1.01
4D	-12.34	1.36	1.32
5T	-9.70	1.17	0.81
Fatal-and-injury crashes			
2U	-16.22	1.66	0.65
3T	-16.45	1.69	0.59
4U	-12.08	1.25	0.99
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

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Exhibit 12-6: Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Exhibit 12-5)



760

761 Equation 12-10 is first applied to determine N_{brmv} using the coefficients for total
 762 crashes in Exhibit 12-5. N_{brmv} is then divided into components by severity level,
 763 $N_{brmv(FI)}$ for fatal-and-injury crashes and $N_{brmv(PDO)}$ for property-damage-only crashes.
 764 These preliminary values of $N_{brmv(FI)}$ and $N_{brmv(PDO)}$, designated as $N'_{brmv(FI)}$ and
 765 $N'_{brmv(PDO)}$ in Equation 12-11, are determined with Equation 12-10 using the
 766 coefficients for fatal-and-injury and property-damage-only crashes, respectively, in
 767 Exhibit 12-5. The following adjustments are then made to assure that $N_{brmv(FI)}$ and
 768 $N_{brmv(PDO)}$ sum to N_{brmv} :

769

$$N_{brmv(FI)} = N_{brmv(TOTAL)} \left(\frac{N'_{brmv(FI)}}{N'_{brmv(FI)} + N'_{brmv(PDO)}} \right) \quad (12-11)$$

770

$$N_{brmv(PDO)} = N_{brmv(TOTAL)} - N_{brmv(FI)} \quad (12-12)$$

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The proportions in Exhibit 12-7 are used to separate $N_{brmv(FI)}$ and $N_{brmv(PDO)}$ into components by collision type.

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Exhibit 12-7: Distribution of Multiple-Vehicle Nondriveway Collisions for Roadway Segments by Manner of Collision Type

Collision type	Proportion of crashes by severity level for specific road types									
	2U		3T		4U		4D		5T	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.730	0.778	0.845	0.842	0.511	0.506	0.832	0.662	0.846	0.651
Head-on collision	0.068	0.004	0.034	0.020	0.077	0.004	0.020	0.007	0.021	0.004
Angle collision	0.085	0.079	0.069	0.020	0.181	0.130	0.040	0.036	0.050	0.059
Sideswipe, same direction	0.015	0.031	0.001	0.078	0.093	0.249	0.050	0.223	0.061	0.248
Sideswipe, opposite direction	0.073	0.055	0.017	0.020	0.082	0.031	0.010	0.001	0.004	0.009
Other multiple-vehicle collisions	0.029	0.053	0.034	0.020	0.056	0.080	0.048	0.071	0.018	0.029

775

Source: HSIS data for Washington (2002-2006)

776

Single-Vehicle Crashes

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SPFs for single-vehicle crashes for roadway segments are applied as follows:

778

$$N_{brsv} = \exp(a + b \times \ln(AADT) + \ln(L)) \tag{12-13}$$

779

Exhibit 12-8 presents the values of the coefficients and factors used in Equation 12-13 for each roadway type. Equation 12-13 is first applied to determine N_{brsv} using the coefficients for total crashes in Exhibit 12-8. N_{brsv} is then divided into components by severity level, $N_{brsv(FI)}$ for fatal-and-injury crashes and $N_{brsv(PDO)}$ for property-damage-only crashes. Preliminary values of $N_{brsv(FI)}$ and $N_{brsv(PDO)}$, designated as $N'_{brsv(FI)}$ and $N'_{brsv(PDO)}$ in Equation 12-14, are determined with Equation 12-13 using the coefficients for fatal-and-injury and property-damage-only crashes, respectively, in Exhibit 12-8. The following adjustments are then made to assure that $N_{brsv(FI)}$ and $N_{brsv(PDO)}$ sum to N_{brsv} :

788

$$N_{brsv(FI)} = N_{brsv(TOTAL)} \left(\frac{N'_{brsv(FI)}}{N'_{brsv(FI)} + N'_{brsv(PDO)}} \right) \tag{12-14}$$

789

$$N_{brsv(PDO)} = N_{brsv(TOTAL)} - N_{brsv(FI)} \tag{12-15}$$

790

791

The proportions in Exhibit 12-10 are used to separate $N_{brsv(FI)}$ and $N_{brsv(PDO)}$ into components by crash type.

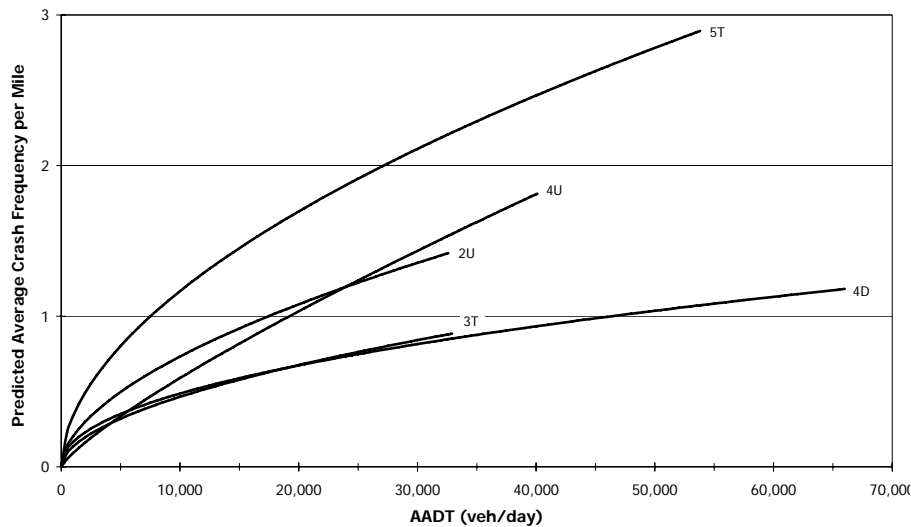
792

This section presents the SPFs and adjustment factors for single-vehicle crashes for roadway segments.

793 **Exhibit 12-8: SPF Coefficients for Single-Vehicle Crashes on Roadway Segments**

Road type	Coefficients used in Equation 12-11		Overdispersion parameter (k)
	Intercept (a)	AADT (b)	
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

794 **Exhibit 12-9: Graphical Form of the SPF for Single-Vehicle Crashes (from Equation 12-13**
 795 **and Exhibit 12-8)**



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Exhibit 12-10: Distribution of Single-Vehicle Crashes for Roadway Segments by Collision Type

Collision type	Proportion of crashes by severity level for specific road types									
	2U		3T		4U		4D		5T	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Collision with animal	0.026	0.066	0.001	0.001	0.001	0.001	0.001	0.063	0.016	0.049
Collision with fixed object	0.723	0.759	0.688	0.963	0.612	0.809	0.500	0.813	0.398	0.768
Collision with other object	0.010	0.013	0.001	0.001	0.020	0.029	0.028	0.016	0.005	0.061
Other single-vehicle collision	0.241	0.162	0.310	0.035	0.367	0.161	0.471	0.108	0.581	0.122

799

Source: HSIS data for Washington (2002-2006)

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Multiple-Vehicle Driveway-Related Collisions

This section presents the SPFs and adjustment factors for multiple-vehicle driveway-related collisions within a roadway segment.

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The model presented above for multiple-vehicle collisions addressed only collisions that are not related to driveways. Driveway-related collisions also generally involve multiple vehicles, but are addressed separately because the frequency of driveway-related collisions on a roadway segment depends on the number and type of driveways. Only unsignalized driveways are considered; signalized driveways are analyzed as signalized intersections.

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The total number of multiple-vehicle driveway-related collisions within a roadway segment is determined as:

809

$$N_{brdwy} = \sum_{\substack{\text{all} \\ \text{driveway} \\ \text{types}}} n_j \times N_j \times \left(\frac{AADT}{15,000} \right)^t \tag{12-16}$$

810

Where,

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- N_j = Number of driveway-related collisions per driveway per year for driveway type j from Exhibit 12-11;
- n_j = number of driveways within roadway segment of driveway type j including all driveways on both sides of the road; and
- t = coefficient for traffic volume adjustment from Exhibit 12-11.

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The number of driveways of a specific type, n_j, is the sum of the number of driveways of that type for both sides of the road combined. The number of driveways is determined separately for each side of the road and then added together.

820

Seven specific driveway types have been considered in modeling. These are:

821
822

- Major commercial driveways
- Minor commercial driveways

- 823 ■ Major industrial/institutional driveways
- 824 ■ Minor industrial/institutional driveways
- 825 ■ Major residential driveways
- 826 ■ Minor residential driveways
- 827 ■ Other driveways

828 Major driveways are those that serve sites with 50 or more parking spaces. Minor
 829 driveways are those that serve sites with less than 50 parking spaces. It is not
 830 intended that an exact count of the number of parking spaces be made for each
 831 site. Driveways can be readily classified as major or minor from a quick review
 832 of aerial photographs that show parking areas or through user judgment based
 833 on the character of the establishment served by the driveway. Commercial
 834 driveways provide access to establishments that serve retail customers.
 835 Residential driveways serve single- and multiple-family dwellings.
 836 Industrial/institutional driveways serve factories, warehouses, schools,
 837 hospitals, churches, offices, public facilities, and other places of employment.
 838 Commercial sites with no restriction on access along an entire property frontage
 839 are generally counted as two driveways.

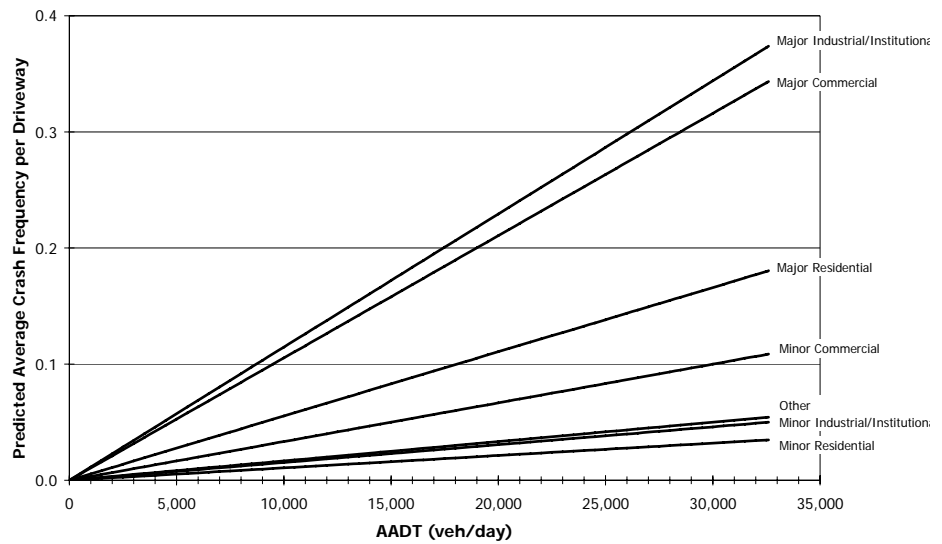
840 **Exhibit 12-11: SPF Coefficients for Multiple-Vehicle Driveway Related Collisions**

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
Overdispersion parameter (k)					
All driveways	0.81	1.10	0.81	1.39	0.10
Proportion of fatal-and-injury crashes (f_{dwy})					
All driveways	0.323	0.243	0.342	0.284	0.269
Proportion of property-damage-only crashes					
All driveways	0.677	0.757	0.658	0.716	0.731

841 Note: Includes only unsignalized driveways; signalized driveways are analyzed as signalized intersections. Major
 842 driveways serve 50 or more parking spaces; minor driveways serve less than 50 parking spaces.
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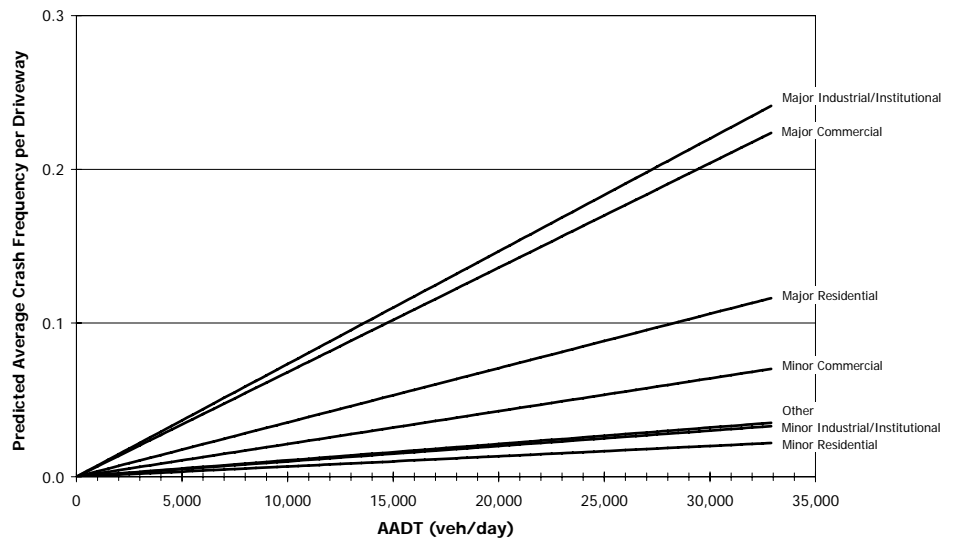
Exhibit 12-12: Graphical Form of the SPF for Multiple Vehicle Driveway Related Collisions on Two-Lane Undivided Arterials (2U) (from Equation 12-16 and Exhibit 12-11)



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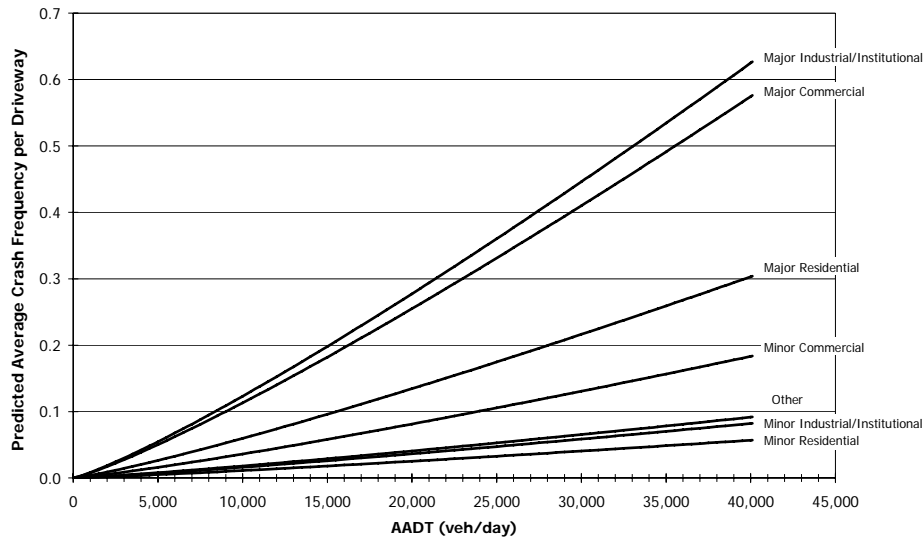
Exhibit 12-13: Graphical Form of the SPF for Multiple Vehicle Driveway Related Collisions on Three-Lane Undivided Arterials (3T) (from Equation 12-16 and Exhibit 12-11)



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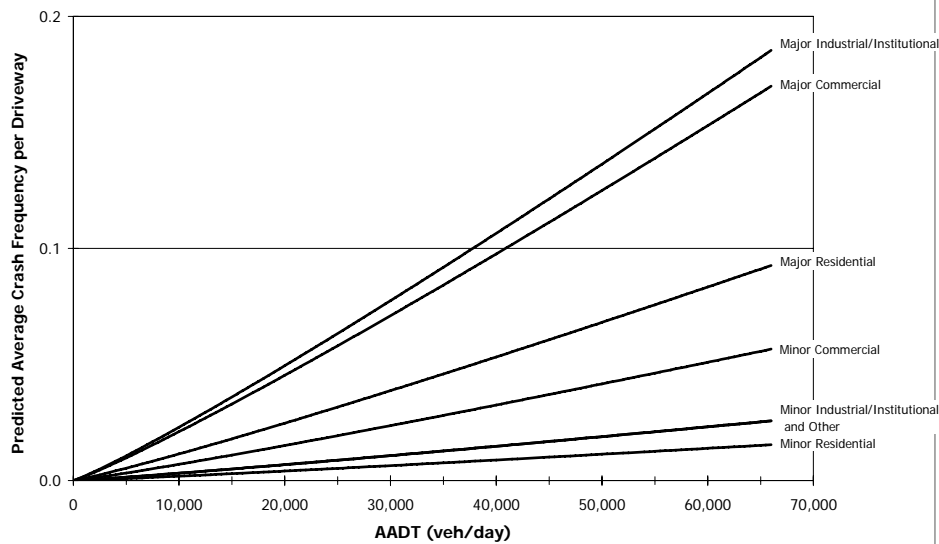
Exhibit 12-14: Graphical Form of the SPF for Multiple Vehicle Driveway Related Collisions on on Four-Lane Undivided Arterials (4U) (from Equation 12-16 and Exhibit 12-11)



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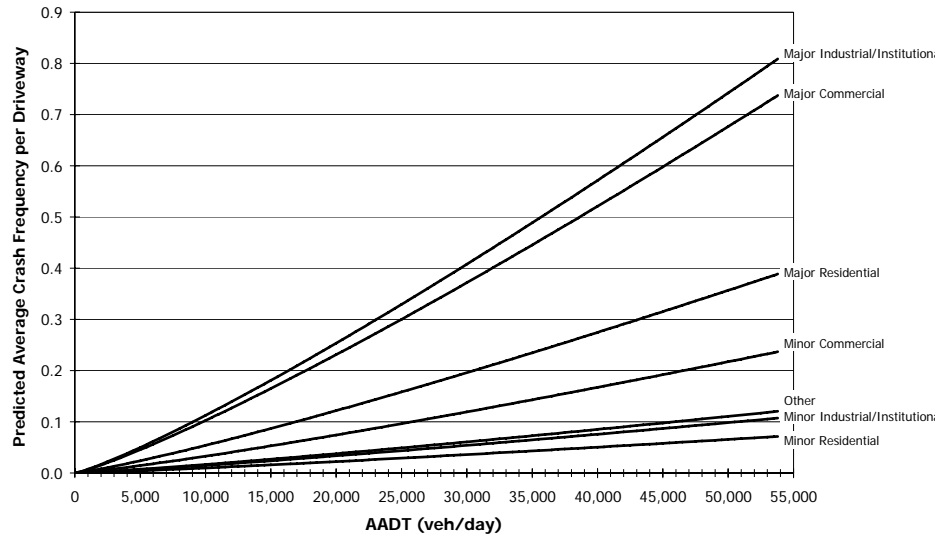
Exhibit 12-15: Graphical Form of the SPF for Multiple Vehicle Driveway Related Collisions on Four-Lane Divided Arterials(4D) (from Equation 12-16 and Exhibit 12-11)



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Exhibit 12-16: Graphical Form of the SPF for Multiple Vehicle Driveway Related Collisions on Five-Lane Arterials Including a Center Two-Way Left-Turn Lane)(from Equation 12-16 and Exhibit 12-11)



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Driveway-related collisions can be separated into components by severity level as follows:

$$N_{brdwy(FI)} = N_{brdwy(TOTAL)} \times f_{dwy} \tag{12-17}$$

$$N_{brdwy(PDO)} = N_{brdwy(TOTAL)} - N_{brdwy(FI)} \tag{12-18}$$

868

Where,

869 f_{dwy} = proportion of driveway-related collisions that involve
870 fatalities or injuries

871 The values of N_j and f_{dwy} are shown in Exhibit 12-11.

872 **Vehicle-Pedestrian Collisions**

This section presents the method to calculate the number of vehicle-pedestrian collisions per year for a roadway segment.

873
874

The number of vehicle-pedestrian collisions per year for a roadway segment is estimated as:

$$N_{pedr} = N_{br} \times f_{pedr} \tag{12-19}$$

876

Where,

877 f_{pedr} = pedestrian accident adjustment factor.

878

The value N_{br} used in Equation 12-19 is that determined with Equation 12-3.

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Exhibit 12-17 presents the values of f_{pedr} for use in Equation 12-19. All vehicle-pedestrian collisions are considered to be fatal-and-injury crashes. The values of f_{pedr} are likely to depend on the climate and the walking environment in particular states or communities. HSM users are encouraged to replace the values in Exhibit 12-17 with suitable values for their own state or community through the calibration process (see the Appendix to Part C).

885 **Exhibit 12-17: Pedestrian Accident Adjustment Factor for Roadway Segments**

Road type	Pedestrian Accident Adjustment Factor (f_{pedr})	
	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

886 Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All
 887 pedestrian collisions resulting from this adjustment factor is treated as fatal-and-injury crashes and none as
 888 property-damage-only crashes. Source: HSIS data for Washington (2002-2006)
 889

890 **Vehicle-Bicycle Collisions**

891 The number of vehicle-bicycle collisions per year for a roadway segment is
 892 estimated as:

893
$$N_{biker} = N_{br} \times f_{biker} \tag{12-20}$$

894 Where,

895 f_{biker} = bicycle accident adjustment factor.

896 The value of N_{br} used in Equation 12-20 is determined with Equation 12-3.

897 Exhibit 12-18 presents the values of f_{biker} for use in Equation 12-18. All vehicle-
 898 bicycle collisions are considered to be fatal-and-injury crashes. The values of f_{biker} are
 899 likely to depend on the climate and bicycling environment in particular states or
 900 communities. HSM users are encouraged to replace the values in Exhibit 12-18 with
 901 suitable values for their own state or community through the calibration process (see
 902 the Appendix to *Part C*).

903 **Exhibit 12-18: Bicycle Accident Adjustment Factors for Roadway Segments**

Road type	Bicycle Accident Adjustment Factor (f_{biker})	
	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

904 Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All
 905 bicycle collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as
 906 property-damage-only crashes. Source: HSIS data for Washington (2002-2006)

This section presents the method to calculate vehicle-bicycle collisions per year for a roadway segment.

This section introduces the SPFs for intersections on urban and suburban arterials.

907 **12.6.2. Safety Performance Functions for Urban and Suburban Arterial**
 908 **Intersections**

909 The predictive models for predicting the frequency of crashes related to an
 910 intersection is presented in Equations 12-5 through 12-7. The structure of the
 911 predictive models for intersections is similar to the predictive models for roadway
 912 segments.

913 The effect of traffic volume on predicted crash frequency for intersections is
 914 incorporated through SPFs, while the effect of geometric and traffic control features
 915 are incorporated through AMFs. Each of the SPFs for intersections incorporates
 916 separate effects for the AADTs on the major- and minor-road legs, respectively.

917 SPFs and adjustment factors have been developed for four types of intersections
 918 on urban and suburban arterials. These are:

- 919 ■ Three-leg intersections with STOP control on the minor-road approach (3ST)
- 920 ■ Three-leg signalized intersections (3SG)
- 921 ■ Four-leg intersections with STOP control on the minor-road approaches
 922 (4ST)
- 923 ■ Four-leg signalized intersections (4SG)

924 Other types of intersections may be found on urban and suburban arterials but
 925 are not addressed by the Chapter 12 SPFs.

926 The SPFs for each of the four intersection types identified above predict total
 927 crash frequency per year for crashes that occur within the limits of the intersection.
 928 The SPFs and adjustment factors address the following four types of collisions, (the
 929 corresponding Equations and Exhibits are indicated in Exhibit 12-4):

- 930 ■ multiple-vehicle collisions
- 931 ■ single-vehicle crashes
- 932 ■ vehicle-pedestrian collisions
- 933 ■ vehicle-bicycle collisions

934 Guidance on the estimation of traffic volumes for the major and minor road legs
 935 for use in the SPFs is presented in Step 3. The AADT(s) used in the SPF are the
 936 AADT(s) for the selected year of the evaluation period. The SPFs for intersections are
 937 applicable to the following AADT ranges:

- 938 ■ 3ST Intersections AADT_{maj}: 0 to 45,700 vehicles per day and
 939 AADT_{min}: 0 to 9,300 vehicles per day
- 940 ■ 4ST Intersections AADT_{maj}: 0 to 46,800 vehicles per day and
 941 AADT_{min}: 0 to 5,900 vehicles per day
- 942 ■ 3SG Intersections AADT_{maj}: 0 to 58,100 vehicles per day and
 943 AADT_{min}: 0 to 16,400 vehicles per day
- 944 ■ 4SG Intersections AADT_{maj}: 0 to 67,700 vehicles per day and
 945 AADT_{min}: 0 to 33,400 vehicles per day

The traffic volume boundary conditions for the chapter 12 intersection SPFs are presented here.

- 946 ■ 4SG Intersections Pedestrian Models:
- 947 ○ AADT_{maj}: 80,200 vehicles per day
- 948 ○ AADT_{min}: 49,100 vehicles per day
- 949 ○ PedVol: 34,200 pedestrians per day crossing all four legs combined

950 Application to sites with AADTs substantially outside this range may not
951 provide reliable results.

952 **Multiple-Vehicle Collisions**

953 SPFs for multiple-vehicle intersection-related collisions are applied as follows:

954
$$N_{bimv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min})) \quad (12-21)$$

955 Where,

956 AADT_{maj} = average daily traffic volume (vehicles/day) for major road
957 (both directions of travel combined);

958 AADT_{min} = average daily traffic volume (vehicles/day) for minor road
959 (both directions of travel combined); and

960 a, b, c = regression coefficients.

961 Exhibit 12-19 presents the values of the coefficients a, b, and c used in applying
962 Equation 12-21. The SPF overdispersion parameter, k, is also presented in Exhibit 12-
963 19.

964 Equation 12-21 is first applied to determine N_{bimv} using the coefficients for total
965 crashes in Exhibit 12-19. N_{bimv} is then divided into components by crash severity level,
966 N_{bimv(FI)} for fatal-and-injury crashes and N_{bimv(PDO)} for property-damage-only crashes.
967 Preliminary values of N_{bimv(FI)} and N_{bimv(PDO)}, designated as N'_{bimv(FI)} and N'_{bimv(PDO)} in
968 Equation 12-22, are determined with Equation 12-21 using the coefficients for fatal-
969 and-injury and property-damage-only crashes, respectively, in Exhibit 12-19. The
970 following adjustments are then made to assure that N_{bimv(FI)} and N_{bimv(PDO)} sum to
971 N_{bimv}:

972
$$N_{bimv(FI)} = N_{bimv(TOTAL)} \times \left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}} \right) \quad (12-22)$$

973
$$N_{bimv(PDO)} = N_{bimv(TOTAL)} - N_{bimv(FI)} \quad (12-23)$$

974 The proportions in Exhibit 12-24 are used to separate N_{bimv(FI)} and N_{bimv(PDO)} into
975 components by manner of collision.

SPFs for multiple-vehicle intersection-related collisions are presented here.

976

Exhibit 12-19: SPF Coefficients for Multiple-Vehicle Collisions at Intersections

Intersection type	Coefficients used in Equation 12-21			Over-dispersion parameter (k)
	Intercept (a)	AA _{DT} _{maj} (b)	AA _{DT} _{min} (c)	
Total crashes				
3ST	-13.36	1.11	0.41	0.80
3SG	-12.13	1.11	0.26	0.33
4ST	-8.90	0.82	0.25	0.40
4SG	-10.99	1.07	0.23	0.39
Fatal-and-injury crashes				
3ST	-14.01	1.16	0.30	0.69
3SG	-11.58	1.02	0.17	0.30
4ST	-11.13	0.93	0.28	0.48
4SG	-13.14	1.18	0.22	0.33
Property-damage-only crashes				
3ST	-15.38	1.20	0.51	0.77
3SG	-13.24	1.14	0.30	0.36
4ST	-8.74	0.77	0.23	0.40
4SG	-11.02	1.02	0.24	0.44

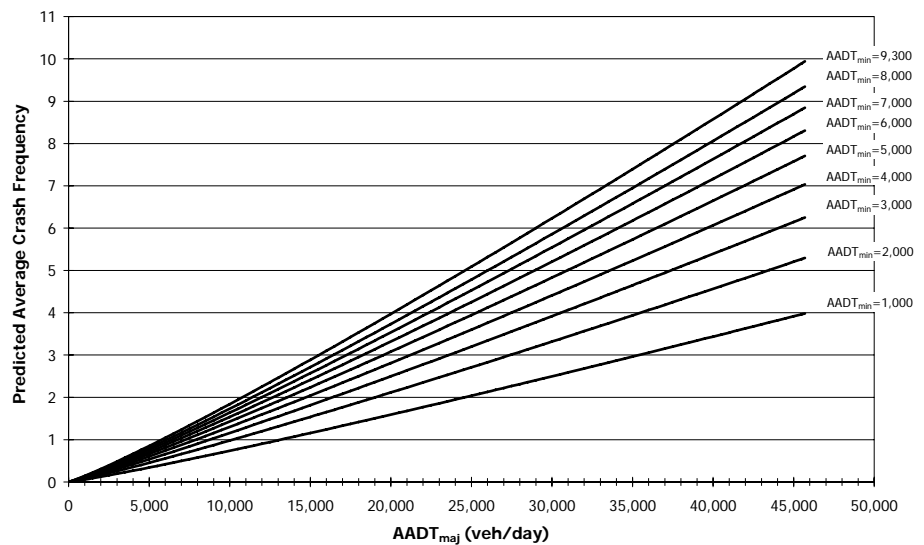
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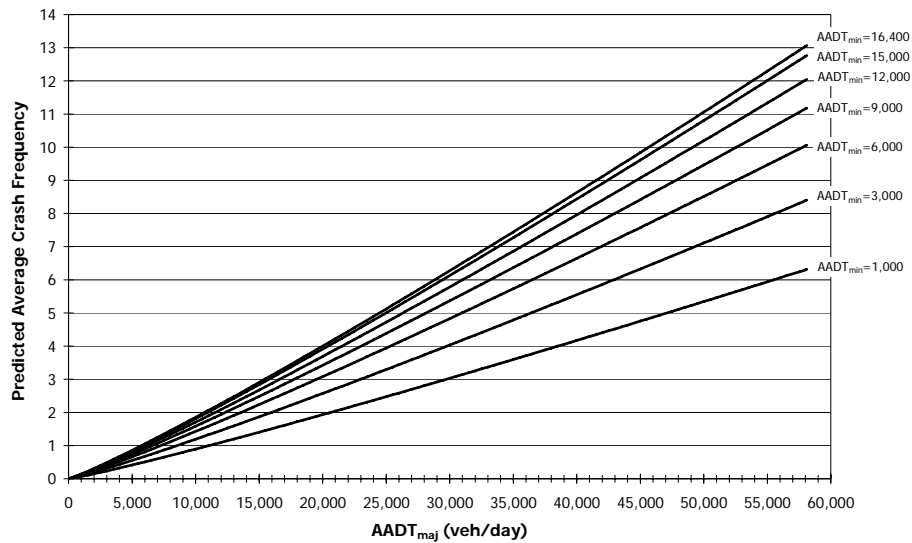
Exhibit 12-20: Graphical Form of the Intersection SPF for Multiple Vehicle collisions on Three-Leg Intersections with Minor-Road Stop Control (3ST) (from Equation 12-21 and Exhibit 12-19)



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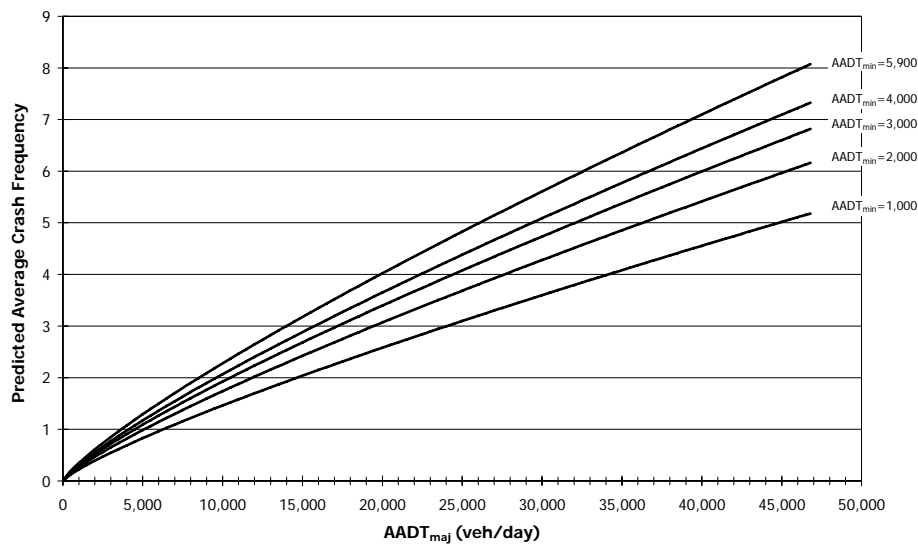
Exhibit 12-21: Graphical Form of the Intersection SPF for Multiple Vehicle collisions on Three-Leg Signalized Intersections (3SG) (from Equation 12-21 and Exhibit 12-19)



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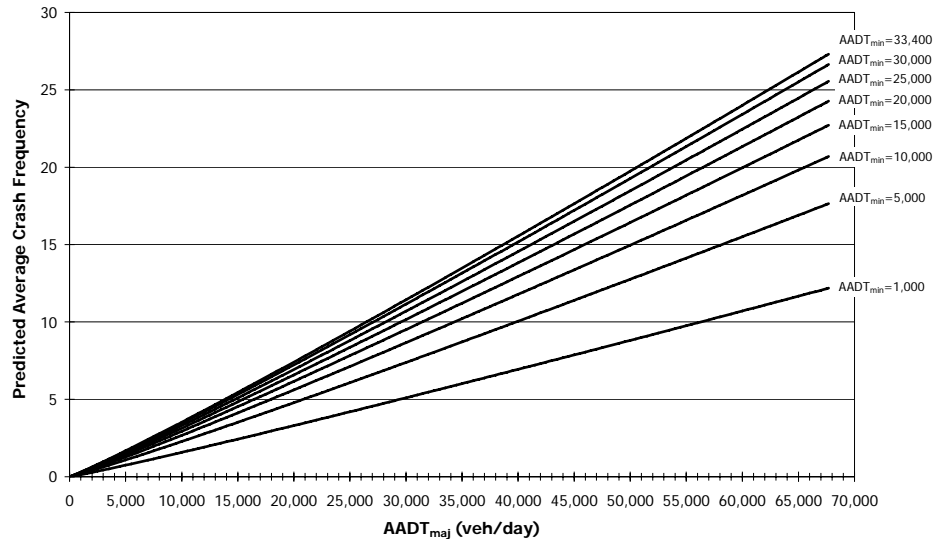
Exhibit 12-22: Graphical Form of the Intersection SPF for Multiple Vehicle collisions on Four-Leg Intersections with Minor-Road Stop Control (4ST) (from Equation 12-21 and Exhibit 12-19)



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Exhibit 12-23: Graphical Form of the Intersection SPF for Multiple Vehicle collisions on Four-Leg Signalized Intersections (4SG) (from Equation 12-21 and Exhibit 12-19)



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Exhibit 12-24: Distribution of Multiple-Vehicle Collisions for Intersections by Collision Type

Manner of collision	Proportion of crashes by severity level for specific intersections types							
	3ST		3SG		4ST		4SG	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.421	0.440	0.549	0.546	0.338	0.374	0.450	0.483
Head-on collision	0.045	0.023	0.038	0.020	0.041	0.030	0.049	0.030
Angle collision	0.343	0.262	0.280	0.204	0.440	0.335	0.347	0.244
Sideswipe	0.126	0.040	0.076	0.032	0.121	0.044	0.099	0.032
Other multiple-vehicle collisions	0.065	0.235	0.057	0.198	0.060	0.217	0.055	0.211

996
997

Source: HSIS data for California (2002-2006)

998

Single-Vehicle Crashes

This section presents SPFs for single-vehicle crashes at intersections.

999

SPFs for single-vehicle crashes are applied as follows:

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$$N_{bisv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min})) \quad (12-24)$$

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Exhibit 12-25 presents the values of the coefficients and factors used in Equation 12-24 for each roadway type. Equation 12-24 is first applied to determine N_{bisv} using the coefficients for total crashes in Exhibit 12-25. N_{bisv} is then divided into components by severity level, $N_{bisv(FI)}$ for fatal-and-injury crashes and $N_{bisv(PDO)}$ for property-damage-only crashes. Preliminary values of $N_{bisv(FI)}$ and $N_{bisv(PDO)}$, designated as $N'_{bisv(FI)}$ and $N'_{bisv(PDO)}$ in Equation 12-25, are determined with Equation 12-24 using the coefficients for fatal-and-injury and property-damage-only crashes, respectively, in Exhibit 12-25. The following adjustments are then made to assure that $N_{bisv(FI)}$ and $N_{bisv(PDO)}$ sum to N_{bisv} .

1010
$$N_{bisv(FI)} = N_{bisv(TOTAL)} \times \left(\frac{N'_{bisv(FI)}}{N'_{bisv(FI)} + N'_{bisv(PDO)}} \right) \quad (12-25)$$

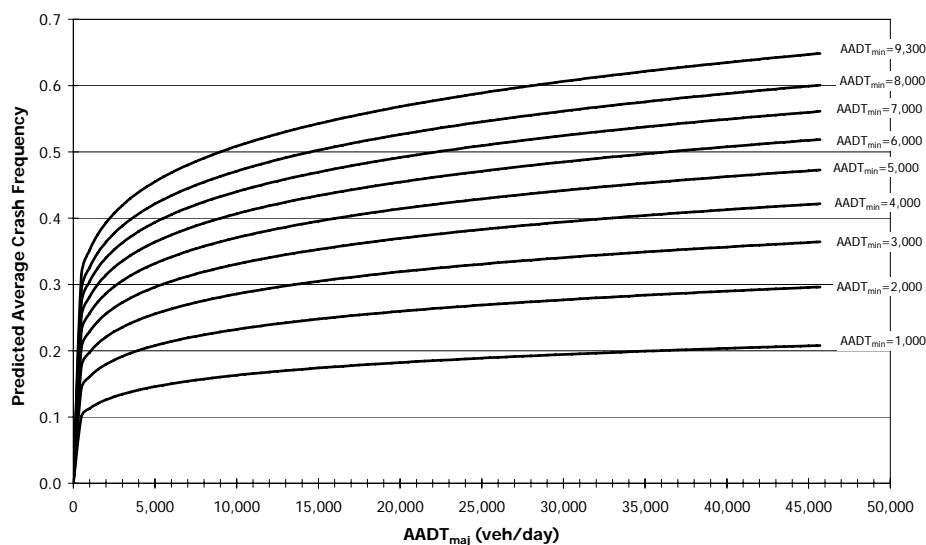
1011
$$N_{bisv(PDO)} = N_{bisv(TOTAL)} - N_{bisv(FI)} \quad (12-26)$$

1012 **Exhibit 12-25: SPF Coefficients for Single-Vehicle Crashes at Intersections**

Intersection type	Coefficients used in Equation 12-24			Over-dispersion parameter (k)
	Intercept (a)	AAADT _{maj} (b)	AAADT _{min} (c)	
Total crashes				
3ST	-6.81	0.16	0.51	1.14
3SG	-9.02	0.42	0.40	0.36
4ST	-5.33	0.33	0.12	0.65
4SG	-10.21	0.68	0.27	0.36
Fatal-and-injury crashes				
3ST				
3SG	-9.75	0.27	0.51	0.24
4ST				
4SG	-9.25	0.43	0.29	0.09
Property-damage-only crashes				
3ST	-8.36	0.25	0.55	1.29
3SG	-9.08	0.45	0.33	0.53
4ST	-7.04	0.36	0.25	0.54
4SG	-11.34	0.78	0.25	0.44

1013 Note: Where no models are available, Equation 12-27 is used.

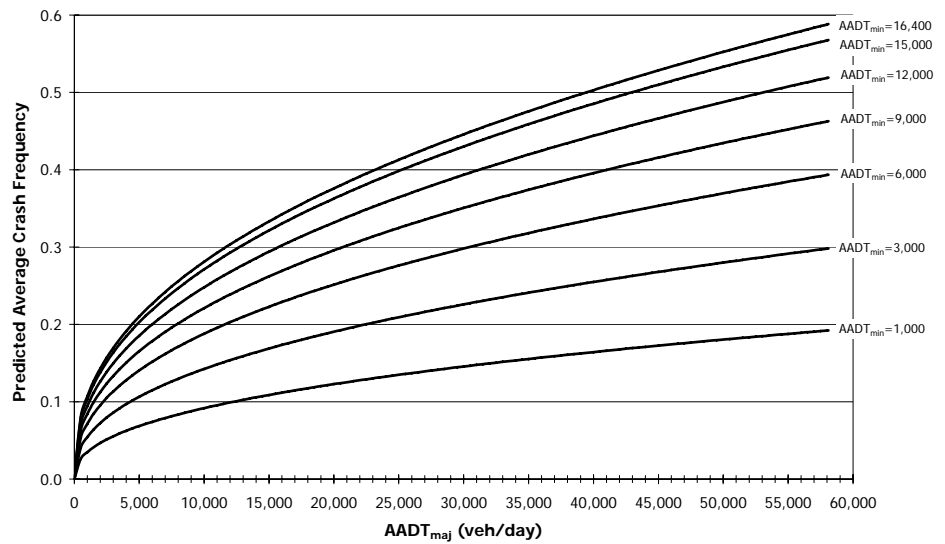
1014 **Exhibit 12-26: Graphical Form of the Intersection SPF for Single-Vehicle Crashes on**
 1015 **Three-leg Intersections with Minor-Road Stop Control (3ST) (from Equation**
 1016 **12-24 and Exhibit 12-25)**



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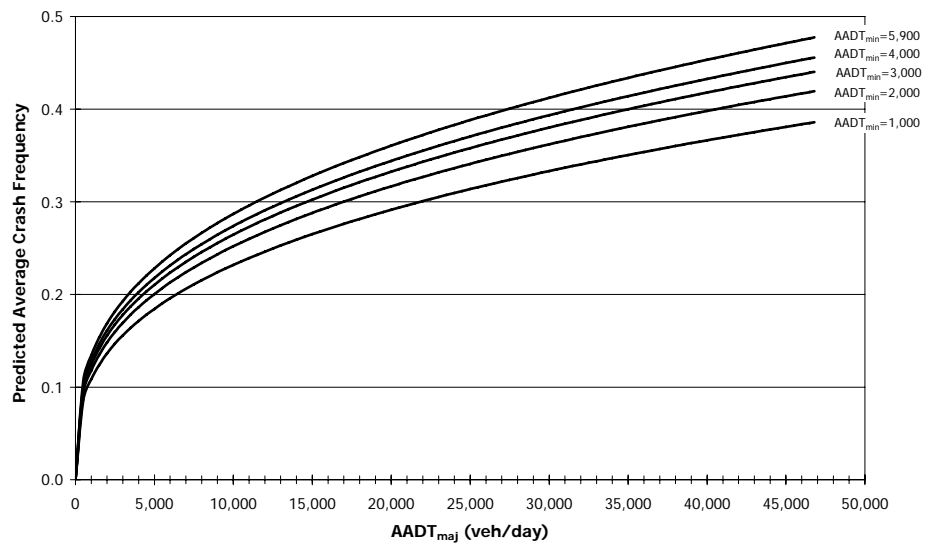
Exhibit 12-27: Graphical Form of the Intersection SPF for Single-Vehicle Crashes on Three-Leg Signalized Intersections (3SG) (from Equation 12-24 and Exhibit 12-25)



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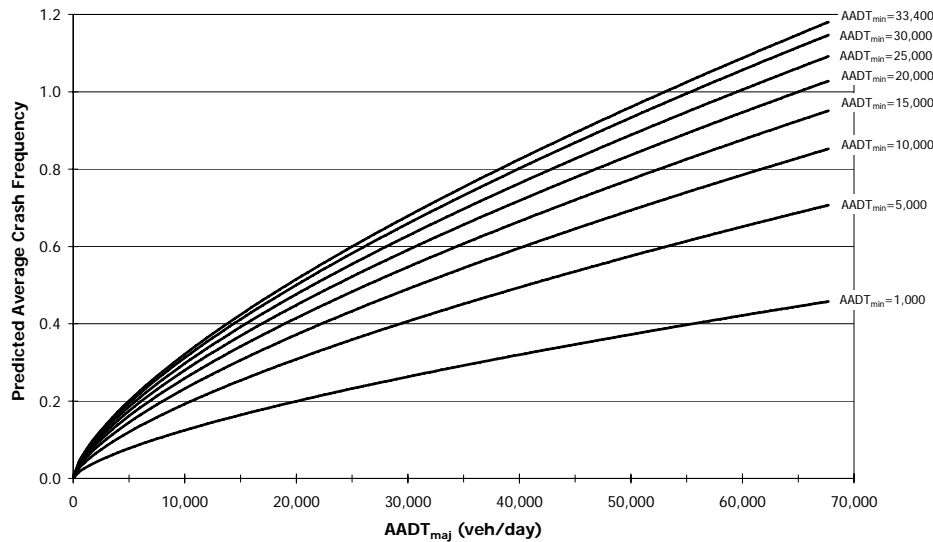
Exhibit 12-28: Graphical Form of the Intersection SPF for Single-Vehicle Crashes on Four-leg Stop Controlled Intersections (4ST) (from Equation 12-24 and Exhibit 12-25)



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Exhibit 12-29: Graphical Form of the Intersection SPF for Single-Vehicle Crashes on Four-Leg Signalized Intersections (4SG) (from Equation 12-24 and Exhibit 12-25)



1029

The proportions in Exhibit 12-30 are used to separate $N_{bisv(FI)}$ and $N_{bisv(PDO)}$ into components by crash type.

1030
1031

Exhibit 12-30: Distribution of Single-Vehicle Crashes for Intersection by Collision Type

Crash type	Proportion of crashes by severity level for specific road types							
	3ST		3SG		4ST		4SG	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Collision with parked vehicle	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001
Collision with animal	0.003	0.018	0.001	0.003	0.001	0.026	0.002	0.002
Collision with fixed object	0.762	0.834	0.653	0.895	0.679	0.847	0.744	0.870
Collision with other object	0.090	0.092	0.091	0.069	0.089	0.070	0.072	0.070
Other single-vehicle collision	0.039	0.023	0.045	0.018	0.051	0.007	0.040	0.023
Noncollision	0.105	0.030	0.209	0.014	0.179	0.049	0.141	0.034

1033
1034

Source: HSIS data for California (2002-2006)

1035
1036
1037

Since there are no models for fatal-and-injury crashes at three- and four-leg STOP-controlled intersections in Exhibit 12-25, Equation 12-25 is replaced with the following equation in these cases:

1038

$$N_{bisv(FI)} = N_{bisv(TOTAL)} \times f_{bisv} \tag{12-27}$$

1039

Where,

1040

f_{bisv} = proportion of fatal-and-injury crashes for combined sites.

This section presents SPFs for estimating the number of vehicle-pedestrian collisions at signalized and unsignalized intersections.

1041 The default value of f_{biso} in Equation 12-27 is 0.31 for 3ST and 0.28 for 4ST
1042 intersections. It is recommended that these default values be updated based on
1043 locally available data.

1044 **SPFs for Vehicle-Pedestrian Collisions**

1045 Separate SPFs are provided for estimation of the number of vehicle-pedestrian
1046 collisions at signalized and unsignalized intersections.

1047 *SPFs for Signalized Intersections*

1048 The number of vehicle-pedestrian collisions per year at a signalized intersection
1049 is estimated with a SPF and a set of AMFs that apply specifically to vehicle-
1050 pedestrian collisions. The model for estimating vehicle-pedestrian collisions at
1051 signalized intersections is:

$$1052 \quad N_{pedi} = N_{pedbase} \times AMF_{1p} \times AMF_{2p} \times AMF_{3p} \quad (12-28)$$

1053 Where,

1054 $N_{pedbase}$ = predicted number of vehicle-pedestrian collisions per year
1055 for base conditions at signalized intersections.

1056 $AMF_{1p} \dots AMF_{3p}$ = accident modification factors for vehicle-pedestrian collisions
1057 at signalized intersections.

1058 The SPF for vehicle-pedestrian collisions at signalized intersections is:

$$1059 \quad N_{pedbase} = \exp(a + b \times \ln(AADT_{tot}) + c \times \ln\left(\frac{AADT_{min}}{AADT_{maj}}\right) + d \times \ln(PedVol) + e \times n_{lanesx}) \quad (12-29)$$

1060 Where,

1061 $AADT_{tot}$ = sum of the average daily traffic volumes (vehicles per day)
1062 for the major and minor roads (= $AADT_{maj} + AADT_{min}$);

1063 $PedVol$ = sum of daily pedestrian volumes (pedestrians/day) crossing
1064 all intersection legs;

1065 n_{lanesx} = maximum number of traffic lanes crossed by a pedestrian in
1066 any crossing maneuver at the intersection considering the
1067 presence of refuge islands;

1068 a, b, c, d, e = regression coefficients.

1069 Determination of values for $AADT_{maj}$ and $AADT_{min}$ is addressed in the discussion
1070 of Step 3. Only pedestrian crossing maneuvers immediately adjacent to the
1071 intersection (e.g., at a marked crosswalk or along the extended path of any sidewalk
1072 present) are considered in determining the pedestrian volumes. Exhibit 12-31
1073 presents the values of the coefficients a, b, c, d , and e used in applying Equation 12-29.

1074 The coefficient values in Exhibit 12-31 are intended for estimating total vehicle-
1075 pedestrian collisions. All vehicle-pedestrian collisions are considered to be fatal-and-
1076 injury crashes.

1077 The application of Equation 12-29 requires data on the total pedestrian volumes
1078 crossing the intersection legs. Reliable estimates will be obtained when the value of
1079 $PedVol$ in Equation 12-29 is based on actual pedestrian volume counts. Where
1080 pedestrian volume counts are not available, they may be estimated using Exhibit 12-
1081 32. Replacing the values in Exhibit 12-32 with locally derived values is encouraged.

1082 The value of n_{lanesx} in Equation 12-29 represents the maximum number of traffic
 1083 lanes that a pedestrian must cross in any crossing maneuver at the intersection. Both
 1084 through and turning lanes that are crossed by a pedestrian along the crossing path
 1085 are considered. If the crossing path is broken by an island that provides a suitable
 1086 refuge for the pedestrian so that the crossing may be accomplished in two (or more)
 1087 stages, then the number of lanes crossed in each stage is considered separately. To be
 1088 considered as a suitable refuge, an island must be raised or depressed; a flush or
 1089 painted island is not treated as a refuge for purposes of determining the value of
 1090 n_{lanesx} .

1091 **Exhibit 12-31: SPFs for Vehicle-Pedestrian Collisions at Signalized Intersections**

Intersection type	Coefficients used in Equation 12-29					Over-dispersion parameter (k)
	Intercept (a)	AADT _{tot} (b)	AADT _{min} /AADT _{maj} (c)	PedVol (d)	n_{lanesx} (e)	
Total crashes						
3SG	-6.60	0.05	0.24	0.41	0.09	0.52
4SG	-9.53	0.40	0.26	0.45	0.04	0.24

1092

1093 **Exhibit 12-32: Estimates of Pedestrian Crossing Volumes Based on General Level of**
 1094 **Pedestrian Activity**

General level of pedestrian activity	Estimate of PedVol (pedestrians/day) for use in Equation 12-29	
	3SG intersections	4SG intersections
High	1,700	3,200
Medium-high	750	1,500
Medium	400	700
Medium-low	120	240
Low	20	50

1095

1096 *SPFs for STOP-Controlled Intersections*

1097 The number of vehicle-pedestrian collisions per year for a STOP-controlled
 1098 intersection is estimated as:

1099
$$N_{pedl} = N_{bj} \times f_{pedl} \tag{12-30}$$

1100 Where,

1101 f_{pedl} = pedestrian accident adjustment factor.

1102 The value of N_{bj} used in Equation 12-30 is that determined with Equation 12-6.

1103 Exhibit 12-33 presents the values of f_{pedl} for use in Equation 12-30. All vehicle-
 1104 pedestrian collisions are considered to be fatal-and-injury crashes. The values of f_{pedl}
 1105 are likely to depend on the climate and walking environment in particular states or
 1106 communities. HSM users are encouraged to replace the values in Exhibit 12-33 with
 1107 suitable values for their own state or community through the calibration process (see
 1108 the Appendix to Part C).

1109 **Exhibit 12-33: Pedestrian Accident Adjustment Factors for STOP-controlled Intersections**

Intersection type	Pedestrian Accident Adjustment Factor (f_{pedi})
3ST	0.021
4ST	0.022

1110 Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All
 1111 pedestrian collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none
 1112 as property-damage-only crashes. Source: HGIS data for California (2002-2006)

1113 **Vehicle-Bicycle Collisions**

This section presents calculations for estimating the number of vehicle-bicycle collisions per year for an intersection.

1114 The number of vehicle-bicycle collisions per year for an intersection is estimated
 1115 as:

1116
$$N_{bikei} = N_{bi} \times f_{bikei} \tag{12-31}$$

1117 Where,

1118 f_{bikei} = bicycle accident adjustment factor.

1119 The value of N_{bi} used in Equation 12-31 is determined with Equation 12-6.

1120 Exhibit 12-34 presents the values of f_{bikei} for use in Equation 12-31. All vehicle-
 1121 bicycle collisions are considered to be fatal-and-injury crashes. The values of f_{bikei} are
 1122 likely to depend on the climate and bicycling environment in particular states or
 1123 communities. HSM users are encouraged to replace the values in Exhibit 12-34 with
 1124 suitable values for their own state or community through the calibration process (see
 1125 the Appendix to *Part C*).

1126 **Exhibit 12-34: Bicycle Accident Adjustment Factors for Intersections**

Intersection type	Bicycle Accident Adjustment Factor (f_{bikei})
3ST	0.016
3SG	0.011
4ST	0.018
4SG	0.015

1127 NOTE: These factors apply to the methodology for predicting total crashes (all severity levels combined). All
 1128 bicycle collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as
 1129 property-damage-only crashes. Source: HGIS data for California (2002-2006)

1130 **12.7. ACCIDENT MODIFICATION FACTORS**

This section presents the AMFs for the SPFs in Chapter 12.

1131 In Step 10 of the predictive method shown in Section 12.4, Accident Modification
 1132 Factors are applied to the selected Safety Performance Function (SPF), which was
 1133 selected in Step 9. SPFs provided in Chapter 12 are presented in Section 12.6. A
 1134 general overview of Accident Modification Factors (AMFs) is presented in *Chapter 3*
 1135 Section 3.5.3. The *Part C Introduction and Applications Guidance* provides further
 1136 discussion on the relationship of AMFs to the predictive method. This section
 1137 provides details of the specific AMFs applicable to the SPFs presented in Section 12.6.

1138 Accident Modification Factors (AMFs) are used to adjust the SPF estimate of
 1139 predicted average crash frequency for the effect of individual geometric design and
 1140 traffic control features, as shown in the general predictive model for Chapter 12
 1141 shown in Equation 12-1. The AMF for the SPF base condition of each geometric
 1142 design or traffic control feature has a value of 1.00. Any feature associated with

1143 higher crash frequency than the base condition has an AMF with a value greater than
 1144 1.00; any feature associated with lower crash frequency than the base condition has
 1145 an AMF with a value less than 1.00.

1146 The AMFs used in Chapter 12 are consistent with the AMFs in the *Part D*,
 1147 although they have, in some cases, been expressed in a different form to be applicable
 1148 to the base conditions of the SPFs. The AMFs presented in Chapter 12 and the specific
 1149 SPFs which they apply to are summarized in Exhibit 12-35.

1150 **Exhibit 12-35: Summary of AMFs in Chapter 12 and the Corresponding SPFs**

Applicable SPF	AMF	AMF Description	AMF Equations and Exhibits
Roadway Segments	AMF _{1r}	On-Street Parking	Equation 12-32 and Exhibit 12-36
	AMF _{2r}	Roadside Fixed Objects	Equation 12-33 and Exhibit 12-37 and 12-38
	AMF _{3r}	Median Width	Exhibit 12-39
	AMF _{4r}	Lighting	Equation 12-34 and Exhibit 12-40
	AMF _{5r}	Automated Speed Enforcement	See text
Multiple-vehicle collisions and single-vehicle crashes at intersections	AMF _{1i}	Intersection Left-Turn Lanes	Exhibit 12-41
	AMF _{2i}	Intersection Left-Turn Signal Phasing	Exhibit 12-42
	AMF _{3i}	Intersection Right-Turn Lanes	Exhibit 12-43
	AMF _{4i}	Right Turn on Red	Equation 12-35
	AMF _{5i}	Lighting	Equation 12-36 and Exhibit 12-44
	AMF _{6i}	Red Light Cameras	Equation 12-37, 12-38, 12-39
Vehicle-Pedestrian Collisions at Signalized Intersections	AMF _{1p}	Bus Stops	Exhibit 12-45
	AMF _{2p}	Schools	Exhibit 12-46
	AMF _{3p}	Alcohol Sales Establishments	Exhibit 12-47

1151

1152 **12.7.1. Accident Modification Factors for Roadway Segments**

1153 The AMFs for geometric design and traffic control features of urban and
 1154 suburban arterial roadway segments are presented below. These AMFs are
 1155 determined in Step 10 of the predictive method and used in Equation 12-3 to adjust
 1156 the SPF for urban and suburban arterial roadway segments, to account for differences
 1157 between the base conditions and the local site conditions.

1158 **AMF_{tr} - On-Street Parking**

1159 The AMF for on-street parking, where present, is based on research by
 1160 Bonneson⁽¹⁾. The base condition is the absence of on-street parking on a roadway
 1161 segment. The AMF is determined as:

1162
$$AMF_{tr} = 1 + p_{pk} \times (f_{pk} - 1.0) \tag{12-32}$$

1163 Where,

1164 AMF_{tr} = accident modification factor for the effect of on-street parking
 1165 on total accidents;

1166 f_{pk} = factor from Exhibit 12-36;

1167 p_{pk} = proportion of curb length with on-street parking = (0.5
 1168 L_{pk}/L); and

1169 L_{pk} = sum of curb length with on-street parking for both sides of
 1170 the road combined (miles);

1171 L = length of roadway segment (miles).

1172 This AMF applies to total roadway segment crashes.

1173 The sum of curb length with on-street parking (L_{pk}) can be determined from field
 1174 measurements or video log review to verify parking regulations. Estimates can be
 1175 made by deducting from twice the roadway segment length allowances for
 1176 intersection widths, crosswalks, and driveway widths.

1177 **Exhibit 12-36: Values of f_{pk} Used in Determining the Accident Modification Factor for On-**
 1178 **street Parking**

Road type	Type of parking and land use			
	Parallel parking		Angle parking	
	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

1179 **AMF_{2r} - Roadside Fixed Objects**

1180 The base condition is the absence of roadside fixed objects on a roadway
 1181 segment. The AMF for roadside fixed objects, where present, has been adapted from
 1182 the work of Zegeer and Cynecki⁽¹⁵⁾ on predicting utility pole crashes. The AMF is
 1183 determined with the following equation:

1184
$$AMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1.0 - p_{fo}) \quad (12-33)$$

1185 Where,

1186 AMF_{2r} = accident modification factor for the effect of roadside fixed
 1187 objects on total crashes;

1188 f_{offset} = fixed-object offset factor from Exhibit 12-37;

1189 D_{fo} = fixed-object density (fixed objects/mi) for both sides of the
 1190 road combined;

1191 p_{fo} = fixed-object collisions as a proportion of total crashes from
 1192 Exhibit 12-38.

1193 This AMF applies to total roadway segment crashes. If the computed value of
 1194 AMF_{2r} is less than 1.00, it is set equal to 1.00. This can only occur for very low fixed
 1195 object densities.

1196 In estimating the density of fixed objects (D_{fo}), only point objects that are 4 inches
 1197 or more in diameter and do not have breakaway design are considered. Point objects
 1198 that are within 70-ft of one another longitudinally along the road are counted as a
 1199 single object. Continuous objects that are not behind point objects are counted as one
 1200 point object for each 70-ft of length. The offset distance (O_{fo}) shown in Exhibit 12-37 is
 1201 an estimate of the average distance from the edge of the traveled way to roadside
 1202 objects over an extended roadway segment. If the average offset to fixed objects
 1203 exceeds 30-ft, use the value of f_{offset} for 30-ft. Only fixed objects on the roadside on the
 1204 right side of the roadway in each direction of travel are considered; fixed objects in
 1205 the roadway median on divided arterials are not considered.

1206 **Exhibit 12-37: 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

1207

1208

Exhibit 12-38: 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

1209

AMF_{3r} - Median Width

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An AMF for median widths on divided roadway segments of urban and suburban arterials is presented in Exhibit 12-39 based on the work of Harkey et al.⁽⁶⁾. The base condition for this AMF is a median width of 15-ft. The AMF applies to total crashes and represents the effect of median width in reducing cross-median collisions; the AMF assumes that nonintersection collision types other than cross-median collisions are not affected by median width. The AMF in Exhibit 12-39 has been adapted from the AMF in Exhibit 13-18 based on the estimate by Harkey et al.⁽⁶⁾ that cross-median collisions represent 12.0% of crashes on divided arterials.

1218
1219
1220
1221
1222
1223

This AMF applies only to traversable medians without traffic barriers. 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 AMF value of 1.00 is used for medians with traffic barriers. The value of this AMF is 1.00 for undivided facilities.

1224
1225

Exhibit 12-39: AMFs for Median Widths on Divided Roadway Segments without a Median Barrier (AMF_{3r})

Median width (ft)	AMF
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

1226

1227 **AMF_{4r} - Lighting**

1228 The base condition for lighting is the absence of roadway segment lighting
 1229 (AMF_{4r} = 1.00). The AMF for lighted roadway segments is determined, based on the
 1230 work of Elvik and Vaa⁽³⁾, as:

1231
$$AMF_{4r} = 1.0 - (p_{nr} \times (1.0 - 0.72 \times p_{inr} - 0.83 \times p_{pnr})) \quad (12-34)$$

1232 Where,

1233 AMF_{4r} = accident modification factor for the effect of roadway
 1234 segment lighting on total crashes;

1235 p_{inr} = proportion of total nighttime crashes for unlighted roadway
 1236 segments that involve a fatality or injury;

1237 p_{pnr} = proportion of total nighttime crashes for unlighted roadway
 1238 segments that involve property damage only;

1239 p_{nr} = proportion of total crashes for unlighted roadway segments
 1240 that occur at night.

1241 AMF_{4r} applies to total roadway segment crashes. Exhibit 12-40 presents default
 1242 values for the nighttime crash proportions p_{inr}, p_{pnr}, and p_{nr}. Replacement of the
 1243 estimates in Exhibit 12-40 with locally derived values is encouraged. If lighting
 1244 installation increases the density of roadside fixed objects, the value of AMF_{2r} is
 1245 adjusted accordingly.

1246 **Exhibit 12-40: Nighttime Crash Proportions for Unlighted Roadway Segments**

Roadway Segment type	Proportion of total nighttime crashes by severity level		Proportion of crashes that occur at night
	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

1247 **AMF_{5r} - Automated Speed Enforcement**

1248 Automated speed enforcement systems use video or photographic identification
 1249 in conjunction with radar or lasers to detect speeding drivers. These systems
 1250 automatically record vehicle identification information without the need for police
 1251 officers at the scene. The base condition for automated speed enforcement is that it is
 1252 absent. Chapter 17 presents an AMF of 0.83 for the reduction of all types of fatal and
 1253 injury crashes from implementation of automated speed enforcement. This AMF is
 1254 assumed to apply to roadway segments between intersections with fixed camera sites
 1255 where the camera is always present or where drivers have no way of knowing
 1256 whether the camera is present or not. No information is available on the effect of
 1257 automated speed enforcement on noninjury crashes. With the conservative
 1258 assumption that automated speed enforcement has no effect on noninjury crashes,
 1259 the value of the AMF for automated speed enforcement would be 0.95.

1260 **12.7.2. Accident Modification Factors for Intersections**

1261 The effects of individual geometric design and traffic control features of
 1262 intersections are represented in the predictive models by AMFs. AMF_{Ti} through
 1263 AMF_{4i} are applied to multiple-vehicle collisions and single-vehicle crashes at
 1264 intersections, but not to vehicle-pedestrian and vehicle-bicycle collisions. AMF_{Tp}
 1265 through AMF_{3p} are applied to vehicle-pedestrian collisions at four-leg signalized
 1266 intersections (4SG), but not to multiple-vehicle collisions and single-vehicle crashes
 1267 and not to other intersection types.

1268 ***AMF_{Ti} - Intersection Left-Turn Lanes***

1269 The base condition for intersection left-turn lanes is the absence of left-turn lanes
 1270 on the intersection approaches. The AMFs for presence of left-turn lanes are
 1271 presented in Exhibit 12-41. These AMFs apply to installation of left-turn lanes on any
 1272 approach to a signalized intersection, but only on uncontrolled major-road
 1273 approaches to STOP-controlled intersections. The AMFs for installation of left-turn
 1274 lanes on multiple approaches to an intersection are equal to the corresponding AMF
 1275 for installation of a left-turn lane on one approach raised to a power equal to the
 1276 number of approaches with left-turn lanes. There is no indication of any change in
 1277 crash frequency for providing a left-turn lane on an approach controlled by a STOP
 1278 sign, so the presence of a left-turn lane on a STOP-controlled approach is not
 1279 considered in applying Exhibit 12-41. The AMFs in the exhibit apply to total
 1280 intersection crashes (not including vehicle-pedestrian and vehicle-bicycle collisions).
 1281 The AMFs for installation of left-turn lanes are based on research by Harwood et al.
 1282 (7). An AMF of 1.00 is always used when no left-turn lanes are present.

1283 **Exhibit 12-41: Accident Modification Factor (AMF_{Ti}) for Installation of Left-Turn Lanes on**
 1284 **Intersection Approaches**

Intersection type	Intersection traffic control	Number of approaches with left-turn lanes ^a			
		One approach	Two approaches	Three approaches	Four approaches
Three-leg intersection	Minor-road STOP control ^b	0.67	0.45	–	–
	Traffic signal	0.93	0.86	0.80	–
Four-leg intersection	Minor-road STOP control ^b	0.73	0.53	–	–
	Traffic signal	0.90	0.81	0.73	0.66

1285 ^a STOP-controlled approaches are not considered in determining the number of approaches with left-turn lanes.

1286 ^b Stop signs present on minor-road approaches only.

1288 ***AMF_{Zi} - Intersection Left-Turn Signal Phasing***

1289 The AMF for left-turn signal phasing is based on the results of work by Hauer (10),
 1290 as modified in a study by Lyon et al⁽¹¹⁾. Types of left-turn signal phasing considered
 1291 include permissive, protected, protected/permissive, and permissive/protected.
 1292 Protected/permissive operation is also referred to as a leading left-turn signal phase;
 1293 permissive/protected operation is also referred to as a lagging left-turn signal phase.
 1294 The AMF values are presented in Exhibit 12-42. The base condition for this AMF is
 1295 permissive left-turn signal phasing. This AMF applies to total intersection crashes
 1296 (not including vehicle-pedestrian and vehicle-bicycle collisions) and is applicable
 1297 only to signalized intersections. An AMF value of 1.00 is always used for
 1298 unsignalized intersections.

1299 If several approaches to a signalized intersection have left-turn phasing, the
 1300 values of AMF_{2i} for each approach are multiplied together.

1301 **Exhibit 12-42: Accident Modification Factor (AMF_{2i}) for Type of Left-Turn Signal Phasing**

Type of left-turn signal phasing	AMF_{2i}
Permissive	1.00
Protected/permissive or permissive/protected	0.99
Protected	0.94

1302 Note: Use $AMF_{2i} = 1.00$ for all unsignalized intersections. If several approaches to a signalized intersection have
 1303 left-turn phasing, the values of AMF_{2i} for each approach are multiplied together.

1304 **AMF_{3i} - Intersection Right-Turn Lanes**

1305 The base condition for intersection right-turn lanes is the absence of right-turn
 1306 lanes on the intersection approaches. The AMFs for presence of right-turn lanes
 1307 based on research by Harwood et al.⁽⁷⁾ are presented in Exhibit 12-43. These AMFs
 1308 apply to installation of right-turn lanes on any approach to a signalized intersection,
 1309 but only on uncontrolled major-road approaches to STOP-controlled intersections.
 1310 The AMFs for installation of right-turn lanes on multiple approaches to an
 1311 intersection are equal to the corresponding AMF for installation of a right-turn lane
 1312 on one approach raised to a power equal to the number of approaches with right-turn
 1313 lanes. There is no indication of any change in crash frequency for providing a right-
 1314 turn lane on an approach controlled by a STOP sign, so the presence of a right-turn
 1315 lane on a STOP-controlled approach is not considered in applying Exhibit 12-43.

1316 The AMFs in Exhibit 12-43 apply to total intersection crashes (not including
 1317 vehicle-pedestrian and vehicle-bicycle collisions). An AMF value of 1.00 is always
 1318 used when no right-turn lanes are present. This AMF applies only to right-turn lanes
 1319 that are identified by marking or signing. The AMF is not applicable to long tapers,
 1320 flares, or paved shoulders that may be used informally by right-turn traffic.

1321 **Exhibit 12-43: Accident Modification Factor (AMF_{3i}) for Installation of Right-Turn Lanes
 1322 on Intersection Approaches**

Intersection type	Type of traffic control	Number of approaches with right-turn lanes ^a			
		One approach	Two approaches	Three approaches	Four approaches
Three-leg intersection	Minor-road STOP control ^b	0.86	0.74	–	–
	Traffic signal	0.96	0.92	–	–
Four-leg intersection	Minor-road STOP control ^b	0.86	0.74	–	–
	Traffic signal	0.96	0.92	0.88	0.85

1323 a STOP-controlled approaches are not considered in determining the number of approaches with right-turn lanes.

1324 b STOP signs present on minor road approaches only.

1325 **AMF_{4i} - Right Turn on Red**

1326 The AMF for prohibiting right turn on red on one or more approaches to a
 1327 signalized intersection has been derived from a study by Clark⁽²⁾ and from the AMFs
 1328 for right-turn-on-red operation shown in *Chapter 14*. The base condition for AMF_{4i} is

1329 permitting a right turn on red at all approaches to a signalized intersection. The AMF
 1330 is determined as:

1331
$$AMF_{4i} = 0.98^{(n_{prohib})} \tag{12-35}$$

1332 Where,

1333 AMF_{4i} = accident modification factor for the effect of prohibiting right
 1334 turns on red on total crashes; and

1335 n_{prohib} = number of signalized intersection approaches for which right
 1336 turn on red is prohibited.

1337 This AMF applies to total intersection crashes (not including vehicle-pedestrian
 1338 and vehicle-bicycle collisions) and is applicable only to signalized intersections. An
 1339 AMF value of 1.00 is used for unsignalized intersections.

1340 **AMF_{5i} - Lighting**

1341 The base condition for lighting is the absence of intersection lighting. The AMF
 1342 for lighted intersections is adapted from the work of Elvik and Vaa⁽³⁾, as:

1343
$$AMF_{5i} = 1 - 0.38 \times p_{ni} \tag{12-36}$$

1344 Where,

1345 AMF_{5i} = accident modification factor for the effect of intersection
 1346 lighting on total crashes;

1347 p_{ni} = proportion of total crashes for unlighted intersections that
 1348 occur at night.

1349 This AMF applies to total intersection crashes (not including vehicle-pedestrian
 1350 and vehicle-bicycle collisions). Exhibit 12-44 presents default values for the nighttime
 1351 crash proportion p_{ni}. HSM users are encouraged to replace the estimates in Exhibit
 1352 12-44 with locally derived values.

1353 **Exhibit 12-44: Nighttime Crash Proportions for Unlighted Intersections**

Intersection Type	Proportion of crashes that occur at night
	p _{ni}
3ST	0.238
4ST	0.229
3SG and 4SG	0.235

1354

1355 **AMF_{6i} - Red Light Cameras**

1356 The base condition for red light cameras is their absence. The AMF for
 1357 installation of a red light camera for enforcement of red signal violations at a
 1358 signalized intersection is based on an evaluation by Persaud et. al.⁽¹²⁾. As shown in
 1359 Chapter 14, this study indicates an AMF for red light camera installation of 0.74 for
 1360 right-angle collisions and an AMF of 1.18 for rear-end collisions. In other words, red
 1361 light cameras would typically be expected to reduce right-angle collisions and
 1362 increase rear-end collisions. There is no evidence that red light camera installation
 1363 affects other collision types. Therefore, an AMF for the effect of red light camera
 1364 installation on total crashes can be computed with the following equations:

1365
$$AMF_{6i} = 1 - p_{ra} \times (1 - 0.74) - p_{re} \times (1 - 1.18) \quad (12-37)$$

1366
$$p_{ra} = \frac{p_{ramv(FI)} \times N_{bimv(FI)} + p_{ramv(PDO)} \times N_{bimv(PDO)}}{(N_{bimv(FI)} + N_{bimv(PDO)} + N_{bisv})} \quad (12-38)$$

1367
$$p_{re} = \frac{p_{remv(FI)} \times N_{bimv(FI)} + p_{remv(PDO)} \times N_{bimv(PDO)}}{(N_{bimv(FI)} + N_{bimv(PDO)} + N_{bisv})} \quad (12-39)$$

1368 Where,

1369 AMF_{6i} = accident modification factor for installation of red light
 1370 cameras at signalized intersections;

1371 p_{ra} = proportion of crashes that are multiple-vehicle, right-angle
 1372 collisions;

1373 p_{re} = proportion of crashes that are multiple-vehicle, rear-end
 1374 collisions;

1375 p_{ramv(FI)} = proportion of multiple-vehicle fatal-and-injury crashes
 1376 represented by right-angle collisions;

1377 p_{ramv(PDO)} = proportion of multiple-vehicle property-damage-only crashes
 1378 represented by right-angle collisions;

1379 p_{remv(FI)} = proportion of multiple-vehicle fatal-and-injury crashes
 1380 represented by rear-end collisions;

1381 p_{remv(PDO)} = proportion of multiple-vehicle property-damage-only crashes
 1382 represented by rear-end collisions.

1383 The values of N_{bimv(FI)} is available from Equation 12-22, the value of N_{bimv(PDO)} is
 1384 available from Equation 12-23, and the value of N_{bisv} is available from Equation 12-24.
 1385 The values of p_{ramv(FI)}, p_{ramv(PDO)}, p_{remv(FI)}, and p_{remv(PDO)} can be determined from data
 1386 for the applicable intersection type in Exhibit 12-24. The values in Exhibit 12-24 may
 1387 be updated with data for a particular jurisdiction as part of the calibration process
 1388 presented in the Appendix to Part C. The data in Exhibit 12-24, by definition,
 1389 represent average values for a broad range of signalized intersections. Because
 1390 jurisdictions are likely to implement red-light cameras at intersections with higher
 1391 than average proportions of right-angle collisions, it is acceptable to replace the
 1392 values in Exhibit 12-24 with estimate based on data for a specific intersection when
 1393 determining the value of the red light camera AMF.

This section presents the AMFs for vehicle-pedestrian collisions at signalized intersections.

1394 **Accident Modification Factors for Vehicle-Pedestrian Collisions at Signalized**
 1395 **Intersections**

1396 The AMFs for vehicle-pedestrian collisions at signalized intersections are
 1397 presented below.

1398 **AMF_{1p} - Bus Stops**

1399 The AMFs for the number of bus stops within 1,000-ft of the center of the
 1400 intersection are presented in Exhibit 12-45. The base condition for bus stops is the
 1401 absence of bus stops near the intersection. These AMFs apply to total vehicle-
 1402 pedestrian collisions and are based on research by Harwood et al.⁽⁸⁾.

1403 **Exhibit 12-45: Accident Modification Factor (AMF_{1p}) for the Presence of Bus Stops Near**
 1404 **the Intersection**

Number of bus stops within 1,000 ft of the intersection	AMF _{1p}
0	1.00
1 or 2	2.78
3 or more	4.15

1405

1406 In applying Exhibit 12-45, multiple bus stops at the same intersection (i.e., bus
 1407 stops in different intersection quadrants or located some distance apart along the
 1408 same intersection leg) are counted separately. Bus stops located at adjacent
 1409 intersections would also be counted as long as any portion of the bus stop is located
 1410 within 1,000-ft of the intersection being evaluated.

1411 **AMF_{2p} - Schools**

1412 The base condition for schools is the absence of a school near the intersection.
 1413 The AMF for schools within 1,000-ft of the center of the intersection is presented in
 1414 Exhibit 12-46. A school may be counted if any portion of the school grounds is within
 1415 1,000-ft of the intersection. Where one or more schools are located near the
 1416 intersection, the value of the AMF is independent of the number of schools present.
 1417 This AMF applies to total vehicle-pedestrian collisions and is based on research by
 1418 Harwood et al.⁽⁸⁾.

1419 This AMF indicates that an intersection with a school nearby is likely to
 1420 experience more vehicle-pedestrian collisions than an intersection without schools,
 1421 even if the traffic and pedestrian volumes at the two intersections are identical. Such
 1422 increased crash frequencies indicate that school children are at higher risk than other
 1423 pedestrians.

1424 **Exhibit 12-46: Accident Modification Factor (AMF_{2p}) for the Presence of Schools near the**
 1425 **Intersection**

Presence of schools within 1,000 ft of the intersection	AMF _{2p}
No school present	1.00
School present	1.35

1426

1427 **AMF_{3p} - Alcohol Sales Establishments**

1428 The base condition for alcohol sales establishments is the absence of alcohol sales
 1429 establishments near the intersection. The AMF for the number of alcohol sales
 1430 establishments within 1,000-ft of the center of an intersection is presented in Exhibit
 1431 12-47. Any alcohol sales establishment wholly or partly within 1,000-ft of the
 1432 intersection may be counted. The AMF applies to total vehicle-pedestrian collisions
 1433 and is based on research by Harwood et al.⁽⁸⁾.

1434 This AMF indicates that an intersection with alcohol sales establishments nearby is
 1435 likely to experience more vehicle-pedestrian collisions than an intersection without
 1436 alcohol sales establishments even if the traffic and pedestrian volumes at the two
 1437 intersections are identical. This indicates the likelihood of higher risk behavior on the
 1438 part of either pedestrians or drivers near alcohol sales establishments. The AMF
 1439 includes any alcohol sales establishment which may include liquor stores, bars,
 1440 restaurants, convenience stores, or grocery stores. Alcohol sales establishments are
 1441 counted if they are on any intersection leg, or even on another street, as long as they
 1442 are within 1,000-ft of the intersection being evaluated.

1443 **Exhibit 12-47: Accident Modification Factor (AMF_{3p}) for the Number of Alcohol Sales**
 1444 **Establishments Near the Intersection**

Number of alcohol sales establishments within 1,000-ft of the intersection	AMF _{3p}
0	1.00
1-8	1.12
9 or more	1.56

1445 **12.8. CALIBRATION OF THE SPFS TO LOCAL CONDITIONS**

1446 In Step 10 of the predictive method, presented in Section 12.4, the predictive
 1447 model is calibrated to local state or geographic conditions. Crash frequencies, even
 1448 for nominally similar roadway segments or intersections, can vary widely from one
 1449 jurisdiction to another. Geographic regions differ markedly in climate, animal
 1450 population, driver populations, crash reporting threshold, and crash reporting
 1451 practices. These variations may result in some jurisdictions experiencing a different
 1452 number of reported traffic crashes on urban and suburban arterial highways than
 1453 others. Calibration factors are included in the methodology to allow highway
 1454 agencies to adjust the SPFs to match actual local conditions.

1455 The calibration factors for roadway segments and intersections (defined below as
 1456 C_r and C_i , respectively) will have values greater than 1.0 for roadways that, on
 1457 average, experience more crashes than the roadways used in the development of the
 1458 SPFs. The calibration factors for roadways that experience fewer crashes on average
 1459 than the roadways used in the development of the SPFs will have values less than 1.0.
 1460 The calibration procedures are presented in the Appendix to *Part C*.

1461 Calibration factors provide one method of incorporating local data to improve
 1462 estimated crash frequencies for individual agencies or locations. Several other default
 1463 values used in the methodology, such as collision type distribution, can also be
 1464 replaced with locally derived values. The derivation of values for these parameters is
 1465 addressed in the calibration procedure in the Appendix to *Part C*.

The calibration procedures are presented in the Appendix to Part C.

1466 **12.9. INTERIM PREDICTIVE METHOD FOR ROUNDABOUTS**

1467 Sufficient research has not yet been conducted to form the basis for development
 1468 of a predictive method for roundabouts. Since many jurisdictions are planning
 1469 projects to convert existing intersections into modern roundabouts, an interim
 1470 predictive method is presented here. This interim procedure is applicable to a
 1471 location at which a modern roundabout has been constructed or is being planned to
 1472 replace an existing intersection with minor-road STOP control or an existing
 1473 signalized intersection. The interim procedure is:

- 1474 1. Apply the predictive method from Chapter 12 to estimate the crash
 1475 frequency, N_{int} , for the existing intersection.
- 1476 2. Multiply N_{int} by the appropriate AMF from Chapter 12 for conversion on an
 1477 existing intersection to a modern roundabout. The applicable AMFs are:
 - 1478 o 0.56 for conversion of a two-way STOP-controlled intersection to a
 1479 modern roundabout.
 - 1480 o 0.52 for conversion of a signalized intersection to a modern
 1481 roundabout.

1482 These AMFs are applicable to all crash severities and collision types for both one
 1483 and two-lane roundabouts in all settings.

1484 At present, there are no available SPFs to determine predicted average crash
 1485 frequency of an existing or newly constructed roundabout where no intersection
 1486 currently exists.

1487 **12.10. LIMITATIONS OF PREDICTIVE METHOD IN CHAPTER 12**

The limitations of the predictive method are presented in the Part C Introduction and Applications Guide.

1488 The limitations of the predictive method which apply generally across all of the
 1489 *Part C* chapters are discussed in Section C.14 of the *Part C Introduction and Applications*
 1490 *Guidance* chapter. This section discusses limitations of the specific predictive models
 1491 and the application of the predictive method in Chapter 12.

1492 Where urban and suburban arterials intersect access-controlled facilities (i.e.,
 1493 freeways), the grade-separated interchange facility, including the arterial facility
 1494 within the interchange area, cannot be addressed with the predictive method for
 1495 urban and suburban arterials.

1496 **12.11. APPLICATION OF CHAPTER 12 PREDICTIVE METHOD**

1497 The predictive method presented in Chapter 12 applies to urban and suburban
 1498 arterials. The predictive method is applied to by following the 18 steps presented in
 1499 Section 12.4. Appendix A provides a series of worksheets for applying the predictive
 1500 method and the predictive models detailed in this chapter. All computations within
 1501 these worksheets are conducted with values expressed to three decimal places. This
 1502 level of precision is needed for consistency in computations. In the last stage of
 1503 computation, rounding the final estimate expected average crash frequency to one
 1504 decimal place.

1505 **12.12. SUMMARY**

1506 The predictive method is used to estimate the expected average crash frequency
 1507 for a series of contiguous sites (entire urban or suburban arterial facility), or a single
 1508 individual site. A urban or suburban facility is defined in Section 12.3.

1509 The predictive method for urban and suburban arterial highways is applied by
1510 following the 18 steps of the predictive method presented in Section 12.4. Predictive
1511 models, developed for urban and suburban arterial facilities, are applied in Steps 9,
1512 10, and 11 of the method. These models have been developed to estimate the
1513 predicted average crash frequency of an individual intersection or homogenous
1514 roadway segment. The facility is divided into these individual sites in Step 5 of the
1515 predictive method.

1516 Where observed data are available, the EB Method may be applied in Step 13 or
1517 15 of the predictive method, to improve the reliability of the estimate. The EB Method
1518 can be applied at the site-specific level or at the project specific level. It may also be
1519 applied to a future time period if site conditions will not change in the future period.
1520 The EB Method is described in the *Part C* Appendix A.2.

1521 Each predictive model in Chapter 12 consists of a Safety Performance Function
1522 (SPF), Accident Modification Factors, a calibration factor and pedestrian and bicyclist
1523 factors. The SPF is selected in Step 9, and is used to estimate the predicted average
1524 crash frequency for a site with base conditions. The estimate can be for total crashes,
1525 or by crash severity or collision type distribution. In order to account for differences
1526 between the base conditions of the SPF and the actual conditions of the local site,
1527 AMFs are applied in Step 10, which adjust the predicted number of crashes according
1528 to the geometric conditions of the site.

1529 In order to account for the differences in state or regional crash frequencies, the
1530 SPF is calibrated to the specific state and or geographic region to which they apply.
1531 The process for determining calibration factors for the predictive models is described
1532 in the *Part C* Appendix A.1.

1533 Section 12.13 presents 6 sample problems which detail the application of the
1534 predictive method. A series of template worksheets have been developed to assist
1535 with applying the predictive method in Chapter 12. These worksheets are utilized to
1536 solve the sample problems in Section 12.13 and Appendix A contains blank versions
1537 of the worksheets.

1538 **12.13. SAMPLE PROBLEMS**

1539 In this section, six sample problems are presented using the predictive method
1540 steps for urban and suburban arterials. Sample Problems 1 and 2 illustrate how to
1541 calculate the predicted average crash frequency for urban and suburban arterial
1542 roadway segments. Sample Problem 3 illustrates how to calculate the predicted
1543 average crash frequency for a STOP-controlled intersection. Sample Problem 4
1544 illustrates a similar calculation for a signalized intersection. Sample Problem 5
1545 illustrates how to combine the results from Sample Problems 1 through 4 in a case
1546 where site-specific observed crash data are available (i.e. using the site-specific EB
1547 Method). Sample Problem 6 illustrates how to combine the results from sample
1548 Problems 1 through 4 in a case where site-specific observed crash data are not
1549 available (i.e. using the project-level EB Method).

1550

Exhibit 12-48: List of Sample Problems in Chapter 12

Problem No.	Page No.	Description
1	12-61	Predicted average crash frequency for a three-lane TWLTL arterial roadway segment
2	12-79	Predicted average crash frequency for a four-lane divided arterial roadway segment
3	12-95	Predicted average crash frequency for a three-leg STOP-controlled intersection
4	12-109	Predicted average crash frequency for a four-leg signalized intersection
5	12-123	Expected average crash frequency for a facility when site-specific observed crash data are available
6	12-130	Expected average crash frequency for a facility when site-specific observed crash data are not available

1551

1552 **12.13.1. Sample Problem 1**1553 ***The Site/Facility***

1554 A three-lane urban arterial roadway segment with a center two-way left-turn
1555 lane (TWLTL).

1556 ***The Question***

1557 What is the predicted average crash frequency of the roadway segment for a
1558 particular year?

1559 ***The Facts***

- 1.5-mi length
- 11,000 veh/day
- 1.0 mile of parallel on-street commercial parking on each side of street
- 30 driveways (10 minor commercial, 2 major residential, 15 minor residential, 3 minor industrial/institutional)
- 10 roadside fixed objects per mile
- 6-ft offset to roadside fixed objects
- Lighting present
- 35-mph posted speed

1560 ***Assumptions***

- 1561 ▪ Collision type distributions used are the default values presented in Exhibits
1562 12-7 and 12-10 and Equations 12-19 and 12-20.
- 1563 ▪ The calibration factor is assumed to be 1.00.

1564 ***Results***

1565 Using the predictive method steps as outlined below, the predicted average crash
1566 frequency for the roadway segment in Sample Problem 1 is determined to be 7.0
1567 crashes per year (rounded to one decimal place).

1568 ***Steps***1569 **Step 1 through 8**

1570 To determine the predicted average crash frequency of the roadway segment in
1571 Sample Problem 1, only Steps 9 through 11 are conducted. No other steps are
1572 necessary because only one roadway segment is analyzed for one year, and the EB
1573 Method is not applied.

1574 **Step 9 – For the selected site, determine and apply the appropriate Safety**
 1575 **Performance Function (SPF) for the site's facility type, and traffic control**
 1576 **features.**

1577 For a three-lane urban arterial roadway segment with TWLTL, SPF values for
 1578 multiple-vehicle nondriveway, single-vehicle, multiple-vehicle driveway-related,
 1579 vehicle-pedestrian and vehicle-bicycle collisions are determined. The calculations for
 1580 vehicle-pedestrian and vehicle-bicycle collisions are shown in Step 10 since the AMF
 1581 values are needed for these models.

1582 *Multiple-Vehicle Nondriveway Collisions*

1583 The SPF for multiple-vehicle nondriveway collisions for the roadway segment is
 1584 calculated from Equation 12-10 and Exhibit 12-5 as follows:

$$1585 \quad N_{brmv} = \exp(a + b \times \ln(AADT) + \ln(L))$$

$$1586 \quad N_{brmv(TOTAL)} = \exp(-12.40 + 1.41 \times \ln(11,000) + \ln(1.5))$$

$$1587 \quad = 3.085 \text{ crashes/year}$$

$$1588 \quad N_{brmv(FI)} = \exp(-16.45 + 1.69 \times \ln(11,000) + \ln(1.5))$$

$$1589 \quad = 0.728 \text{ crashes/year}$$

$$1590 \quad N_{brmv(PDO)} = \exp(-11.95 + 1.33 \times \ln(11,000) + \ln(1.5))$$

$$1591 \quad = 2.298 \text{ crashes/year}$$

1592 These initial values for fatal and injury (FI) and property damage only (PDO)
 1593 crashes are then adjusted using Equations 12-11 and 12-12 to assure that they sum to
 1594 the value for total crashes as follows:

$$1595 \quad N_{brmv(FI)} = N_{brmv(TOTAL)} \left(\frac{N'_{brmv(FI)}}{N'_{brmv(FI)} + N'_{brmv(PDO)}} \right)$$

$$1596 \quad = 3.085 \left(\frac{0.728}{0.728 + 2.298} \right)$$

$$1597 \quad = 0.742 \text{ crashes/year}$$

$$1598 \quad N_{brmv(PDO)} = N_{brmv(TOTAL)} - N_{brmv(FI)}$$

$$1599 \quad = 3.085 - 0.742$$

$$1600 \quad = 2.343 \text{ crashes/year}$$

1601 *Single-Vehicle Crashes*

1602 The SFP for single-vehicle crashes for the roadway segments is calculated from
 1603 Equation 12-13 and Exhibit 12-8 as follows:

$$1604 \quad N_{brsv} = \exp(a + b \times \ln(AADT) + \ln(L))$$

$$1605 \quad N_{brsv(TOTAL)} = \exp(-5.74 + 0.54 \times \ln(11,000) + \ln(1.5))$$

$$1606 \quad = 0.734 \text{ crashes/year}$$

$$N_{brsv(FI)} = \exp(-6.37 + 0.47 \times \ln(11,000) + \ln(1.5))$$

$$= 0.204 \text{ crashes/year}$$

$$N_{brsv(PDO)} = \exp(-6.29 + 0.56 \times \ln(11,000) + \ln(1.5))$$

$$= 0.510 \text{ crashes/year}$$

1611 These initial values for fatal and injury (FI) and property damage only (PDO)
1612 crashes are then adjusted using Equations 12-14 and 12-15 to assure that they sum to
1613 the value for total crashes as follows:

$$N_{brsv(FI)} = N_{brsv(TOTAL)} \left(\frac{N'_{brsv(FI)}}{N'_{brsv(FI)} + N'_{brsv(PDO)}} \right)$$

$$= 0.734 \times \left(\frac{0.204}{0.204 + 0.510} \right)$$

$$= 0.210 \text{ crashes/year}$$

$$N_{brsv(PDO)} = N_{brsv(TOTAL)} - N_{brsv(FI)}$$

$$= 0.734 - 0.210$$

$$= 0.524 \text{ crashes/year}$$

1620 Multiple-Vehicle Driveway-Related Collisions

1621 The SPF for multiple-vehicle driveway-related collisions for the roadway
1622 segment is calculated from Equation 12-16 as follows:

$$N_{brdwy(TOTAL)} = \sum_{\substack{\text{all} \\ \text{driveway} \\ \text{types}}} n_j \times N_j \times \left(\frac{AADT}{15,000} \right)^{t_j}$$

1623
1624 The number of driveways within the roadway segment, n_j , for Sample Problem 1
1625 is 10 minor commercial, 2 major residential, 15 minor residential, and 3 minor
1626 industrial/institutional.

1627 The number of driveway-related collisions, N_j , and the regression coefficient for
1628 AADT, t , for a three-lane arterial, are provided in Exhibit 12-11.

$$N_{brdwy(TOTAL)} = 10 \times 0.032 \times \left(\frac{11,000}{15,000} \right)^{(1.0)} + 2 \times 0.053 \times \left(\frac{11,000}{15,000} \right)^{(1.0)}$$

$$+ 15 \times 0.010 \times \left(\frac{11,000}{15,000} \right)^{(1.0)} + 3 \times 0.015 \times \left(\frac{11,000}{15,000} \right)^{(1.0)}$$

$$= 0.455 \text{ crashes/year}$$

1633 Driveway-related collisions can be separated into components by severity level
1634 using Equations 12-17 and 12-18 as follows:

1635 From Exhibit 12-11, for a three-lane arterial the proportion of driveway-related
1636 collisions that involve fatalities and injuries, $f_{dwy} = 0.243$

$$\begin{aligned}
 1637 \quad N_{brdwy(FI)} &= N_{brdwy(TOTAL)} \times f_{dwy} \\
 1638 \quad &= 0.455 \times 0.243 \\
 1639 \quad &= 0.111 \text{ crashes/year} \\
 1640 \quad N_{brdwy(PDO)} &= N_{brdwy(TOTAL)} - N_{brdwy(FI)} \\
 1641 \quad &= 0.455 - 0.111 \\
 1642 \quad &= 0.344 \text{ crashes/year}
 \end{aligned}$$

1643 **Step 10 – Multiply the result obtained in Step 9 by the appropriate AMFs to**
 1644 **adjust base conditions to site specific geometric design and traffic control**
 1645 **features**

1646 Each AMF used in the calculation of the predicted average crash frequency of the
 1647 roadway segment is calculated below:

1648 *On-Street Parking (AMF_{1r})*

1649 AMF_{1r} is calculated from Equation 12-32 as follows:

$$1650 \quad AMF_{1r} = 1 + p_{pk} \times (f_{pk} - 1.0)$$

1651 The proportion of curb length with on-street parking, p_{pk} , is determined as
 1652 follows:

$$1653 \quad p_{pk} = 0.5 \times \frac{L_{pk}}{L}$$

1654 Since 1.0 mile of on-street parking on each side of the road is provided, the sum
 1655 of curb length with on-street parking for both sides of the road combined, $L_{pk} = 2$.

$$\begin{aligned}
 1656 \quad p_{pk} &= 0.5 \times \frac{2}{1.5} \\
 1657 \quad &= 0.66
 \end{aligned}$$

1658 From Exhibit 12-36, $f_{pk} = 2.074$.

$$\begin{aligned}
 1659 \quad AMF_{1r} &= 1 + 0.66 \times (2.074 - 1.0) \\
 1660 \quad &= 1.71
 \end{aligned}$$

1661 *Roadside Fixed Objects (AMF_{2r})*

1662 AMF_{2r} is calculated from Equation 12-33 as follows:

$$1663 \quad AMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1.0 - p_{fo})$$

1664 From Exhibit 12-37, for a roadside fixed object with a 6-ft offset, the fixed-object
 1665 offset factor, f_{offset} , is interpolated as 0.124.

1666 From Exhibit 12-38, for a three-lane arterial the proportion of total crashes, $p_{fo} =$
 1667 0.034.

$$\begin{aligned}
 1668 \quad AMF_{2r} &= 0.124 \times 10 \times 0.034 + (1.0 - 0.034) \\
 1669 \quad &= 1.01
 \end{aligned}$$

1670 *Median Width (AMF_{3r})*

1671 The value of AMF_{3r} is 1.00 for undivided facilities (see Section 12.7.1). It is
1672 assumed that a roadway with TWLTL is undivided.

1673 *Lighting (AMF_{4r})*

1674 AMF_{4r} is calculated from Equation 12-34 as follows:

$$1675 \quad AMF_{4r} = 1.0 - (p_{nr} \times (1.0 - 0.72 \times p_{inr} - 0.83 \times p_{pnr}))$$

1676 For a three-lane arterial, p_{inr} = 0.429, p_{pnr} = 0.571 and p_{nr} = 0.304 (see Exhibit 12-
1677 40).

$$1678 \quad AMF_{4r} = 1.0 - (0.304 \times (1.0 - 0.72 \times 0.429 - 0.83 \times 0.571))$$

$$1679 \quad = 0.93$$

1682 *Automated Speed Enforcement (AMF_{5r})*

1683 Since there is no automated speed enforcement in Sample Problem 1, AMF_{5r}
1684 = 1.00 (i.e. the base condition for AMF_{5r} is the absent of automated speed
1685 enforcement).

1686 The combined AMF value for Sample Problem 1 is calculated below.

$$1687 \quad AMF_{COMB} = 1.71 \times 1.01 \times 0.93$$

$$1688 \quad = 1.61$$

1689 *Vehicle-Pedestrian and Vehicle-Bicycle Collisions*

1690 The predicted average crash frequency of an individual roadway segment
1691 (excluding vehicle-pedestrian and vehicle-bicycle collisions) for SPF base conditions,
1692 N_{br}, is calculated first in order to determine vehicle-pedestrian and vehicle-bicycle
1693 crashes. N_{br} is determined from Equation 12-3 as follows:

$$1694 \quad N_{br} = N_{spf\ rs} \times (AMF_{1r} \times AMF_{2r} \times \dots \times AMF_{nr})$$

1695 From Equation 12-4, N_{spf rs} can be calculated as follows:

$$1696 \quad N_{spf\ rs} = N_{brmv} + N_{brsv} + N_{brwvy}$$

$$1697 \quad = 3.085 + 0.734 + 0.455$$

$$1698 \quad = 4.274 \text{ crashes/year}$$

1699 The combined AMF value for Sample Problem 1 is 1.61.

$$1700 \quad N_{br} = 4.274 \times (1.61)$$

$$1701 \quad = 6.881 \text{ crashes/year}$$

1702 The SPF for vehicle-pedestrian collisions for the roadway segment is calculated
1703 from Equation 12-19 as follows:

$$1704 \quad N_{pedr} = N_{br} \times f_{pedr}$$

1705 From Exhibit 12-17, for a posted speed greater than 30 mph on three-lane
1706 arterials the pedestrian accident adjustment factor, f_{pedr} = 0.013.

$$N_{pedr} = 6.881 \times 0.013$$

$$= 0.089 \text{ crashes/year}$$

The SPF for vehicle-bicycle collisions is calculated from Equation 12-20 as follows:

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

From Exhibit 12-18, for a posted speed greater than 30 mph on three-lane arterials the bicycle accident adjustment factor, $f_{biker}=0.007$.

$$N_{biker} = 6.881 \times 0.007$$

$$= 0.048 \text{ crashes/year}$$

Step 11 – Multiply the result obtained in Step 10 by the appropriate calibration factor.

It is assumed in that a calibration factor, C_r , of 1.00 has been determined for local conditions. See *Part C* Appendix A.1 for further discussion on calibration of the predicted models.

Calculation of Predicted Average Crash Frequency

The predicted average crash frequency is calculated using Equation 12-2 based on the results obtained in Steps 9 through 11 as follows:

$$\begin{aligned} N_{predicted\ rs} &= C_r \times (N_{br} + N_{pedr} + N_{biker}) \\ &= 1.00 \times (6.881 + 0.089 + 0.048) \\ &= 7.018 \text{ crashes/year} \end{aligned}$$

Worksheets

The step-by-step instructions above are provided to illustrate the predictive method for calculating the predicted average crash frequency for a roadway segment. To apply the predictive method steps to multiple segments, a series of twelve worksheets are provided for determining the predicted average crash frequency. The twelve worksheets include:

- Worksheet 1A – General Information and Input Data for Urban and Suburban Arterial Roadway Segments
- Worksheet 1B – Accident Modification Factors for Urban and Suburban Arterial Roadway Segments
- Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Arterial Roadway Segments
- Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Arterial Roadway Segments
- Worksheet 1E – Single-Vehicle Crashes by Severity Level for Urban and Suburban Arterial Roadway Segments

- 1744 ■ Worksheet 1F – Single-Vehicle Crashes by Collision Type for Urban and
1745 Suburban Arterial Roadway Segments
- 1746 ■ Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway
1747 Type for Urban and Suburban Arterial Roadway Segments
- 1748 ■ Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity
1749 Level for Urban and Suburban Arterial Roadway Segments
- 1750 ■ Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban
1751 Arterial Roadway Segments
- 1752 ■ Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial
1753 Roadway Segments
- 1754 ■ Worksheet 1K – Crash Severity Distribution for Urban and Suburban
1755 Arterial Roadway Segments
- 1756 ■ Worksheet 1L – Summary Results for Urban and Suburban Arterial
1757 Roadway Segments

1758 Details of these worksheets are provided below. Blank versions of worksheets
1759 used in the Sample Problems are provided in Chapter 12 Appendix A.

1760 ***Worksheet 1A – General Information and Input Data for Urban and Suburban***
1761 ***Roadway Segments***

1762 Worksheet 1A is a summary of general information about the roadway segment,
1763 analysis, input data (i.e., “The Facts”) and assumptions for Sample Problem 1.

Worksheet 1A – General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Roadway Section	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data	Base Conditions	Site Conditions	
Road type (2U, 3T, 4U, 4D, 5T)	-	3T	
Length of segment, L (mi)	-	1.5	
AADT (veh/day)	-	11,000	
Type of on-street parking (none/parallel/angle)	none	parallel - commercial	
Proportion of curb length with on-street parking	-	0.66	
Median width (ft)	15	not present	
Lighting (present / not present)	not present	present	
Auto speed enforcement (present/not present)	not present	not present	
Major commercial driveways (number)	-	0	
Minor commercial driveways (number)	-	10	
Major industrial/institutional driveways (number)	-	0	
Minor industrial/institutional driveways (number)	-	3	
Major residential driveways (number)	-	2	
Minor residential driveways (number)	-	15	
Other driveways (number)	-	0	
Speed Category	-	intermediate or high speed (>30 mph)	
Roadside fixed object density (fixed objects/mi)	not present	10	
Offset to roadside fixed objects (ft)	not present	6	
Calibration Factor, C _r	1.0	1.0	

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Worksheet 1B – Accident Modification Factors for Urban and Suburban Roadway Segments

In Step 10 of the predictive method, Accident Modification Factors are applied to account for the effects of site specific geometric design and traffic control devices. Section 12.7 presents the tables and equations necessary for determining the AMF values. Once the value for each AMF has been determined, all of the AMFs are multiplied together in Column 6 of Worksheet 1B which indicates the combined AMF value.

Worksheet 1B – Accident Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
AMF for On-Street Parking	AMF for Roadside Fixed Objects	AMF for Median Width	AMF for Lighting	AMF for Auto Speed Enforcement	Combined AMF
AMF _{1r}	AMF _{2r}	AMF _{3r}	AMF _{4r}	AMF _{5r}	AMF _{COMB}
from Equation 12-32	from Equation 12-33	from Exhibit 12-39	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.71	1.01	1.00	0.93	1.00	1.61

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Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

The SPF for multiple-vehicle nondriveway collisions along the roadway segment in Sample Problem 1 is calculated using Equation 12-10 and entered into Column 4 of Worksheet 1C. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 1 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle nondriveway crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N_{brmv} from Equation 12-10	Proportion of total crashes	Adjusted N_{brmv} (4) _{TOTAL} * (5)	Combined AMFs (6) from Worksheet 1B	Calibration factor C_r	Predicted N_{brmv} (6)*(7)*(8)
	from Exhibit 12-5								
	a	b							
Total	-12.40	1.41	0.66	3.085	1.000	3.085	1.61	1.00	4.967
Fatal and injury (FI)	-16.45	1.69	0.59	0.728	(4) _{FI} /((4) _{FI} + (4) _{PDO})	0.743	1.61	1.00	1.196
					0.241				
Property damage only (PDO)	-11.95	1.33	0.59	2.298	(5) _{TOTAL} -(5) _{FI}	2.342	1.61	1.00	3.771
					0.759				

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Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

Worksheet 1D presents the default proportions for collision type (from Exhibit 12-7) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for multiple-vehicle nondriveway crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only, PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for multiple-vehicle nondriveway crashes (from Column 9, Worksheet 1C) into components by crash severity and collision type.

Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type ^(FI)	Predicted N _{brmv} ^(FI) (crashes/year)	Proportion of Collision Type ^(PDO)	Predicted N _{brmv} ^(PDO) (crashes/year)	Predicted N _{brmv} ^(TOTAL) (crashes/year)
	from Exhibit 12-7	(9) _{FI} from Worksheet 1C	from Exhibit 12-7	(9) _{PDO} from Worksheet 1C	(9) _{TOTAL} from Worksheet 1C
Total	1.000	1.196	1.000	3.771	4.967
		(2)* (3) _{FI}		(4)* (5) _{PDO}	(3)+ (5)
Rear-end collision	0.845	1.011	0.842	3.175	4.186
Head-on collision	0.034	0.041	0.020	0.075	0.116
Angle collision	0.069	0.083	0.020	0.075	0.158
Sideswipe, same direction	0.001	0.001	0.078	0.294	0.295
Sideswipe, opposite direction	0.017	0.020	0.020	0.075	0.095
Other multiple-vehicle collision	0.034	0.041	0.020	0.075	0.116

Worksheet 1E – Single-Vehicle Crashes by Severity Level for Urban and Suburban Roadway Segments

The SPF for single-vehicle crashes along the roadway segment in Sample Problem 1 is calculated using Equation 12-13 and entered into Column 4 of Worksheet 1E. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 1 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle nondriveway crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

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Worksheet 1E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N_{brsv}	Proportion of total crashes	Adjusted N_{brsv}	Combined AMFs	Calibration factor	Predicted N_{brsv}
	from Exhibit 12-8								
	a	b							
Total	-5.74	0.54	1.37	0.734	1.000	0.734	1.61	1.00	1.182
Fatal and injury (FI)	-6.37	0.47	1.06	0.204	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$	0.210	1.61	1.00	0.338
					0.286				
Property damage only (PDO)	-6.29	0.56	1.93	0.510	$(5)_{TOTAL} - (5)_{FI}$	0.524	1.61	1.00	0.844
					0.714				

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Worksheet 1F – Single-Vehicle Crashes by Collision Type for Urban and Suburban Roadway Segments

Worksheet 1F presents the default proportions for collision type (from Exhibit 12-8) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for single-vehicle crashes by collision type is presented in 3 (Fatal and Injury, FI), 5 (Property Damage Only, PDO), and Columns 6 (Total).

These proportions may be used to separate the predicted average crash frequency for single-vehicle crashes (from Column 9, Worksheet 1E) into components by crash severity and collision type.

Worksheet 1F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type _(F1)	Predicted N _{brsv (F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{brsv (PDO)} (crashes/year)	Predicted N _{brsv (TOTAL)} (crashes/year)
	from Exhibit 12-10	(9) _{F1} from Worksheet 1E	from Exhibit 12-10	(9) _{PDO} from Worksheet 1E	(9) _{TOTAL} from Worksheet 1E
Total	1.000	0.338	1.000	0.844	1.182
		(2) * (3) _{F1}		(4) * (5) _{PDO}	(3) + (5)
Collision with animal	0.001	0.000	0.001	0.001	0.001
Collision with fixed object	0.688	0.233	0.963	0.813	1.046
Collision with other object	0.001	0.000	0.001	0.001	0.001
Other single-vehicle collision	0.310	0.105	0.035	0.030	0.135

Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments

Worksheet 1G determines and presents the number of driveway-related multiple-vehicle collisions. The number of driveways along both sides of the road is entered in Column 2 by driveway type (Column 1). The associated number of crashes per driveway per year by driveway type as found in Exhibit 12-11 is entered in Column 3. Column 4 contains the regression coefficient for AADT also found in Exhibit 12-11. The initial average crash frequency of multiple-vehicle driveway-related crashes is calculated from Equation 12-16 and entered into Column 5. The overdispersion parameter from Exhibit 12-11 is entered into Column 6; however, the overdispersion parameter is not needed for Sample Problem 1 (as the EB Method is not utilized).

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Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway type	Number of driveways, n_j	Crashes per driveway per year, N_j	Coefficient for traffic adjustment, t	Initial N_{brdwy}	Overdispersion parameter, k
		from Exhibit 12-11	from Exhibit 12-11	Equation 12-16 $n_j^* N_j^* (AADT/15,000)^t$	from Exhibit 12-11
Major commercial	0	0.102	1.000	0.000	-
Minor commercial	10	0.032	1.000	0.235	
Major industrial/institutional	0	0.110	1.000	0.000	
Minor industrial/institutional	3	0.015	1.000	0.033	
Major residential	2	0.053	1.000	0.078	
Minor residential	15	0.010	1.000	0.110	
Other	0	0.016	1.000	0.000	
Total	-	-	-	0.456	

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Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments

The initial average crash frequency of multiple-vehicle driveway-related crashes from Column 5 of Worksheet 1G is entered in Column 2. This value is multiplied by the proportion of crashes by severity (Column 3) found in Exhibit 12-11 and the adjusted value is entered into Column 4. Column 5 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 6 represents the calibration factor. Column 7 calculates the predicted average crash frequency of multiple-vehicle driveway-related crashes using the values in Column 4, the combined AMF in Column 5, and the calibration factor in Column 6.

Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Initial N_{brdwy}	Proportion of total accidents (f_{dwy})	Adjusted N_{brdwy}	Combined AMFs	Calibration factor, C_r	Predicted N_{brdwy}
	(5) _{TOTAL} from Worksheet 1G	from Exhibit 12-11	(2) _{TOTAL} * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.456	1.000	0.456	1.61	1.00	0.734
Fatal and injury (FI)	-	0.243	0.111	1.61	1.00	0.179
Property damage only (PDO)	-	0.757	0.345	1.61	1.00	0.555

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Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments

The predicted average crash frequency of multiple-vehicle nondriveway, single-vehicle and multiple-vehicle driveway-related predicted crashes from Worksheets 1C, 1E, and 1H are entered into Columns 2, 3, and 4, respectively. These values are summed in Column 5. Column 6 contains the pedestrian accident adjustment factor (see Exhibit 12-17). Column 7 represents the calibration factor. The predicted average crash frequency of vehicle-pedestrian collisions (Column 8) is the product of Columns 5, 6 and 7. Since all vehicle-pedestrian crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{pedr}	Calibration factor, C_r	Predicted N_{pedr}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-17		(5)*(6)*(7)
Total	4.967	1.182	0.734	6.883	0.013	1.00	0.089
Fatal and injury (FI)	-	-	-	-	-	1.00	0.089

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Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments

The predicted average crash frequency of multiple-vehicle nondriveway, single-vehicle and multiple-vehicle driveway-related predicted crashes from Worksheets 1C, 1E, and 1H are entered into Columns 2, 3, and 4, respectively. These values are summed in Column 5. Column 6 contains the bicycle accident adjustment factor (see Exhibit 12-18). Column 7 represents the calibration factor. The predicted average crash frequency of vehicle-bicycle collisions (Column 8) is the product of Columns 5, 6 and 7. Since all vehicle-bicycle collisions are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{biker}	Calibration factor, C_r	Predicted N_{biker}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-18		(5)*(6)*(7)
Total	4.967	1.182	0.734	6.883	0.007	1.00	0.048
Fatal and injury	-	-	-	-	-	1.00	0.048

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Worksheet 1K – Crash Severity Distribution for Urban and Suburban Roadway Segments

Worksheet 1K provides a summary of all collision types by severity level. Values from Worksheets 1C, 1E, 1H, 1I, and 1J are presented and summed to provide the predicted average crash frequency for each severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 3)
- Total crashes (Column 4)

Worksheet 1K – Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H;	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	1.011	3.175	4.186
Head-on collisions (from Worksheet 1D)	0.041	0.075	0.116
Angle collisions (from Worksheet 1D)	0.083	0.075	0.158
Sideswipe, same direction (from Worksheet 1D)	0.001	0.294	0.295
Sideswipe, opposite direction (from Worksheet 1D)	0.020	0.075	0.095
Driveway-related collisions (from Worksheet 1H)	0.179	0.555	0.734
Other multiple-vehicle collision (from Worksheet 1D)	0.041	0.075	0.116
Subtotal	1.376	4.324	5.700
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.001	0.001
Collision with fixed object (from Worksheet 1F)	0.233	0.813	1.046
Collision with other object (from Worksheet 1F)	0.000	0.001	0.001
Other single-vehicle collision (from Worksheet 1F)	0.105	0.030	0.135
Collision with pedestrian (from Worksheet 1I)	0.089	0.000	0.089
Collision with bicycle (from Worksheet 1J)	0.048	0.000	0.048
Subtotal	0.475	0.845	1.320
Total	1.851	5.169	7.020

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Worksheet 1L– Summary Results for Urban and Suburban Roadway Segments

Worksheet 1L presents a summary of the results. Using the roadway segment length and the AADT, the worksheet presents the crash rate in miles per year (Column 4) and in million vehicle miles (Column 6).

Worksheet 1L – Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash severity level	Predicted average crash frequency, $N_{predicted}$ (crashes/year)	Roadway segment length, L (mi)	Crash rate (crashes/mi/year)
	(Total) from Worksheet 1K		(2)/(3)
Total	7.020	1.5	4.7
Fatal and injury (FI)	1.851	1.5	1.2
Property damage only (PDO)	5.169	1.5	3.4

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1851 **12.13.2. Sample Problem 2**1852 ***The Highway***

1853 A four-lane divided urban arterial roadway segment.

1854 ***The Question***1855 What is the predicted average crash frequency of the roadway segment for a
1856 particular year?1857 ***The Facts***

- 0.75-mi length
- 23,000 veh/day
- On-street parking not permitted
- 8 driveways (1 major commercial, 4 minor commercial, 1 major residential, 1 minor residential, 1 minor industrial/institutional)
- 20 roadside fixed objects per mile
- 12-ft offset to roadside fixed objects
- 40-ft median
- Lighting present
- 30-mph posted speed

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1859 ***Assumptions***

- 1860 ▪ Collision type distributions used are the default values presented in Exhibits
1861 12-7 and 12-10 and Equations 12-19 and 12-20.
- 1862 ▪ The calibration factor is assumed to be 1.00.

1863 ***Results***

1864 Using the predictive method steps as outlined below, the predicted average crash
1865 frequency for the roadway segment in Sample Problem 2 is determined to be 3.4
1866 crashes per year (rounded to one decimal place).

1867 ***Steps***1868 **Step 1 through 8**

1869 To determine the predicted average crash frequency of the roadway segment in
1870 Sample Problem 2, only Steps 9 through 11 are conducted. No other steps are
1871 necessary because only one roadway segment is analyzed for one year, and the EB
1872 Method is not applied.

1873 **Step 9 – For the selected site, determine and apply the appropriate Safety**
1874 **Performance Function (SPF) for the site’s facility type, and traffic control**
1875 **features.**

1876 For a four-lane divided urban arterial roadway segment, SPF values for multiple-
1877 vehicle nondriveway, single-vehicle, multiple-vehicle driveway-related, vehicle-
1878 pedestrian and vehicle-bicycle collisions are determined. The calculations for total

1879 multiple-vehicle nondriveway, single-vehicle and multiple-vehicle driveway-related
 1880 collisions are presented below. Detailed steps for calculating SPFs for fatal and injury
 1881 (FI) and property damage only (PDO) crashes are presented in Sample Problem 1.
 1882 The calculations for vehicle-pedestrian and vehicle-bicycle collisions are shown in
 1883 Step 10 since the AMF values are needed for these two models.

1884 *Multiple-Vehicle Nondriveway Collisions*

1885 The SPF for multiple-vehicle nondriveway collisions for the roadway segment is
 1886 calculated from Equation 12-10 and Exhibit 12-5 as follows:

$$1887 \quad N_{brmv} = \exp(a + b \times \ln(AADT) + \ln(L))$$

$$1888 \quad N_{brmv(TOTAL)} = \exp(-12.34 + 1.36 \times \ln(23,000) + \ln(0.75))$$

$$1889 \quad = 2.804 \text{ crashes/year}$$

1890 *Single-Vehicle Crashes*

1891 The SFP for single-vehicle crashes for the roadway segments is calculated from
 1892 Equation 12-13 and Exhibit 12-8 as follows:

$$1893 \quad N_{brsv} = \exp(a + b \times \ln(AADT) + \ln(L))$$

$$1894 \quad N_{brsv(TOTAL)} = \exp(-5.05 + 0.47 \times \ln(23,000) + \ln(0.75))$$

$$1895 \quad = 0.539 \text{ crashes/year}$$

1896 *Multiple-Vehicle Driveway-Related Collisions*

1897 The SPF for multiple-vehicle driveway-related collisions for the roadway
 1898 segment is calculated from Equation 12-16 as follows:

$$1899 \quad N_{brdwy(TOTAL)} = \sum_{\substack{\text{all} \\ \text{driveway} \\ \text{types}}} n_j \times N_j \times \left(\frac{AADT}{15,000} \right)^{f_j}$$

1900 The number of driveways within the roadway segment, n_j , for Sample Problem 1
 1901 is 1 major commercial, 4 minor commercial, 1 major residential, 1 minor residential,
 1902 and 1 minor industrial/institutional.

1903 The number of driveway-related collisions, N_j , and the regression coefficient for
 1904 AADT, t , for a four-lane divided arterial, are provided in Exhibit 12-11.

$$1905 \quad N_{brdwy(TOTAL)} = 1 \times 0.033 \times \left(\frac{23,000}{15,000} \right)^{(1.106)} + 4 \times 0.011 \times \left(\frac{23,000}{15,000} \right)^{(1.106)} + 1 \times 0.018 \times \left(\frac{23,000}{15,000} \right)^{(1.106)}$$

$$1906 \quad + 1 \times 0.003 \times \left(\frac{23,000}{15,000} \right)^{(1.106)} + 1 \times 0.005 \times \left(\frac{23,000}{15,000} \right)^{(1.106)}$$

$$1907 \quad = 0.165 \text{ crashes/year}$$

1908 The fatal and injury (FI) and property damage only (PDO) SPF values for
 1909 multiple-vehicle nondriveway collisions, single-vehicle crashes and multiple-vehicle
 1910 driveway-related collisions can be determined by using the same procedure
 1911 presented in Sample Problem 1.

1912 **Step 10 – Multiply the result obtained in Step 9 by the appropriate AMFs to**
 1913 **adjust base conditions to site specific geometric design and traffic control**
 1914 **features**

1915 Each AMF used in the calculation of the predicted average crash frequency of the
 1916 roadway segment is calculated below:

1917 *On-Street Parking (AMF_{1r})*

1918 Since on-street parking is not permitted, AMF_{1r}=1.00 (i.e. the base condition for
 1919 AMF_{1r} is the absence of on-street parking).

1920 *Roadside Fixed Objects (AMF_{2r})*

1921 AMF_{2r} is calculated from Equation 12-33 as follows:

$$1922 \quad AMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1.0 - p_{fo})$$

1923 From Exhibit 12-37, for a roadside fixed object with a 12-ft offset, the fixed-object
 1924 offset factor, f_{offset} , is interpolated as 0.079.

1925 From Exhibit 12-38, for a four-lane divided arterial the proportion of total
 1926 crashes, $p_{fo} = 0.036$.

$$1927 \quad AMF_{2r} = 0.079 \times 20 \times 0.036 + (1.0 - 0.036)$$

$$1928 \quad = 1.02$$

1929 *Median Width (AMF_{3r})*

1930 From Exhibit 12-39, for a four-lane divided arterial with a 40-ft median, AMF_{3r} =
 1931 0.97.

1932 *Lighting (AMF_{4r})*

1933 AMF_{4r} can be calculated from Equation 12-34 as follows:

$$1934 \quad AMF_{4r} = 1.0 - (p_{nr} \times (1.0 - 0.72 \times p_{inr} - 0.83 \times p_{pnr}))$$

1935 For a four-lane divided arterial, $p_{inr} = 0.364$, $p_{pnr} = 0.636$ and $p_{nr} = 0.410$ (see Exhibit
 1936 12-40).

$$1937 \quad AMF_{4r} = 1.0 - (0.410 \times (1.0 - 0.72 \times 0.364 - 0.83 \times 0.636))$$

$$1938 \quad = 0.91$$

1939 *Automated Speed Enforcement (AMF_{5r})*

1940 Since there is no automated speed enforcement in Sample Problem 2, AMF_{5r} =
 1941 1.00 (i.e. the base condition for AMF_{5r} is the absent of automated speed enforcement).

1942 The combined AMF value for Sample Problem 2 is calculated below.

$$1943 \quad AMF_{COMB} = 1.02 \times 0.97 \times 0.91$$

$$1944 \quad = 0.90$$

1945 *Vehicle-Pedestrian and Vehicle-Bicycle Collisions*

1946 The predicted average crash frequency of an individual roadway segment
 1947 (excluding vehicle-pedestrian and vehicle-bicycle collisions) for SPF base conditions,
 1948 N_{br} , is calculated first in order to determine vehicle-pedestrian and vehicle-bicycle
 1949 crashes. N_{br} is determined from Equation 12-3 as follows:

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

1951 From Equation 12-4, $N_{spf\ rs}$ can be calculated as follows:

$$\begin{aligned} N_{spf\ rs} &= N_{brmv} + N_{brsv} + N_{brdwy} \\ &= 2.804 + 0.539 + 0.165 \\ &= 3.508 \text{ crashes/year} \end{aligned}$$

1955 The combined AMF value for Sample Problem 2 is 0.90.

$$\begin{aligned} N_{br} &= 3.508 \times (0.90) \\ &= 3.157 \text{ crashes/year} \end{aligned}$$

1958 The SPF for vehicle-pedestrian collisions for the roadway segment is calculated
1959 from Equation 12-19 as follows:

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

1961 From Exhibit 12-17, for a posted speed of 30 mph on four-lane divided arterials
1962 the pedestrian accident adjustment factor, $f_{pedr} = 0.067$.

$$\begin{aligned} N_{pedr} &= 3.157 \times 0.067 \\ &= 0.212 \text{ crashes/year} \end{aligned}$$

1965 The SPF for vehicle-bicycle collisions is calculated from Equation 12-20 as
1966 follows:

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

1968 From Exhibit 12-18, for a posted speed of 30 mph on four-lane divided arterials
1969 the bicycle accident adjustment factor, $f_{biker} = 0.013$.

$$\begin{aligned} N_{biker} &= 3.157 \times 0.013 \\ &= 0.041 \text{ crashes/year} \end{aligned}$$

1973 **Step 11 – Multiply the result obtained in Step 10 by the appropriate calibration**
1974 **factor.**

1975 It is assumed in that a calibration factor, C_r , of 1.00 has been determined for local
1976 conditions. See *Part C* Appendix A.1 for further discussion on calibration of the
1977 predicted models.

1978 **Calculation of Predicted Average Crash Frequency**

1979 The predicted average crash frequency is calculated using Equation 12-2 based
1980 on the results obtained in Steps 9 through 11 as follows:

$$\begin{aligned} N_{predicted\ rs} &= C_r \times (N_{br} + N_{pedr} + N_{biker}) \\ &= 1.00 \times (3.157 + 0.212 + 0.041) \\ &= 3.410 \end{aligned}$$

1984 **Worksheets**

1985 The step-by-step instructions above are provided to illustrate the predictive
 1986 method for calculating the predicted average crash frequency for a roadway segment.
 1987 To apply the predictive method steps to multiple segments, a series of twelve
 1988 worksheets are provided for determining the predicted average crash frequency. The
 1989 twelve worksheets include:

- 1990 ■ Worksheet 1A – General Information and Input Data for Urban and
 1991 Suburban Arterial Roadway Segments
- 1992 ■ Worksheet 1B – Accident Modification Factors for Urban and Suburban
 1993 Arterial Roadway Segments
- 1994 ■ Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level
 1995 for Urban and Suburban Arterial Roadway Segments
- 1996 ■ Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type
 1997 for Urban and Suburban Arterial Roadway Segments
- 1998 ■ Worksheet 1E – Single-Vehicle Crashes by Severity Level for Urban and
 1999 Suburban Arterial Roadway Segments
- 2000 ■ Worksheet 1F – Single-Vehicle Crashes by Collision Type for Urban and
 2001 Suburban Arterial Roadway Segments
- 2002 ■ Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway
 2003 Type for Urban and Suburban Arterial Roadway Segments
- 2004 ■ Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity
 2005 Level for Urban and Suburban Arterial Roadway Segments
- 2006 ■ Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban
 2007 Arterial Roadway Segments
- 2008 ■ Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial
 2009 Roadway Segments
- 2010 ■ Worksheet 1K – Crash Severity Distribution for Urban and Suburban
 2011 Arterial Roadway Segments
- 2012 ■ Worksheet 1L – Summary Results for Urban and Suburban Arterial
 2013 Roadway Segments

2014 Details of these worksheets are provided below. Blank versions of worksheets
 2015 used in the Sample Problems are provided in Chapter 12 Appendix A.

2016 **Worksheet 1A – General Information and Input Data for Urban and Suburban**
 2017 **Roadway Segments**

2018 Worksheet 1A is a summary of general information about the roadway segment,
 2019 analysis, input data (i.e., “The Facts”) and assumptions for Sample Problem 2.

Worksheet 1A – General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Roadway Section	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data	Base Conditions	Site Conditions	
Road type (2U, 3T, 4U, 4D, 5T)	-	4D	
Length of segment, L (mi)	-	0.75	
AADT (veh/day)	-	23,000	
Type of on-street parking (none/parallel/angle)	none	None	
Proportion of curb length with on-street parking	-	N/A	
Median width (ft)	15	40	
Lighting (present / not present)	not present	present	
Auto speed enforcement (present/not present)	not present	not present	
Major commercial driveways (number)	-	1	
Minor commercial driveways (number)	-	4	
Major industrial/institutional driveways (number)	-	-	
Minor industrial/institutional driveways (number)	-	1	
Major residential driveways (number)	-	1	
Minor residential driveways (number)	-	1	
Other driveways (number)	-	-	
Speed Category	-	Low (30mph)	
Roadside fixed object density (fixed objects/mi)	not present	20	
Offset to roadside fixed objects (ft)	not present	12	
Calibration Factor, C _r	1.0	1.0	

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Worksheet 1B – Accident Modification Factors for Urban and Suburban Roadway Segments

In Step 10 of the predictive method, Accident Modification Factors are applied to account for the effects of site specific geometric design and traffic control devices. Section 12.7 presents the tables and equations necessary for determining the AMF values. Once the value for each AMF has been determined, all of the AMFs are multiplied together in Column 6 of Worksheet 1B which indicates the combined AMF value.

Worksheet 1B – Accident Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
AMF for On-Street Parking	AMF for Roadside Fixed Objects	AMF for Median Width	AMF for Lighting	AMF for Auto Speed Enforcement	Combined AMF
AMF _{1r}	AMF _{2r}	AMF _{3r}	AMF _{4r}	AMF _{5r}	AMF _{COMB}
from Equation 12-32	from Equation 12-33	from Exhibit 12-39	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.02	0.97	0.91	1.00	0.90

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Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

The SPF for multiple-vehicle nondriveway collisions along the roadway segment in Sample Problem 1 is calculated using Equation 12-10 and entered into Column 4 of Worksheet 1C. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 2 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle nondriveway crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N_{brmv}	Proportion of total crashes	Adjusted N_{brmv}	Combined AMFs	Calibration factor	Predicted N_{brmv}
	from Exhibit 12-5								
	a	b							
Total	-12.34	1.36	1.32	2.804	1.000	2.804	0.90	1.00	2.524
Fatal and injury (FI)	-12.76	1.28	1.31	0.825	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$	0.780	0.90	1.00	0.702
					0.278				
Property damage only (PDO)	-12.81	1.38	1.34	2.143	$(5)_{TOTAL} - (5)_{FI}$	2.024	0.90	1.00	1.822
					0.722				

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Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

Worksheet 1D presents the default proportions for collision type (from Exhibit 12-7) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for multiple-vehicle nondriveway crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only, PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for multiple-vehicle nondriveway crashes (from Column 9, Worksheet 1C) into components by crash severity and collision type.

Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type ^(FI)	Predicted N _{brmv} ^(FI) (crashes/year)	Proportion of Collision Type ^(PDO)	Predicted N _{brmv} ^(PDO) (crashes/year)	Predicted N _{brmv} ^(TOTAL) (crashes/year)
	from Exhibit 12-7	(9) _{FI} from Worksheet 1C	from Exhibit 12-7	(9) _{PDO} from Worksheet 1C	(9) _{TOTAL} from Worksheet 1C
Total	1.000	0.702	1.000	1.822	2.524
		(2)* (3) _{FI}		(4)* (5) _{PDO}	(3)+ (5)
Rear-end collision	0.832	0.584	0.662	1.206	1.790
Head-on collision	0.020	0.014	0.007	0.013	0.027
Angle collision	0.040	0.028	0.036	0.066	0.094
Sideswipe, same direction	0.050	0.035	0.223	0.406	0.441
Sideswipe, opposite direction	0.010	0.007	0.001	0.002	0.009
Other multiple-vehicle collision	0.048	0.034	0.071	0.129	0.163

Worksheet 1E – Single-Vehicle Crashes by Severity Level for Urban and Suburban Roadway Segments

The SPF for single-vehicle crashes along the roadway segment in Sample Problem 1 is calculated using Equation 12-13 and entered into Column 4 of Worksheet 1E. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 2 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle nondriveway crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

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Worksheet 1E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N_{brsv}	Proportion of total crashes	Adjusted N_{brsv}	Combined AMFs	Calibration factor	Predicted N_{brsv}
	from Exhibit 12-8								
	a	b	(4) _{TOTAL} * (5)	(6) from Worksheet 1B		C_r	(6) * (7) * (8)		
Total	-5.05	0.47	0.86	0.539	1.000	0.539	0.90	1.00	0.485
Fatal and injury (FI)	-8.71	0.66	0.28	0.094	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$	0.094	0.90	1.00	0.085
					0.174				
Property damage only (PDO)	-5.04	0.45	1.06	0.446	$(5)_{TOTAL} - (5)_{FI}$	0.445	0.90	1.00	0.401
					0.826				

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Worksheet 1F – Single-Vehicle Crashes by Collision Type for Urban and Suburban Roadway Segments

Worksheet 1F presents the default proportions for collision type (from Exhibit 12-8) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for single-vehicle crashes by collision type is presented in 3 (Fatal and Injury, FI), 5 (Property Damage Only, PDO), and Columns 6 (Total).

These proportions may be used to separate the predicted average crash frequency for single-vehicle crashes (from Column 9, Worksheet 1E) into components by crash severity and collision type.

Worksheet 1F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type _(F1)	Predicted N _{brsv (F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{brsv (PDO)} (crashes/year)	Predicted N _{brsv (TOTAL)} (crashes/year)
	from Exhibit 12-10	(9) _{F1} from Worksheet 1E	from Exhibit 12-10	(9) _{PDO} from Worksheet 1E	(9) _{TOTAL} from Worksheet 1E
Total	1.000	0.085	1.000	0.401	0.485
		(2) * (3) _{F1}		(4) * (5) _{PDO}	(3) + (5)
Collision with animal	0.001	0.000	0.063	0.025	0.025
Collision with fixed object	0.500	0.043	0.813	0.326	0.369
Collision with other object	0.028	0.002	0.016	0.006	0.008
Other single-vehicle collision	0.471	0.040	0.108	0.043	0.083

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Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments

Worksheet 1G determines and presents the number of driveway-related multiple-vehicle collisions. The number of driveways along both sides of the road is entered in Column 2 by driveway type (Column 1). The associated number of crashes per driveway per year by driveway type as found in Exhibit 12-11 is entered in Column 3. Column 4 contains the regression coefficient for AADT also found in Exhibit 12-11. The initial average crash frequency of multiple-vehicle driveway-related crashes is calculated from Equation 12-16 and entered into Column 5. The overdispersion parameter from Exhibit 12-11 is entered into Column 6; however, the overdispersion parameter is not needed for Sample Problem 2 (as the EB Method is not utilized).

Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway type	Number of driveways, n_j	Crashes per driveway per year, N_j	Coefficient for traffic adjustment, t	Initial N_{brdwy}	Overdispersion parameter, k
		from Exhibit 12-11	from Exhibit 12-11	Equation 12-16 $n_j^* N_j^* (AADT/15,000)^t$	from Exhibit 12-11
Major commercial	1	0.033	1.106	0.053	-
Minor commercial	4	0.011	1.106	0.071	
Major industrial/institutional	0	0.036	1.106	0.000	
Minor industrial/institutional	1	0.005	1.106	0.008	
Major residential	1	0.018	1.106	0.029	
Minor residential	1	0.003	1.106	0.005	
Other	0	0.005	1.106	0.000	
Total	-	-	-	0.166	

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Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments

The initial average crash frequency of multiple-vehicle driveway-related crashes from Column 5 of Worksheet 1G is entered in Column 2. This value is multiplied by the proportion of crashes by severity (Column 3) found in Exhibit 12-11 and the adjusted value is entered into Column 4. Column 5 represents the combined AMF (from Column 6 in Worksheet 1B), and Column 6 represents the calibration factor. Column 7 calculates the predicted average crash frequency of multiple-vehicle driveway-related crashes using the values in Column 4, the combined AMF in Column 5, and the calibration factor in Column 6.

Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Initial N_{brdwy}	Proportion of total accidents (f_{dwy})	Adjusted N_{brdwy}	Combined AMFs	Calibration factor, C_r	Predicted N_{brdwy}
	(5) _{TOTAL} from Worksheet 1G	from Exhibit 12-11	(2) _{TOTAL} * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.166	1.000	0.166	0.90	1.00	0.149
Fatal and injury (FI)	-	0.284	0.047	0.90	1.00	0.042
Property damage only (PDO)	-	0.716	0.119	0.90	1.00	0.107

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Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments

The predicted average crash frequency of multiple-vehicle nondriveway, single-vehicle and multiple-vehicle driveway-related predicted crashes from Worksheets 1C, 1E, and 1H are entered into Columns 2, 3, and 4, respectively. These values are summed in Column 5. Column 6 contains the pedestrian accident adjustment factor (see Exhibit 12-17). Column 7 represents the calibration factor. The predicted average crash frequency of vehicle-pedestrian collisions (Column 8) is the product of Columns 5, 6 and 7. Since all vehicle-pedestrian crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 1I – Vehicle-Pedestrian Collisions							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{pedr}	Calibration factor, C_r	Predicted N_{pedr}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-17		(5)*(6)*(7)
Total	2.524	0.485	0.149	3.158	0.067	1.000	0.212
Fatal and injury (FI)	-	-	-	-	-	1.00	0.212

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Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments

The predicted average crash frequency of multiple-vehicle nondriveway, single-vehicle and multiple-vehicle driveway-related predicted crashes from Worksheets 1C, 1E, and 1H are entered into Columns 2, 3, and 4, respectively. These values are summed in Column 5. Column 6 contains the bicycle accident adjustment factor (see Exhibit 12-18). Column 7 represents the calibration factor. The predicted average crash frequency of vehicle-bicycle collisions (Column 8) is the product of Columns 5, 6 and 7. Since all vehicle-bicycle collisions are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{biker}	Calibration factor, C_r	Predicted N_{biker}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-18		(5)*(6)*(7)
Total	2.524	0.485	0.149	3.158	0.013	1.00	0.041
Fatal and injury	-	-	-	-	-	1.00	0.041

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Worksheet 1K – Crash Severity Distribution for Urban and Suburban Roadway Segments

Worksheet 1K provides a summary of all collision types by severity level. Values from Worksheets 1C, 1E, 1H, 1I, and 1J are presented and summed to provide the predicted average crash frequency for each severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 3)
- Total crashes (Column 4)

Worksheet 1K – Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H;	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	0.584	1.206	1.790
Head-on collisions (from Worksheet 1D)	0.014	0.013	0.027
Angle collisions (from Worksheet 1D)	0.028	0.066	0.094
Sideswipe, same direction (from Worksheet 1D)	0.035	0.406	0.441
Sideswipe, opposite direction (from Worksheet 1D)	0.007	0.002	0.009
Driveway-related collisions (from Worksheet 1H)	0.042	0.107	0.149
Other multiple-vehicle collision (from Worksheet 1D)	0.034	0.129	0.163
Subtotal	0.744	1.929	2.673
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.025	0.025
Collision with fixed object (from Worksheet 1F)	0.043	0.326	0.369
Collision with other object (from Worksheet 1F)	0.002	0.006	0.008
Other single-vehicle collision (from Worksheet 1F)	0.040	0.043	0.083
Collision with pedestrian (from Worksheet 1I)	0.212	0.000	0.212
Collision with bicycle (from Worksheet 1J)	0.041	0.000	0.041
Subtotal	0.338	0.400	0.738
Total	1.082	2.329	3.411

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Worksheet 1L– Summary Results for Urban and Suburban Roadway Segments

Worksheet 1L presents a summary of the results. Using the roadway segment length and the AADT, the worksheet presents the crash rate in miles per year (Column 4) and in million vehicle miles (Column 6).

Worksheet 1L – Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash severity level	Predicted average crash frequency, $N_{predicted}$ (crashes/year)	Roadway segment length, L (mi)	Crash rate (crashes/mi/year)
	(Total) from Worksheet 1K		(2)/(3)
Total	3.411	0.75	4.5
Fatal and injury (FI)	1.082	0.75	1.4
Property damage only (PDO)	2.329	0.75	3.1

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2108 **12.13.3. Sample Problem 3**2109 ***The Site/Facility***

2110 A three-leg stop-controlled intersection located on an urban arterial.

2111 ***The Question***2112 What is the predicted accident frequency of the unsignalized intersection for a
2113 particular year?2114 ***The Facts***

- 1 left-turn lane on one major road approach
- AADT of major road is 14,000 veh/day
- No right-turn lanes on any approach
- AADT of minor road is 4,000 veh/day

2115 ***Assumptions***

- 2116 ■ Collision type distributions used are the default values from Exhibits 12-24
2117 and 12-30 and Equations 12-30 and 12-31.
- 2118 ■ The calibration factor is assumed to be 1.00.

2119 ***Results***2120 Using the predictive method steps as outlined below, the predicted average crash
2121 frequency for the unsignalized intersection in Sample Problem 3 is determined to be
2122 1.6 crashes per year (rounded to one decimal place).2123 **Steps**2124 **Step 1 through 8**2125 To determine the predicted average crash frequency of the roadway segment in
2126 Sample Problem 3, only Steps 9 through 11 are conducted. No other steps are
2127 necessary because only one roadway segment is analyzed for one year, and the EB
2128 Method is not applied.2129 **Step 9 – For the selected site, determine and apply the appropriate Safety
2130 Performance Function (SPF) for the site’s facility type, and traffic control
2131 features.**2132 For a three-leg stop-controlled intersection, SPF values for multiple-vehicle,
2133 single-vehicle, vehicle-pedestrian and vehicle-bicycle collisions are determined. The
2134 calculations for vehicle-pedestrian and vehicle-bicycle collisions are shown in Step 10
2135 since the AMF values are needed for these two models.

2136 *Multiple-Vehicle Crashes*

2137 The SPF for multiple-vehicle collisions for a single three-leg stop-controlled
2138 intersection is calculated from Equation 12-21 and Exhibit 12-19 as follows:

$$2139 N_{bimv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min}))$$

$$2140 N_{bimv(TOTAL)} = \exp(-13.63 + 1.11 \times \ln(14,000) + 0.41 \times \ln(4,000))$$

$$2141 = 1.892 \text{ crashes/year}$$

$$2142 N_{bimv(FI)} = \exp(-14.01 + 1.16 \times \ln(14,000) + 0.30 \times \ln(4,000))$$

$$2143 = 0.639 \text{ crashes/year}$$

$$2144 N_{bimv(PDO)} = \exp(-15.38 + 1.20 \times \ln(14,000) + 0.51 \times \ln(4,000))$$

$$2145 = 1.358 \text{ crashes/year}$$

2146 These initial values for fatal and injury (FI) and property damage only (PDO)
2147 crashes are then adjusted using Equations 12-22 and 12-23 to assure that they sum to
2148 the value for total crashes as follows:

$$2149 N_{bimv(FI)} = N_{bimv(TOTAL)} \times \left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}} \right)$$

$$2150 = 1.892 \times \left(\frac{0.639}{0.639 + 1.358} \right)$$

$$2151 = 0.605 \text{ crashes/year}$$

$$2152 N_{bimv(PDO)} = N_{bimv(TOTAL)} - N_{bimv(FI)}$$

$$2153 = 1.892 - 0.605$$

$$2154 = 1.287 \text{ crashes/year}$$

2155 *Single-Vehicle Crashes*

2156 The SPF for single-vehicle crashes for a single three-leg stop-controlled
2157 intersection is calculated from Equation 12-24 and Exhibit 12-25 as follows:

$$2158 N_{bisv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min}))$$

$$2159 N_{bisv(TOTAL)} = \exp(-6.81 + 0.16 \times \ln(14,000) + 0.51 \times \ln(4,000))$$

$$2160 = 0.349 \text{ crashes/year}$$

$$2161 N_{bisv(PDO)} = \exp(-8.36 + 0.25 \times \ln(14,000) + 0.55 \times \ln(4,000))$$

$$2162 = 0.244 \text{ crashes/year}$$

2163 Since there are no models for fatal and injury crashes at a three-leg stop-
2164 controlled intersections, $N_{bisv(FI)}$ is calculated using Equation 12-27 (in place of
2165 Equation 12-25), and the initial value for $N_{bisv(PDO)}$ calculated above is then adjusted
2166 using Equation 12-26 to assure that fatal-and-injury and property-damage-only
2167 crashes sum to the value for total crashes as follows:

$$2168 N_{bisv(FI)} = N_{bisv(TOTAL)} \times f_{bisv}$$

2169 For a three-leg stop-controlled intersection, the default proportion of fatal-and-
2170 injury crashes, $f_{bisv} = 0.31$ (see Section 12.6.2, Single-Vehicle Crashes)

$$2171 \quad N_{bisv(FI)} = 0.349 \times 0.31$$

$$2172 \quad = 0.108 \text{ crashes/year}$$

$$2173 \quad N_{bisv(PDO)} = N_{bisv(TOTAL)} - N_{bisv(FI)}$$

$$2174 \quad = 0.349 - 0.108$$

$$2175 \quad = 0.241 \text{ crashes/year}$$

2176 **Step 10 – Multiply the result obtained in Step 9 by the appropriate AMFs to**
2177 **adjust base conditions to site specific geometric design and traffic control**
2178 **features**

2179 Each AMF used in the calculation of the predicted average crash frequency of the
2180 intersection is calculated below:

2181 *Intersection Left-Turn Lanes (AMF_{1i})*

2182 From Exhibit 12-41, for a three-leg stop-controlled intersection with one left-turn
2183 lane on the major road, $AMF_{1i} = 0.67$.

2184 *Intersection Left-Turn Signal Phasing (AMF_{2i})*

2185 For unsignalized intersections, $AMF_{2i} = 1.00$.

2186 *Intersection Right-Turn Lanes (AMF_{3i})*

2187 Since no right-turn lanes are present, AMF_{3i} is 1.00 (i.e. the base condition for
2188 AMF_{3i} is the absent of right-turn lanes on the intersection approaches).

2189 *Right Turn on Red (AMF_{4i})*

2190 For unsignalized intersections, $AMF_{4i} = 1.00$.

2191 *Lighting (AMF_{5i})*

2192 Since there is no lighting at this intersection, AMF_{5i} is 1.00 (i.e. the base condition
2193 for AMF_{5i} is the absence of intersection lighting).

2194 *Red Light Cameras (AMF_{6i})*

2195 For unsignalized intersections, AMF_{6i} is always 1.00.

2196 The combined AMF value for Sample Problem 3 is 0.67.

2197 *Vehicle-Pedestrian and Vehicle-Bicycle Collisions*

2198 The predicted average crash frequency of an intersection (excluding vehicle-
2199 pedestrian and vehicle-bicycle collisions) for SPF base conditions, N_{biv} , must be
2200 calculated in order to determine vehicle-pedestrian and vehicle-bicycle crashes. N_{bi} is
2201 determined from Equation 12-6 as follows:

$$2202 \quad N_{bi} = N_{spf \ int} \times (AMF_{1i} \times AMF_{2i} \times \dots \times AMF_{6i})$$

2203 From Equation 12-7, $N_{spf \ int}$ can be calculated as follows:

$$2204 \quad N_{spf \ int} = N_{bimv} + N_{bisv}$$

$$2205 \qquad \qquad \qquad = 1.892 + 0.349$$

$$2206 \qquad \qquad \qquad = 2.241 \text{ crashes/year}$$

2207 The combined AMF value for Sample Problem 3 is 0.67.

$$2208 \qquad \qquad \qquad N_{bi} = 2.241 \times (0.67)$$

$$2209 \qquad \qquad \qquad = 1.501 \text{ crashes/year}$$

2210 The SPF for vehicle-pedestrian collisions for a three-leg stop-controlled
2211 intersection is calculated from Equation 12-30 as follows:

$$2212 \qquad \qquad \qquad N_{pedi} = N_{bi} \times f_{pedi}$$

2213 From Exhibit 12-33, for a three-leg stop-controlled intersection the pedestrian
2214 accident adjustment factor, $f_{pedi} = 0.211$.

$$2215 \qquad \qquad \qquad N_{pedi} = 1.501 \times 0.211$$

$$2216 \qquad \qquad \qquad = 0.32 \text{ crashes/year}$$

2217 The SPF for vehicle-bicycle collisions is calculated from Equation 12-31 as
2218 follows:

$$2219 \qquad \qquad \qquad N_{bikei} = N_{bi} \times f_{bikei}$$

2220 From Exhibit 12-34, for a three-leg stop-controlled intersection the bicycle
2221 accident adjustment factor, $f_{bikei} = 0.016$.

$$2222 \qquad \qquad \qquad N_{bikei} = 1.501 \times 0.016$$

$$2223 \qquad \qquad \qquad = 0.024 \text{ crashes/year}$$

2224 **Step 11 – Multiply the result obtained in Step 10 by the appropriate calibration**
2225 **factor.**

2226 It is assumed in Sample Problem 3 that a calibration factor, C_i , of 1.00 has been
2227 determined for local conditions. See *Part C* Appendix A.1 for further discussion on
2228 calibration of the predicted models.

2229 **Calculation of Predicted Average Crash Frequency**

2230 The predicted average crash frequency is calculated using Equation 12-5 based
2231 on results obtained in Steps 9 through 11 as follows:

$$2232 \qquad \qquad \qquad N_{predicted\ int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei})$$

$$2233 \qquad \qquad \qquad = 1.00 \times (1.501 + 0.32 + 0.024)$$

$$2234 \qquad \qquad \qquad = 1.557 \text{ crashes/year}$$

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2236 **Worksheets**

2237 The step-by-step instructions above are provided to illustrate the predictive
2238 method for calculating the predicted average crash frequency for an intersection. To
2239 apply the predictive method steps to multiple intersections, a series of twelve
2240 worksheets are provided for determining the predicted average crash frequency at
2241 intersections. The twelve worksheets include:

- 2242 ■ Worksheet 2A – General Information and Input Data for Urban and
2243 Suburban Arterial Intersections
- 2244 ■ Worksheet 2B – Accident Modification Factors for Urban and Suburban
2245 Arterial Intersections
- 2246 ■ Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and
2247 Suburban Arterial Intersections
- 2248 ■ Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and
2249 Suburban Arterial Intersections
- 2250 ■ Worksheet 2E – Single-Vehicle Crashes by Severity Level for Urban and
2251 Suburban Arterial Intersections
- 2252 ■ Worksheet 2F – Single-Vehicle Crashes by Collision Type for Urban and
2253 Suburban Arterial Intersections
- 2254 ■ Worksheet 2G – Vehicle-Pedestrian Collisions for Urban and Suburban
2255 Arterial Stop-Controlled Intersections
- 2256 ■ Worksheet 2H – Accident Modification Factors for Vehicle-Pedestrian
2257 Collisions for Urban and Suburban Arterial Signalized Intersections
- 2258 ■ Worksheet 2I – Vehicle-Pedestrian Collisions for Urban and Suburban
2259 Arterial Signalized Intersections
- 2260 ■ Worksheet 2J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial
2261 Intersections
- 2262 ■ Worksheet 2K – Crash Severity Distribution for Urban and Suburban
2263 Arterial Intersections
- 2264 ■ Worksheet 2L – Summary Results for Urban and Suburban Arterial
2265 Intersections

2266 Details of these worksheets are provided below, except for Worksheets 2H and 2I
2267 which are only used for signalized intersections. Blank versions of worksheets used
2268 in the Sample Problems are provided in Chapter 12 Appendix A.

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Worksheet 2A – General Information and Input Data for Urban and Suburban Arterial Intersections

Worksheet 2A is a summary of general information about the intersection, analysis, input data (i.e., “The Facts”) and assumptions for Sample Problem 3.

Worksheet 2A – General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Intersection	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data		Base Conditions	Site Conditions
Intersection type (3ST, 3SG, 4ST, 4SG)		-	3ST
AADT _{major} (veh/day)		-	14,000
AADT _{minor} (veh/day)		-	4,000
Intersection lighting (present/not present)		not present	not present
Calibration factor, C _i		1.00	1.00
Data for unsignalized intersections only:		-	-
Number of major-road approaches with left-turn lanes (0,1,2)		0	1
Number of major-road approaches with right-turn lanes (0,1,2)		0	0
Data for signalized intersections only:		-	-
Number of approaches with left-turn lanes (0,1,2,3,4)		0	N/A
Number of approaches with right-turn lanes (0,1,2,3,4)		0	N/A
Number of approaches with left-turn signal phasing		-	N/A
Type of left-turn signal phasing		permissive	N/A
Intersection red light cameras (present/not present)		not present	N/A
Sum of all pedestrian crossing volumes (PedVol)		-	N/A
Maximum number of lanes crossed by a pedestrian (n _{lanesx})		-	N/A
Number of bus stops within 300 m (1,000 ft) of the intersection		0	N/A
Schools within 300 m (1,000 ft) of the intersection (present/not present)		not present	N/A
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	N/A

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Worksheet 2B – Accident Modification Factors for Urban and Suburban Arterial Intersections

In Step 10 of the predictive method, Accident Modification Factors are applied to account for the effects of site specific geometric design and traffic control devices. Section 12.7 presents the tables and equations necessary for determining the AMF values. Once the value for each AMF has been determined, all of the AMFs are multiplied together in Column 7 of Worksheet 2B which indicates the combined AMF value.

Worksheet 2B – Accident Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AMF for Left-Turn Lanes	AMF for Left-Turn Signal Phasing	AMF for Right-Turn Lanes	AMF for Right Turn on Red	AMF for Lighting	AMF for Red Light Cameras	Combined AMF
AMF _{1i}	AMF _{2i}	AMF _{3i}	AMF _{4i}	AMF _{5i}	AMF _{6i}	AMF _{COMB}
from Exhibit 12-41	from Exhibit 12-42	from Exhibit 12-43	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)
0.67	1.00	1.00	1.00	1.00	1.00	0.67

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Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections

The SPF for multiple-vehicle collisions at the intersection in Sample Problem 3 is calculated using Equation 12-22 and entered into Column 4 of Worksheet 2C. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 3 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 7 in Worksheet 2B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections										
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N_{bimv}	Proportion of total crashes	Adjusted N_{bimv}	Combined AMFs	Calibration Factor, C_i	Predicted N_{bimv}
	from Exhibit 12-19			from Exhibit 12-19	from Equation 12-22		$(4)_{TOTAL} * (5)$	(7) from Worksheet 2B		$(6) * (7) * (8)$
	a	b	c							
Total	-13.36	1.11	0.41	0.80	1.892	1.000	1.892	0.67	1.00	1.268
Fatal and injury (FI)	-14.01	1.16	0.30	0.69	0.639	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$	0.605	0.67	1.00	0.405
						0.320				
Property damage only (PDO)	-15.38	1.20	0.51	0.77	1.358	$(5)_{TOTAL} - (5)_{FI}$	1.287	0.67	1.00	0.862
						0.680				

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Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections

Worksheet 2D presents the default proportions for collision type (from Exhibit 12-24) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for multiple-vehicle crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for multiple-vehicle crashes (from Column 9, Worksheet 2C) into components by crash severity and collision type.

Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(FI)	Predicted $N_{bimv(FI)}$ (crashes/year)	Proportion of Collision Type _(PDO)	Predicted $N_{bimv(PDO)}$ (crashes/year)	Predicted $N_{bimv(TOTAL)}$ (crashes/year)
	from Exhibit 12-24	(9) _{FI} from Worksheet 2C	from Exhibit 12-24	(9) _{PDO} from Worksheet 2C	(9) _{PDO} from Worksheet 2C
Total	1.000	0.405	1.000	0.862	1.268
		(2)* (3) _{FI}		(4)* (5) _{PDO}	(3) + (5)
Rear-end collision	0.421	0.171	0.440	0.379	0.550
Head-on collision	0.045	0.018	0.023	0.020	0.038
Angle collision	0.343	0.139	0.262	0.226	0.365
Sideswipe	0.126	0.051	0.040	0.034	0.085
Other multiple-vehicle collision	0.065	0.026	0.235	0.203	0.229

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Worksheet 2E– Single-Vehicle Crashes by Severity Level for Urban and Suburban Arterial Intersections

The SPF for single-vehicle crashes at the intersection in Sample Problem 3 is calculated using Equation 12-25 for total and property damage only (PDO) crashes and entered into Column 4 of Worksheet 2E. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2, and 3; however, the overdispersion parameter is not needed for Sample Problem 3 (as the EB Method is not utilized). Since there are no models for fatal and injury crashes at a three-leg stop-controlled intersections, $N_{bisv(FI)}$ is calculated using Equation 12-27 (in place of Equation 12-25), and the value is entered into Column 4 and 6 since no further adjustment is required. Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 7 in Worksheet 2B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of single-vehicle crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

Worksheet 2E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections										
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N_{bisv}	Proportion of total crashes	Adjusted N_{bisv}	Combined AMFs	Calibration Factor, C_i	Predicted N_{bisv}
	from Exhibit 12-25									
	a	b	c							
Total	-6.81	0.16	0.51	1.14	0.349	1.000	0.349	0.67	1.00	0.234
Fatal and injury (FI)	N/A	N/A	N/A	N/A	0.108	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$	0.108	0.67	1.00	0.072
						N/A				
Property damage only (PDO)	-8.36	0.25	0.55	1.29	0.244	$(5)_{TOTAL} - (5)_{FI}$	0.242	0.67	1.00	0.162
						0.693				

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Worksheet 2F – Single-Vehicle Crashes by Collision Type for Urban and Suburban Arterial Intersections

Worksheet 2F presents the default proportions for collision type (from Exhibit 12-30) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for single-vehicle crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for single-vehicle crashes (from Column 9, Worksheet 2E) into components by crash severity and collision type.

Worksheet 2F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(F1)	Predicted N _{b_{sv}(F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{b_{sv}(PDO)} (crashes/year)	Predicted N _{b_{sv}(TOTAL)} (crashes/year)
	Exhibit 12-30	(9) _{F1} from Worksheet 2E	Exhibit 12-30	(9) _{PDO} from Worksheet 2E	(9) _{PDO} from Worksheet 2E
Total	1.000	0.072	1.000	0.162	0.234
		(2)* (3) _{F1}		(4)* (5) _{PDO}	(3)+ (5)
Collision with parked vehicle	0.001	0.000	0.003	0.000	0.000
Collision with animal	0.003	0.000	0.018	0.003	0.003
Collision with fixed object	0.762	0.055	0.834	0.135	0.190
Collision with other object	0.090	0.006	0.092	0.015	0.021
Other single-vehicle collision	0.039	0.003	0.023	0.004	0.007
Single-vehicle noncollision	0.105	0.008	0.030	0.005	0.013

Worksheet 2G– Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Stop-Controlled Intersections

The predicted average crash frequency of multiple-vehicle predicted crashes and single-vehicle predicted crashes from Worksheets 2C and 2E are entered into Columns 2 and 3 respectively. These values are summed in Column 4. Column 5 contains the pedestrian accident adjustment factor (see Exhibit 12-33). Column 6 presents the calibration factor. The predicted average crash frequency of vehicle-pedestrian collision (Column 7) is the product of Columns 4, 5 and 6. Since all vehicle-pedestrian crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 2G – Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Stop-Controlled Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Predicted N _{b_{imv}}	Predicted N _{b_{sv}}	Predicted N _{bi}	f _{pedi}	Calibration factor, C _i	Predicted N _{pedi}
	(9) from Worksheet 2C	(9) from Worksheet 2E	(2)+ (3)	from Exhibit 12-33		(4)* (5)* (6)
Total	1.268	0.234	1.502	0.021	1.00	0.032
Fatal and injury (FI)	-	-	-	-	1.00	0.032

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Worksheet 2J– Vehicle-Bicycle Collisions for Urban and Suburban Arterial Intersections

The predicted average crash frequency of multiple-vehicle predicted crashes and single-vehicle predicted crashes from Worksheets 2C and 2E are entered into Columns 2 and 3 respectively. These values are summed in Column 4. Column 5 contains the bicycle accident adjustment factor (see Exhibit 12-34). Column 6 presents the calibration factor. The predicted average crash frequency of vehicle-bicycle collision (Column 7) is the product of Columns 4, 5 and 6. Since all vehicle-bicycle crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 2J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Predicted N_{blmv}	Predicted N_{blsv}	Predicted N_{bl}	f_{bikei}	Calibration factor, C_i	Predicted N_{pedi}
	(9) from Worksheet 2C	(9) from Worksheet 2E	(2)+(3)	from Exhibit 10-34		(4)*(5)*(6)
Total	1.268	0.234	1.502	0.016	1.000	0.024
Fatal and injury (FI)	-	-	-	-	1.000	0.024

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Worksheet 2K– Crash Severity Distribution for Urban and Suburban Arterial Intersections

Worksheet 2K provides a summary of all collision types by severity level. Values from Worksheets 2D, 2F, 2G and 2J are presented and summed to provide the predicted average crash frequency for each severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 3)
- Total crashes (Column 4)

Worksheet 2K– Crash Severity Distribution for Urban and Suburban Arterial Intersections			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J	(5) from Worksheet 2D and 2F	(6) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J
MULTIPLE-VEHICLE COLLISIONS			
Rear-end collisions (from Worksheet 2D)	0.171	0.379	0.550
Head-on collisions (from Worksheet 2D)	0.018	0.020	0.038
Angle collisions (from Worksheet 2D)	0.139	0.226	0.365
Sideswipe (from Worksheet 2D)	0.051	0.034	0.085
Other multiple-vehicle collision (from Worksheet 2D)	0.026	0.203	0.229
Subtotal	0.405	0.862	1.267
SINGLE-VEHICLE COLLISIONS			
Collision with parked vehicle (from Worksheet 2F)	0.000	0.000	0.000
Collision with animal (from Worksheet 2F)	0.000	0.003	0.003
Collision with fixed object (from Worksheet 2F)	0.055	0.135	0.190
Collision with other object (from Worksheet 2F)	0.006	0.015	0.021
Other single-vehicle collision (from Worksheet 2F)	0.003	0.004	0.007
Single-vehicle noncollision (from Worksheet 2F)	0.008	0.005	0.013
Collision with pedestrian (from Worksheet 2G or 2I)	0.032	0.000	0.032
Collision with bicycle (from Worksheet 2J)	0.024	0.000	0.024
Subtotal	0.128	0.162	0.290
Total	0.533	1.024	1.557

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Worksheet 2L– Summary Results for Urban and Suburban Arterial Intersections

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Worksheet 2L presents a summary of the results.

Worksheet 2L – Summary Results for Urban and Suburban Arterial Intersections	
(1)	(2)
Crash severity level	Predicted average crash frequency, $N_{predicted\ int}$ (crashes/year)
	(Total) from Worksheet 2K
Total	1.557
Fatal and injury (FI)	0.533
Property damage only (PDO)	1.024

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2341 **12.13.4. Sample Problem 4**2342 ***The Intersection***

2343 A four-leg signalized intersection located on an urban arterial.

2344 ***The Question***2345 What is the predicted accident frequency of the signalized intersection for a
2346 particular year?2347 ***The Facts***

- 1 left-turn lane on each of the two major road approaches
- 1 right-turn lane on each of the two major road approaches
- Protected/permissive left-turn signal phasing on major road
- AADT of major road is 15,000 veh/day
- AADT of minor road is 9,000 veh/day
- Lighting is present
- No approaches with prohibited RTOR
- Four-lane divided major road
- Two-lane undivided minor road
- Pedestrian volume is 1,500 peds/day
- The number of bus stops within 1,000 ft of intersection is 2
- A school is present within 1,000 ft of intersection
- The number of alcohol establishments within 1,000 ft of intersection is 6

2348 ***Assumptions***

- 2349 ▪ Collision type distributions used are the default values from Exhibits 12-24
2350 and 12-30 and Equations 12-28 and 12-31.
- 2351 ▪ The calibration factor is assumed to be 1.00.
- 2352 ▪ The maximum number of lanes crossed by a pedestrian is assumed to be 4
2353 (crossing two through lanes, one left turn lane, and one right turn lane across
2354 one side of the divided major road).

2355 ***Results***2356 Using the predictive method steps as outlined below, the predicted average crash
2357 frequency for the unsignalized intersection in Sample Problem 4 is determined to be
2358 3.4 crashes per year (rounded to one decimal place).

2359 **Steps**2360 **Step 1 through 8**

2361 To determine the predicted average crash frequency of the roadway segment in
 2362 Sample Problem 4, only Steps 9 through 11 are conducted. No other steps are
 2363 necessary because only one roadway segment is analyzed for one year, and the EB
 2364 Method is not applied.

2365 **Step 9 – For the selected site, determine and apply the appropriate Safety**
 2366 **Performance Function (SPF) for the site’s facility type, and traffic control**
 2367 **features.**

2368 For a four-leg signalized intersection, SPF values for multiple-vehicle, single-
 2369 vehicle, vehicle-pedestrian and vehicle-bicycle collisions are determined. The
 2370 calculations for total multiple- and single-vehicle collisions are presented below.
 2371 Detailed steps for calculating SPFs for fatal and injury (FI) and property damage only
 2372 (PDO) crashes are presented in Sample Problem 3 (for fatal and injury base crashes at
 2373 a four-leg signalized intersection Equation 12-25 in place of Equation 12-27 is used).
 2374 The calculations for vehicle-pedestrian and vehicle-bicycle collisions are shown in
 2375 Step 10 since the AMF values are needed for these two models.

2376 *Multiple-Vehicle Collisions*

2377 The SPF for multiple-vehicle collisions for a single four-leg signalized
 2378 intersection is calculated from Equation 12-21 and Exhibit 12-19 as follows:

$$2379 \quad N_{bimv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min}))$$

$$2380 \quad N_{bimv(TOTAL)} = \exp(-10.99 + 1.07 \times \ln(15,000) + 0.23 \times \ln(9,000))$$

$$2381 \quad = 4.027 \text{ crashes/year}$$

2382 *Single-Vehicle Crashes*

2383 The SPF for single-vehicle crashes for a single four-leg signalized intersection is
 2384 calculated from Equation 12-24 and Exhibit 12-25 as follows:

$$2385 \quad N_{bisv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min}))$$

$$2386 \quad N_{bisv Total} = \exp(-10.21 + 0.68 \times \ln(15,000) + 0.27 \times \ln(9,000))$$

$$2387 \quad = 0.297 \text{ crashes/year}$$

2388 **Step 10 – Multiply the result obtained in Step 9 by the appropriate AMFs to**
 2389 **adjust base conditions to site specific geometric design and traffic control**
 2390 **features**

2391 Each AMF used in the calculation of the predicted average crash frequency of the
 2392 intersection is calculated below. AMF_{1i} through AMF_{2i} are applied to multiple-vehicle
 2393 collisions and single-vehicle crashes, while AMF_{1p} through AMF_{3p} are applied to
 2394 vehicle-pedestrian collisions.

2395 *Intersection Left-Turn Lanes (AMF_{1i})*

2396 From Exhibit 12-41, for a four-leg signalized intersection with one left-turn lane
 2397 on each of two approaches, $AMF_{1i} = 0.81$.

2398 *Intersection Left-Turn Signal Phasing (AMF_{2i})*

2399 From Exhibit 12-42, for a four-leg signalized intersection with
 2400 protected/permissive left-turn signal phasing for two approaches, AMF_{2i} = 0.98
 2401 (0.99*0.99).

2402 *Intersection Right-Turn Lanes (AMF_{3i})*

2403 Form Exhibit 12-43, for a four-leg signalized intersection with one right-turn lane
 2404 on each of two approaches, AMF_{3i} = 0.92.

2405 *Right Turn on Red (AMF_{4i})*

2406 Since RTOR is not prohibited on any of the intersection legs, AMF_{4i} = 1.00 (i.e. the
 2407 base condition for AMF_{4i} is permitting a RTOR at all approaches to a signalized
 2408 intersection).

2409 *Lighting (AMF_{5i})*

2410 AMF_{5i} is calculated from Equation 12-36.

$$2411 \quad AMF_{5i} = 1 - 0.38 \times p_{ni}$$

2412 From Exhibit 12-44, the proportion of crashes that occur at night, p_{ni} = 0.235.

$$2413 \quad AMF_{5i} = 1 - 0.38 \times 0.235$$

$$2414 \quad = 0.91$$

2415 *Red Light Cameras (AMF_{6i})*

2416 Since no red light cameras are present at this intersection, AMF_{6i} = 1.00 (i.e. the
 2417 base condition for AMF_{6i} is the absence of red light cameras).

2418 The combined AMF value applied to multiple- and single-vehicle crashes in
 2419 Sample Problem 4 is calculated below.

$$2420 \quad AMF_{COMB} = 0.81 \times 0.98 \times 0.92 \times 0.91$$

$$2421 \quad = 0.66$$

2422 *Bus Stop (AMF_{1p})*

2423 From Exhibit 12-45, for two bus stops within 1,000-ft of the center of the
 2424 intersection, AMF_{1p} = 2.78.

2425 *Schools (AMF_{2p})*

2426 From Exhibit 12-46, for one school within 1,000-ft of the center of the intersection,
 2427 AMF_{2p} = 1.35.

2428 *Alcohol Sales Establishments (AMF_{3p})*

2429 From Exhibit 12-47, for six alcohol establishments within 1,000-ft of the center of
 2430 the intersection, AMF_{3p} = 1.12.

2431 *Vehicle-Pedestrian and Vehicle-Bicycle Collisions*

2432 The SPF for vehicle-pedestrian collisions for a four-leg signalized intersection is
 2433 calculated from Equation 12-28 as follows:

$$2434 \quad N_{pedi} = N_{pedbase} \times AMF_{1p} \times AMF_{2p} \times AMF_{3p}$$

2435

2436 $N_{pedbase}$ is calculated from Equation 12-29 using the coefficients from Exhibit 12-31.

$$\begin{aligned}
 N_{pedbase} &= \exp(a + b \times \ln(AADT_{tot}) + c \times \ln(\frac{AADT_{min}}{AADT_{maj}}) + d \times \ln(PedVol) + e \times n_{lanes}) \\
 &= \exp(-9.53 + 0.40 \times \ln(24,000) + 0.26 \times \ln(\frac{9,000}{15,000}) + 0.45 \times \ln(1,500) + 0.04 \times 4) \\
 &= 0.113 \text{ crashes/year}
 \end{aligned}$$

2440

2441 The AMF vehicle-pedestrian collision values calculated above, are $AMF_{1p} = 2.78$,2442 $AMF_{2p} = 1.35$ and $AMF_{3p} = 1.12$.

$$\begin{aligned}
 N_{pedl} &= 0.113 \times 2.78 \times 1.35 \times 1.12 \\
 &= 0.475 \text{ crashes/year}
 \end{aligned}$$

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2444 The predicted average crash frequency of an intersection (excluding vehicle-
 2445 pedestrian and vehicle-bicycle collisions) for SPF base conditions, N_{bi} , must be
 2446 calculated in order to determine vehicle-bicycle crashes. N_{bi} is determined from
 2447 Equation 12-6 as follows:

$$N_{bi} = N_{spf\ int} \times (AMF_{1i} \times AMF_{2i} \times \dots \times AMF_{6i})$$

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2449 From Equation 12-7, $N_{spf\ int}$ can be calculated as follows:

$$\begin{aligned}
 N_{spf\ int} &= N_{bimv} + N_{bisv} \\
 &= 4.027 + 0.297 \\
 &= 4.324 \text{ crashes/year}
 \end{aligned}$$

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The combined AMF value for Sample Problem 4 is 0.66.

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$$\begin{aligned}
 N_{bi} &= 4.324 \times (0.66) \\
 &= 2.854 \text{ crashes/year}
 \end{aligned}$$

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The SPF for vehicle-bicycle collisions is calculated from Equation 12-31 as follows:

$$N_{bikei} = N_{bi} \times f_{bikei}$$

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From Exhibit 12-34, for a four-leg signalized intersection the bicycle accident adjustment factor, $f_{bikei} = 0.015$.

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$$\begin{aligned}
 N_{bikei} &= 2.854 \times 0.015 \\
 &= 0.043 \text{ crashes/year}
 \end{aligned}$$

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Step 11 – Multiply the result obtained in Step 10 by the appropriate calibration factor.

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It is assumed in Sample Problem 4 that a calibration factor, C_i , of 1.00 has been determined for local conditions. See Part C Appendix A.1 for further discussion on calibration of the predicted models.

2468 **Calculation of Predicted Average Crash Frequency**

2469 The predicted average crash frequency is calculated from Equation 12-5 based on
2470 the results obtained in Steps 9 through 11 as follows:

$$\begin{aligned}
 2471 \quad N_{\text{predicted int}} &= C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \\
 2472 &= 1.00 \times (2.854 + 0.475 + 0.043) \\
 2473 &= 3.372 \text{ crashes/year}
 \end{aligned}$$

2474 **Worksheets**

2475 The step-by-step instructions above are provided to illustrate the predictive
2476 method for calculating the predicted average crash frequency for an intersection. To
2477 apply the predictive method steps to multiple intersections, a series of twelve
2478 worksheets are provided for determining the predicted average crash frequency at
2479 intersections. The twelve worksheets include:

- 2480 ■ Worksheet 2A – General Information and Input Data for Urban and
2481 Suburban Arterial Intersections
- 2482 ■ Worksheet 2B – Accident Modification Factors for Urban and Suburban
2483 Arterial Intersections
- 2484 ■ Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and
2485 Suburban Arterial Intersections
- 2486 ■ Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and
2487 Suburban Arterial Intersections
- 2488 ■ Worksheet 2E – Single-Vehicle Crashes by Severity Level for Urban and
2489 Suburban Arterial Intersections
- 2490 ■ Worksheet 2F – Single-Vehicle Crashes by Collision Type for Urban and
2491 Suburban Arterial Intersections
- 2492 ■ Worksheet 2G – Vehicle-Pedestrian Collisions for Urban and Suburban
2493 Arterial Stop-Controlled Intersections
- 2494 ■ Worksheet 2H – Accident Modification Factors for Vehicle-Pedestrian
2495 Collisions for Urban and Suburban Arterial Signalized Intersections
- 2496 ■ Worksheet 2I – Vehicle-Pedestrian Collisions for Urban and Suburban
2497 Arterial Signalized Intersections
- 2498 ■ Worksheet 2J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial
2499 Intersections
- 2500 ■ Worksheet 2K – Crash Severity Distribution for Urban and Suburban
2501 Arterial Intersections
- 2502 ■ Worksheet 2L – Summary Results for Urban and Suburban Arterial
2503 Intersections

2504 Details of these worksheets are provided below, except for Worksheets 2G which
2505 is only used for stop-controlled intersections. Blank versions of worksheets used in
2506 the Sample Problems are provided in Chapter 12 Appendix A.

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Worksheet 2A – General Information and Input Data for Urban and Suburban Arterial Intersections

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Worksheet 2A is a summary of general information about the intersection, analysis, input data (i.e., “The Facts”) and assumptions for Sample Problem 4.

Worksheet 2A – General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Intersection	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data		Base Conditions	Site Conditions
Intersection type (3ST, 3SG, 4ST, 4SG)		-	4SG
AADT _{major} (veh/day)		-	15,000
AADT _{minor} (veh/day)		-	9,000
Intersection lighting (present/not present)		not present	present
Calibration factor, C _i		1.00	1.00
Data for unsignalized intersections only:		-	-
Number of major-road approaches with left-turn lanes (0,1,2)		0	N/A
Number of major-road approaches with right-turn lanes (0,1,2)		0	N/A
Data for signalized intersections only:		-	-
Number of approaches with left-turn lanes (0,1,2,3,4)		0	2
Number of approaches with right-turn lanes (0,1,2,3,4)		0	2
Number of approaches with left-turn signal phasing		-	2
Type of left-turn signal phasing		permissive	protected/permissive
Intersection red light cameras (present/not present)		not present	not present
Sum of all pedestrian crossing volumes (PedVol)		-	1,500
Maximum number of lanes crossed by a pedestrian (n _{lanesx})		-	4
Number of bus stops within 300 m (1,000 ft) of the intersection		0	2
Schools within 300 m (1,000 ft) of the intersection (present/not present)		not present	present
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	6

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Worksheet 2B – Accident Modification Factors for Urban and Suburban Arterial Intersections

In Step 10 of the predictive method, Accident Modification Factors are applied to account for the effects of site specific geometric design and traffic control devices. Section 12.7 presents the tables and equations necessary for determining the AMF values. Once the value for each AMF has been determined, all of the AMFs are multiplied together in Column 7 of Worksheet 2B which indicates the combined AMF value.

Worksheet 2B – Accident Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AMF for Left-Turn Lanes	AMF for Left-Turn Signal Phasing	AMF for Right-Turn Lanes	AMF for Right-Turn-on-Red	AMF for Lighting	AMF for Red Light Cameras	Combined AMF
AMF_{1i}	AMF_{2i}	AMF_{3i}	AMF_{4i}	AMF_{5i}	AMF_{6i}	AMF_{COMB}
from Exhibit 12-41	from Exhibit 12-42	from Exhibit 12-43	from Equation 12-35	from Equation 12-36	from Equation 12-37	$(1)*(2)*(3)*(4)*(5)*(6)$
0.81	0.98	0.92	1.00	0.91	1.00	0.66

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Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections

The SPF for multiple-vehicle collisions at the intersection in Sample Problem 4 is calculated using Equation 12-22 and entered into Column 4 of Worksheet 2C. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2 and 3; however, the overdispersion parameter is not needed for Sample Problem 4 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 7 in Worksheet 2B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of multiple-vehicle crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections										
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N_{bimv}	Proportion of total crashes	Adjusted N_{bimv}	Combined AMFs	Calibration Factor, C_i	Predicted N_{bimv}
	from Exhibit 12-19									
	a	b	c							
Total	-10.99	1.07	0.23	0.39	4.027	1.000	4.027	0.66	1.00	2.658
Fatal and injury (FI)	-13.14	1.18	0.22	0.33	1.233	$(4)_{FI} / ((4)_{FI} + (4)_{PDO})$ 0.318	1.281	0.66	1.00	0.845
Property damage only (PDO)	-11.02	1.02	0.24	0.44	2.647	$(5)_{TOTAL} - (5)_{FI}$ 0.682	2.746	0.66	1.00	1.812

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Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections

Worksheet 2D presents the default proportions for collision type (from Exhibit 12-24) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for multiple-vehicle crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for multiple-vehicle crashes (from Column 9, Worksheet 2C) into components by crash severity and collision type.

Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(FI)	Predicted N _{bimv (FI)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{bimv (PDO)} (crashes/year)	Predicted N _{bimv (TOTAL)} (crashes/year)
	from Exhibit 12-24	(9) _{FI} from Worksheet 2C	from Exhibit 12-24	(9) _{PDO} from Worksheet 2C	(9) _{PDO} from Worksheet 2C
Total	1.000	0.845	1.000	1.812	2.658
		(2) * (3) _{FI}		(4) * (5) _{PDO}	(3) + (5)
Rear-end collision	0.450	0.380	0.483	0.875	1.255
Head-on collision	0.049	0.041	0.030	0.054	0.095
Angle collision	0.347	0.293	0.244	0.442	0.735
Sideswipe	0.099	0.084	0.032	0.058	0.142
Other multiple-vehicle collision	0.55	0.046	0.211	0.382	0.428

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Worksheet 2E– Single-Vehicle Crashes by Severity Level for Urban and Suburban Arterial Intersections

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The SPF for single-vehicle crashes at the intersection in Sample Problem 4 is calculated using Equation 12-25 for total and property damage only (PDO) crashes and entered into Column 4 of Worksheet 2E. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2, and 3; however, the overdispersion parameter is not needed for Sample Problem 4 (as the EB Method is not utilized). Column 5 of the worksheet presents the proportions for crash severity levels calculated from the results in Column 4. These proportions are used to adjust the initial SPF values (from Column 4) to assure that fatal and injury (FI) and property damage only (PDO) crashes sum to the total crashes, as illustrated in Column 6. Column 7 represents the combined AMF (from Column 7 in Worksheet 2B), and Column 8 represents the calibration factor. Column 9 calculates the predicted average crash frequency of single-vehicle crashes using the values in Column 6, the combined AMF in Column 7, and the calibration factor in Column 8.

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Worksheet 2E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections										
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N_{bisv}	Proportion of total crashes	Adjusted N_{bisv}	Combined AMFs	Calibration Factor, C_i	Predicted N_{bisv}
	from Exhibit 12-25									
	a	b	c							
Total	-10.21	0.68	0.27	0.36	0.297	1.000	0.297	0.66	1.000	0.196
Fatal and injury (FI)	-9.25	0.43	0.29	0.09	0.084	$(4)FI / ((4)FI + (4)PDO)$	0.085	0.66	1.000	0.056
						0.287				
Property damage only (PDO)	-11.34	0.78	0.25	0.44	0.209	$(5)TOTAL - (5)FI$	0.212	0.66	1.000	0.140
						0.713				

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Worksheet 2F – Single-Vehicle Crashes by Collision Type for Urban and Suburban Arterial Intersections

Worksheet 2F presents the default proportions for collision type (from Exhibit 12-30) by crash severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 4)

Using the default proportions, the predicted average crash frequency for single-vehicle crashes by collision type is presented in Columns 3 (Fatal and Injury, FI), 5 (Property Damage Only PDO), and 6 (Total).

These proportions may be used to separate the predicted average crash frequency for single-vehicle crashes (from Column 9, Worksheet 2E) into components by crash severity and collision type.

Worksheet 2F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(F1)	Predicted N _{bisv (F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{bisv (PDO)} (crashes/year)	Predicted N _{bisv (TOTAL)} (crashes/year)
	Exhibit 12-30	(9) _{F1} from Worksheet 2E	Exhibit 12-30	(9) _{PDO} from Worksheet 2E	(9) _{PDO} from Worksheet 2E
Total	1.000	0.056	1.000	0.140	0.196
		(2)* (3) _{F1}		(4)* (5) _{PDO}	(3)+ (5)
Collision with parked vehicle	0.001	0.000	0.001	0.000	0.000
Collision with animal	0.002	0.000	0.002	0.000	0.000
Collision with fixed object	0.744	0.042	0.870	0.122	0.164
Collision with other object	0.072	0.004	0.070	0.010	0.014
Other single-vehicle collision	0.040	0.002	0.023	0.003	0.005
Single-vehicle noncollision	0.141	0.008	0.034	0.005	0.013

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Worksheet 2H– Accident Modification Factors for Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections

In Step 10 of the predictive method, Accident Modification Factors are applied to account for the effects of site specific geometric design and traffic control devices. Section 12.7 presents the tables and equations necessary for determining the AMF values for vehicle-pedestrian collision. Once the value for each AMF has been determined, all of the AMFs are multiplied together in Column 4 of Worksheet 2H which indicates the combined AMF value for vehicle-pedestrian collisions.

Worksheet 2H – Accident Modification Factors for Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections			
(1)	(2)	(3)	(4)
AMF for Bus Stops	AMF for Schools	AMF for Alcohol Sales Establishments	Combined AMF
AMF _{1p}	AMF _{2p}	AMF _{3p}	
from Exhibit 12-45	from Exhibit 12-46	from Exhibit 12-47	(1)* (2) * (3)
2.78	1.35	1.12	4.20

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Worksheet 2I– Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections

The predicted number of vehicle-pedestrian collisions per year for base conditions at a signalized intersection, $N_{pedbase}$, is calculated using Equation 12-30 and entered into Column 4 of Worksheet 2I. The coefficients for the SPF and the overdispersion parameter associated with the SPF are entered into Columns 2, and 3; however, the overdispersion parameter is not needed for Sample Problem 4 (as the EB Method is not utilized). Column 5 represents the combined AMF for vehicle-pedestrian collisions (from Column 4 in Worksheet 2H), and Column 6 represents the calibration factor. Column 7 calculates the predicted average crash frequency of vehicle-pedestrian collisions using the values in Column 4, the combined AMF in Column 5, and the calibration factor in Column 6. Since all vehicle-pedestrian crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 2I – Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections

(1)	(2)					(3)	(4)	(5)	(6)	(7)
Crash severity level	SPF Coefficients					Overdispersion Parameter, k	$N_{pedbase}$	Combined AMF	Calibration factor, C_i	Predicted N_{pedi}
	from Exhibit 12-31						from Equation 12-30	(4) from Worksheet 2H		(8)*(9)*(10)
	a	b	c	d	e					
Total	-9.53	0.40	0.26	0.45	0.04	0.24	0.113	4.20	1.00	0.475
Fatal and injury (FI)	-	-	-	-	-	-	-	-	1.00	0.475

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Worksheet 2J– Vehicle-Bicycle Collisions for Urban and Suburban Arterial Intersections

The predicted average crash frequency of multiple-vehicle predicted crashes and single-vehicle predicted crashes from Worksheets 2C and 2E are entered into Columns 2 and 3 respectively. These values are summed in Column 4. Column 5 contains the bicycle accident adjustment factor (see Exhibit 12-34). Column 6 presents the calibration factor. The predicted average crash frequency of vehicle-bicycle collision (Column 7) is the product of Columns 4, 5 and 6. Since all vehicle-bicycle crashes are assumed to involve some level of injury, there are no property damage only crashes.

Worksheet 2J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial Intersections

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Predicted N_{bimv}	Predicted N_{bisv}	Predicted N_{bi}	f_{biket}	Calibration factor, C_i	Predicted N_{pedi}
	(9) from Worksheet 2C	(9) from Worksheet 2E	(2)+(3)	from Exhibit 10-34		(4)*(5)*(6)
Total	2.658	0.196	2.854	0.015	1.00	0.043
Fatal and injury (FI)	-	-	-	-	1.00	0.043

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Worksheet 2K– Crash Severity Distribution for Urban and Suburban Arterial Intersections

Worksheet 2K provides a summary of all collision types by severity level. Values from Worksheets 2D, 2F, 2I and 2J are presented and summed to provide the predicted average crash frequency for each severity level as follows:

- Fatal and injury crashes (Column 2)
- Property damage only crashes (Column 3)
- Total crashes (Column 4)

Worksheet 2K– Crash Severity Distribution for Urban and Suburban Arterial Intersections			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J	(5) from Worksheet 2D and 2F;	(6) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J
MULTIPLE-VEHICLE COLLISIONS			
Rear-end collisions (from Worksheet 2D)	0.380	0.875	1.255
Head-on collisions (from Worksheet 2D)	0.041	0.054	0.095
Angle collisions (from Worksheet 2D)	0.293	0.442	0.735
Sideswipe (from Worksheet 2D)	0.084	0.058	0.142
Other multiple-vehicle collision (from Worksheet 2D)	0.046	0.382	0.428
Subtotal	0.844	1.811	2.655
SINGLE-VEHICLE COLLISIONS			
Collision with parked vehicle (from Worksheet 2F)	0.000	0.000	0.000
Collision with animal (from Worksheet 2F)	0.000	0.000	0.000
Collision with fixed object (from Worksheet 2F)	0.042	0.122	0.164
Collision with other object (from Worksheet 2F)	0.004	0.010	0.014
Other single-vehicle collision (from Worksheet 2F)	0.002	0.003	0.005
Single-vehicle noncollision (from Worksheet 2F)	0.008	0.005	0.013
Collision with pedestrian (from Worksheet 2G or 2I)	0.475	0.000	0.475
Collision with bicycle (from Worksheet 2J)	0.043	0.000	0.043
Subtotal	0.574	0.140	0.714
Total	1.418	1.951	3.369

2582 **Worksheet 2L– Summary Results for Urban and Suburban Arterial**
 2583 **Intersections**

2584 Worksheet 2L presents a summary of the results.

Worksheet 2L – Summary Results for Urban and Suburban Arterial Intersections	
(1)	(2)
Crash severity level	Predicted average crash frequency, $N_{predicted int}$ (crashes/year)
	(Total) from Worksheet 2K
Total	3.369
Fatal and injury (FI)	1.418
Property damage only (PDO)	1.951

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2586 **12.13.5. Sample Problem 5**2587 ***The Project***

2588 A project of interest consists of four sites located on an urban arterial: a three-
2589 lane TWLTL segment; a four-lane divided segment; a three-leg intersection with
2590 minor-road stop control; and a four-leg signalized intersection. (This project is a
2591 compilation of roadway segments and intersections from Sample Problems 1 through
2592 4.)

2593 ***The Question***

2594 What is the expected accident frequency of the project for a particular year
2595 incorporating both the predicted crash frequencies from Sample Problems 1 through
2596 4 and the observed crash frequencies using the **site-specific EB Method**?

2597 ***The Facts***

- 2 roadway segments (3T segment, 4D segment)
- 2 intersections (3ST intersection, 4SG intersection)
- 34 observed crashes (3T segment: 7 multiple-vehicle nondriveway, 4 single-vehicle, 2 multiple-vehicle driveway related; 4D: 6 multiple-vehicle nondriveway, 3 single-vehicle, 1 multiple-vehicle driveway related; 3ST: 2 multiple-vehicle, 3 single-vehicle; 4SG 6 multiple-vehicle, 0 single-vehicle)

2598 ***Outline of Solution***

2599 To calculate the expected average crash frequency, site-specific observed crash
2600 frequencies are combined with predicted crash frequencies for the project using the
2601 site-specific EB Method (i.e. observed crashes are assigned to specific intersections or
2602 roadway segments) presented in Section A.2.4 of *Part C* Appendix.

2603 ***Results***

2604 The expected average crash frequency for the project is 25.4 crashes per year
2605 (rounded to one decimal place).

2606 ***Worksheets***

2607 To apply the site-specific EB Method to multiple roadway segments and
2608 intersections on an urban or suburban arterial combined, three worksheets are
2609 provided for determining the expected average crash frequency. The three
2610 worksheets include:

- 2611 ▪ Worksheet 3A – Predicted Crashes by Collision and Site Type and Observed
2612 Crashes Using the Site-Specific EB Method for Urban and Suburban
2613 Arterials.
- 2614 ▪ Worksheet 3B – Predicted Pedestrian and Bicycle Crashes for Urban and
2615 Suburban Arterials.

- 2616 ■ Worksheet 3C – Site-Specific EB Method Summary Results for Urban and
2617 Suburban Arterials

2618 Details of these worksheets are provided below. Blank versions of worksheets
2619 used in the Sample Problems are provided in Chapter 12 Appendix A.

2620 ***Worksheets 3A – Predicted Crashes by Collision and Site Type and Observed***
2621 ***Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials.***

2622 The predicted average crash frequencies by severity level and collision type
2623 determined in Sample Problems 1 through 4 are entered into Columns 2 through 4 of
2624 Worksheet 3A. Column 5 presents the observed crash frequencies by site and
2625 collision type, and Column 6 presents the overdispersion parameters. The expected
2626 average crash frequency is calculated by applying the site-specific EB Method which
2627 considers both the predicted model estimate and observed crash frequencies for each
2628 roadway segment and intersection. Equation A-5 from *Part C* Appendix is used to
2629 calculate the weighted adjustment and entered into Column 7. The expected average
2630 crash frequency is calculated using Equation A-4 and entered into Column 8.
2631 Detailed calculation of Columns 7 and 8 are provided below.

Worksheet 3A – Predicted Crashes by Collision and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type/ site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$ (VEHICLE)
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (F1)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix
ROADWAY SEGMENTS							
Multiple-vehicle nondriveway							
Segment 1	4.967	1.196	3.771	7	0.66	0.234	6.524
Segment 2	2.524	0.702	1.822	6	1.32	0.231	5.197
Single-vehicle							
Segment 1	1.182	0.338	0.844	4	1.37	0.382	2.924
Segment 2	0.485	0.085	0.401	3	0.86	0.706	1.224
Multiple-vehicle driveway-related							
Segment 1	0.734	0.179	0.555	2	1.10	0.553	1.300
Segment 2	0.149	0.042	0.107	1	1.39	0.828	0.295
INTERSECTIONS							
Multiple-vehicle							
Intersection 1	1.268	0.405	0.862	2	0.80	0.496	1.637
Intersection 2	2.658	0.845	1.812	6	0.39	0.491	4.359
Single-vehicle							
Intersection 1	0.234	0.072	0.162	3	1.14	0.789	0.818
Intersection 2	0.196	0.056	0.140	0	0.36	0.934	0.183
COMBINED (sum of column)	14.397	3.920	10.476	34	-	-	24.461

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2633 *Column 7 - Weighted Adjustment*

2634 The weighted adjustment, w , to be placed on the predictive model estimate is
 2635 calculated using Equation A-5 from *Part C Appendix* as follows:

$$2636 \quad w = \frac{1}{1 + k \times \left(\sum_{\substack{\text{all study} \\ \text{years}}} N_{\text{predicted}} \right)}$$

2637 Multiple-Vehicle Nondriveway Collisions

$$2638 \quad \text{Segment 1} \quad w = \frac{1}{1 + 0.66 \times (4.967)}$$

$$2639 \quad = 0.234$$

$$2640 \quad \text{Segment 2} \quad w = \frac{1}{1 + 1.32 \times (2.524)}$$

$$2641 \quad = 0.231$$

2642 Single-Vehicle Crashes

$$2643 \quad \text{Segment 1} \quad w = \frac{1}{1 + 1.37 \times (1.182)}$$

$$2644 \quad = 0.382$$

$$2645 \quad \text{Segment 2} \quad w = \frac{1}{1 + 0.86 \times (0.485)}$$

$$2646 \quad = 0.706$$

2647 Multiple-Vehicle Driveway Related Collisions

$$2648 \quad \text{Segment 1} \quad w = \frac{1}{1 + 1.10 \times (0.734)}$$

$$2649 \quad = 0.553$$

$$2650 \quad \text{Segment 2} \quad w = \frac{1}{1 + 1.39 \times (0.149)}$$

$$2651 \quad = 0.828$$

2652 Multiple-Vehicle Collisions

$$2653 \quad \text{Intersection 1} \quad w = \frac{1}{1 + 0.80 \times (1.268)}$$

$$2654 \quad = 0.496$$

$$2655 \quad \text{Intersection 2} \quad w = \frac{1}{1 + 0.39 \times (2.658)}$$

$$2656 \quad = 0.491$$

2657 Single-Vehicle Crashes

$$2658 \quad \text{Intersection 1} \quad w = \frac{1}{1 + 1.14 \times (0.234)}$$

$$2659 \quad = 0.789$$

$$2660 \quad \text{Intersection 2} \quad w = \frac{1}{1 + 0.36 \times (0.196)}$$

$$2661 \quad = 0.934$$

2662 *Column 8 - Expected Average Crash Frequency*

2663 The estimate of expected average crash frequency, N_{expected} , is calculated using
 2664 Equation A-4 from *Part C Appendix* as follows:

$$2665 \quad N_{\text{expected}} = w \times N_{\text{predicted}} + (1 - w) \times N_{\text{observed}}$$

2666 Multiple-Vehicle Nondriveway Collisions

$$2667 \quad \text{Segment 1} \quad N_{\text{expected}} = 0.234 \times 4.967 + (1 - 0.234) \times 7$$

$$2668 \quad = 6.524$$

$$2669 \quad \text{Segment 2} \quad N_{\text{expected}} = 0.231 \times 2.524 + (1 - 0.231) \times 6$$

$$2670 \quad = 5.197$$

2671 Single-Vehicle Crashes

$$2672 \quad \text{Segment 1} \quad N_{\text{expected}} = 0.382 \times 1.182 + (1 - 0.382) \times 4$$

$$2673 \quad = 2.924$$

$$2674 \quad \text{Segment 2} \quad N_{\text{expected}} = 0.706 \times 0.485 + (1 - 0.706) \times 3$$

$$2675 \quad = 1.224$$

2676 Multiple-Vehicle Driveway Related Collisions

$$2677 \quad \text{Segment 1} \quad N_{\text{expected}} = 0.553 \times 0.734 + (1 - 0.553) \times 2$$

$$2678 \quad = 1.300$$

$$2679 \quad \text{Segment 2} \quad N_{\text{expected}} = 0.828 \times 0.149 + (1 - 0.828) \times 1$$

$$2680 \quad = 0.295$$

2681 Multiple-Vehicle Collisions

$$2682 \quad \text{Intersection 1} \quad N_{\text{expected}} = 0.496 \times 1.268 + (1 - 0.496) \times 2$$

$$2683 \quad = 1.637$$

$$2684 \quad \text{Intersection 2} \quad N_{\text{expected}} = 0.491 \times 2.658 + (1 - 0.491) \times 6$$

$$2685 \quad = 4.359$$

2686 Single-Vehicle Crashes

$$2687 \quad \text{Intersection 1} \quad N_{\text{expected}} = 0.789 \times 0.234 + (1 - 0.789) \times 3$$

$$2688 \quad = 0.818$$

$$2689 \quad \text{Intersection 2} \quad N_{\text{expected}} = 0.934 \times 0.196 + (1 - 0.934) \times 0$$

$$2690 \quad = 0.183$$

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Worksheets 3B – Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

Worksheet 3B provides a summary of the vehicle-pedestrian and vehicle-bicycle crashes determined in Sample Problems 1 through 4.

Worksheet 3B – Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials		
(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.089	0.048
Segment 2	0.212	0.041
INTERSECTIONS		
Intersection 1	0.032	0.024
Intersection 2	0.475	0.043
COMBINED (sum of column)	0.808	0.156

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Worksheets 3C – Site-Specific EB Method Summary Results for Urban and Suburban Arterials

Worksheet 3C presents a summary of the results. Column 5 calculates the expected average crash frequency by severity level for vehicle crashes only by applying the proportion of predicted average crash frequency by severity level (Column 2) to the expected average crash frequency calculated using the site-specific EB Method. Column 6 calculates the total expected average crash frequency by severity level using the values in Column 3, 4 and 5.

Worksheet 3C – Site-Specific EB Method Summary Results for Urban and Suburban Arterials					
(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	N_{predicted}	N_{ped}	N_{bike}	N_{expected (VEHICLE)}	N_{expected}
Total	(2) _{COMB} Worksheet 3A 14.397	(2) _{COMB} Worksheet 3B 0.808	(3) _{COMB} Worksheet 3B 0.156	(13) _{COMB} Worksheet 3A 24.461	(3) + (4) + (5) 25.4
Fatal and injury (FI)	(3) _{COMB} Worksheet 3A 3.920	(2) _{COMB} Worksheet 3B 0.808	(3) _{COMB} Worksheet 3B 0.156	(5) _{TOTAL} * (2) _{FI} / (2) _{TOTAL} 6.660	(3) + (4) + (5) 7.6
Property damage only (PDO)	(4) _{COMB} Worksheet 3A 10.476	- 0.000	- 0.000	(5) _{TOTAL} * (2) _{PDO} / (2) _{TOTAL} 17.800	(3) + (4) + (5) 17.8

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2702 **12.13.6. Sample Problem 6**

2703 ***The Project***

2704 A project of interest consists of four sites located on an urban arterial: a three-
2705 lane TWLTL segment; a four-lane divided segment; a three-leg intersection with
2706 minor-road stop control; and a four-leg signalized intersection. (This project is a
2707 compilation of roadway segments and intersections from Sample Problems 1 through
2708 4.)

2709 ***The Question***

2710 What is the expected average crash frequency of the project for a particular year
2711 incorporating both the predicted average crash frequencies from Sample Problems 1
2712 through 4 and the observed crash frequencies using the **project-level EB Method**?

2713 ***The Facts***

- 2 roadway segments (3T segment, 4D segment)
- 2 intersection (3ST intersection, 4SG intersection)
- 34 observed crashes (but no information is available to attribute specific crashes to specific sites)

2714 ***Outline of Solution***

2715 Observed crash frequencies for the project as a whole are combined with
2716 predicted average crash frequencies for the project as a whole using the project-level
2717 EB Method (i.e. observed crash data for individual roadway segments and
2718 intersections are not available, but observed crashes are assigned to a facility as a
2719 whole) presented in Section A.2.5 of *Part C* Appendix.

2720 **Results**

2721 The expected average crash frequency for the project is 26.0 crashes per year
2722 (rounded to one decimal place).

2723 ***Worksheets***

2724 To apply the project-level EB Method to multiple roadway segments and
2725 intersections on an urban or suburban arterial combined, three worksheets are
2726 provided for determining the expected average crash frequency. The three
2727 worksheets include:

- 2728 ▪ Worksheet 4A – Predicted Crashes by Collision and Site Type and Observed
2729 Crashes Using the Project-Level EB Method for Urban and Suburban
2730 Arterials
- 2731 ▪ Worksheet 4B – Predicted Pedestrian and Bicycle Crashes for Urban and
2732 Suburban Arterials
- 2733 ▪ Worksheet 4C – Project-EB Method Summary Results for Urban and
2734 Suburban Arterials

2735 Details of these worksheets are provided below. Blank versions of worksheets
2736 used in the Sample Problems are provided in Chapter 12 Appendix A.

2737 ***Worksheets 4A – Predicted Crashes by Collision and Site Type and Observed***
2738 ***Crashes Using the Project-Level EB Method for Urban and Suburban Arterials***

2739 The predicted average crash frequencies by severity level and collision type,
2740 excluding vehicle-pedestrian and vehicle-bicycle collisions, determined in Sample
2741 Problems 1 through 4 are entered in Columns 2 through 4 of Worksheet 4A. Column
2742 5 presents the total observed crash frequencies combined for all sites, and Column 6
2743 presents the overdispersion parameters. The expected average crash frequency is
2744 calculated by applying the project-level EB Method which considers both the
2745 predicted model estimate for each roadway segment and intersection and the project
2746 observed crashes. Column 7 calculates N_{w0} and Column 8 N_{w1} . Equations A-10
2747 through A-14 from *Part C* Appendix are used to calculate the expected average crash
2748 frequency of combined sites. The results obtained from each equation are presented
2749 in Columns 9 through 14. Section A.2.5 in *Part C* Appendix defines all the variables
2750 used in this worksheet. Detailed calculations of Columns 9 through 13 are provided
2751 below.

Worksheet 4A – Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Collision type/ site type	Predicted crashes			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion parameter, k	$N_{predicted\ w0}$	$N_{predicted\ w1}$	w_0	N_o	w_1	N_1	$N_{expected/comb}$ (VEHICLE)
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-8 $(6) * (2)^2$	Equation A-9 $(\sqrt{k} * (6) * (2))$	Equation A-10	Equation A-11	Equation A-12	Equation A-13	Equation A-14
ROADWAY SEGMENTS												
Multiple-vehicle nondriveway												
Segment 1	4.967	1.196	3.771	-	0.66	16.283	1.811	-	-	-	-	-
Segment 2	2.524	0.702	1.822	-	1.32	8.409	1.825	-	-	-	-	-
Single-vehicle												
Segment 1	1.182	0.338	0.844	-	1.37	1.914	1.273	-	-	-	-	-
Segment 2	0.485	0.085	0.401	-	0.86	0.202	0.646	-	-	-	-	-
Multiple-vehicle driveway-related												
Segment 1	0.734	0.179	0.555	-	1.10	0.593	0.899	-	-	-	-	-
Segment 2	0.149	0.042	0.107	-	1.39	0.031	0.455	-	-	-	-	-
INTERSECTIONS												
Multiple-vehicle												
Intersection 1	1.268	0.405	0.862	-	0.80	1.286	1.007	-	-	-	-	-
Intersection 2	2.658	0.845	1.812	-	0.39	2.755	1.018	-	-	-	-	-
Single-vehicle												
Intersection 1	0.234	0.072	0.162	-	1.14	0.062	0.516	-	-	-	-	-
Intersection 2	0.196	0.056	0.140	-	0.36	0.014	0.266	-	-	-	-	-
COMBINED (sum of column)	14.397	3.920	10.476	34	-	31.549	9.716	0.313	27.864	0.597	22.297	25.080

2752 NOTE: $N_{predicted\ w0}$ = Predicted number of total accidents assuming that accidents frequencies are statistically independent

2753
$$N_{predicted\ w0} = \sum_{j=1}^5 k_{mj} N_{mj}^2 + \sum_{j=1}^5 k_{rsj} N_{rsj}^2 + \sum_{j=1}^5 k_{rdj} N_{rdj}^2 + \sum_{j=1}^4 k_{inj} N_{inj}^2 + \sum_{j=1}^4 k_{isj} N_{isj}^2 \quad (A-8)$$

2754 $N_{predicted\ w1}$ = Predicted number of total accidents assuming that accidents frequencies are perfectly correlated

2755
$$N_{predicted\ w1} = \sum_{j=1}^5 \sqrt{k_{mj} N_{mj}} + \sum_{j=1}^5 \sqrt{k_{rsj} N_{rsj}} + \sum_{j=1}^5 \sqrt{k_{rdj} N_{rdj}} + \sum_{j=1}^4 \sqrt{k_{inj} N_{inj}} + \sum_{j=1}^4 \sqrt{k_{isj} N_{isj}} \quad (A-9)$$

2756 *Column 9 – w_0*

2757 The weight placed on predicted crash frequency under the assumption that
2758 accidents frequencies for different roadway elements are statistically independent,
2759 w_0 , is calculated using Equation A-10 from *Part C* Appendix as follows:

$$\begin{aligned}
 2760 \quad w_0 &= \frac{1}{1 + \frac{N_{\text{predicted } w0}}{N_{\text{predicted (TOTAL)}}}} \\
 2761 &= \frac{1}{1 + \frac{31.549}{14.397}} \\
 2762 &= 0.313
 \end{aligned}$$

2763 *Column 10 – N_0*

2764 The expected crash frequency based on the assumption that different roadway
2765 elements are statistically independent, N_0 , is calculated using Equation A-11 from
2766 *Part C* Appendix as follows:

$$\begin{aligned}
 2767 \quad N_0 &= w_0 N_{\text{predicted (TOTAL)}} + (1 - w_0) N_{\text{observed (TOTAL)}} \\
 2768 &= 0.313 \times 14.397 + (1 - 0.313) \times 34 \\
 2769 &= 27.864
 \end{aligned}$$

2770 *Column 11 – w_1*

2771 The weight placed on predicted crash frequency under the assumption that
2772 accidents frequencies for different roadway elements are perfectly correlated, w_1 , is
2773 calculated using Equation A-12 from *Part C* Appendix as follows:

$$\begin{aligned}
 2774 \quad w_1 &= \frac{1}{1 + \frac{N_{\text{predicted } w1}}{N_{\text{predicted (TOTAL)}}}} \\
 2775 &= \frac{1}{1 + \frac{9.716}{14.397}} \\
 2776 &= 0.597
 \end{aligned}$$

2777 *Column 12 – N_1*

2778 The expected crash frequency based on the assumption that different roadway
2779 elements are perfectly correlated, N_1 , is calculated using Equation A-13 from *Part C*
2780 Appendix as follows:

$$\begin{aligned}
 2781 \quad N_1 &= w_1 N_{\text{predicted (TOTAL)}} + (1 - w_1) N_{\text{observed (TOTAL)}} \\
 2782 &= 0.597 \times 14.397 + (1 - 0.597) \times 34 \\
 2783 &= 22.297
 \end{aligned}$$

2784 *Column 13 – N_{expected/comb}*

2785 The expected average crash frequency based of combined sites, N_{expected/comb}, is
 2786 calculated using Equation A-14 from *Part C* Appendix as follows:

$$\begin{aligned}
 2787 \quad N_{\text{expected/comb}} &= \frac{N_0 + N_1}{2} \\
 2788 \quad &= \frac{27.864 + 22.297}{2} \\
 2789 \quad &= 25.080
 \end{aligned}$$

2790

2791 **Worksheets 4B – Predicted Pedestrian and Bicycle Crashes for Urban and**
 2792 **Suburban Arterials**

2793 Worksheet 4B provides a summary of the vehicle-pedestrian and vehicle-bicycle
 2794 crashes determined in Sample Problems 1 through 4.

Worksheet 4B – Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials		
(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.089	0.048
Segment 2	0.212	0.041
INTERSECTIONS		
Intersection 1	0.032	0.024
Intersection 2	0.475	0.043
COMBINED (sum of column)	0.808	0.156

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Worksheets 4C – Project-Level EB Method Summary Results for Urban and Suburban Arterials

Worksheet 4C presents a summary of the results. Column 5 calculates the expected average crash frequency by severity level for vehicle crashes only by applying the proportion of predicted average crash frequency by severity level (Column 2) to the expected average crash frequency calculated using the project-level EB Method. Column 6 calculates the total expected average crash frequency by severity level using the values in Column 3, 4 and 5.

Worksheet 4C – Project-Level EB Method Summary Results for Urban and Suburban Arterials					
(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	N_{predicted}	N_{ped}	N_{bike}	N_{expected/comb} (VEHICLE)	N_{expected}
Total	(2) _{COMB} Worksheet 4A 14.397	(2) _{COMB} Worksheet 4B 0.808	(3) _{COMB} Worksheet 4B 0.156	(13) _{COMB} Worksheet 4A 25.080	(3) + (4) + (5) 26.0
Fatal and injury (FI)	(3) _{COMB} Worksheet 4A 3.920	(2) _{COMB} Worksheet 4B 0.808	(3) _{COMB} Worksheet 4B 0.156	(5) _{TOTAL} * (2) _{FI} / (2) _{TOTAL} 6.829	(3) + (4) + (5) 7.8
Property damage only (PDO)	(4) _{COMB} Worksheet 4A 10.476	- 0.000	- 0.000	(5) _{TOTAL} * (2) _{PDO} / (2) _{TOTAL} 18.250	(3) + (4) + (5) 18.3

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12.14. REFERENCES

2801

1. Bonneson, J. A., K. Zimmerman, and K. Fitzpatrick. *Roadway Safety Design Synthesis*. Report No. FHWA/TX-05/0-4703--1, Texas Department of Transportation, November, 2005.

2802

2804

2. Clark, J. E., S. Maghsoodloo, and D. B. Brown. Public Good Relative to Right-Turn-on-Red in South Carolina and Alabama. In *Transportation Research Record* 926. 1983.

2805

2806

2807

3. Elvik, R. and T. Vaa. *The Handbook of Road Safety Measures*, Elsevier Science, 2004.

2808

2809

4. Federal Highway Administration Interactive Highway Safety Design Model. Available from <http://www.tfhrc.gov/safety/ihsdm/ihsdm.htm>.

2810

2811

5. Federal Highway Administration Planning Glossary, 2008. Available from http://www.fhwa.dot.gov/planning/glossary/glossary_listing.cfm?sort=definition&TitleStart=A.

2812

2813

2814

6. Harkey, D. L., S. Raghavan, B. Jongdea, F. M. Council, K. Eccles, N. Lefler, F. Gross, B. Persaud, C. Lyon, E. Hauer, and J. Bonneson. *Crash Reduction Factors for Traffic Engineering and ITS Improvement*. National Cooperative Highway Research Program Report No. 617, TBB, NCHRP, Washington, D.C.

2815

2816

2817

2818

2819

7. Harwood, D. W., K. M. Bauer, I. B. Potts, D. J. Torbic, K. R. Richard, E. R. Kohlman Rabbani, E. Hauer, and L. Elefteriadou. *Safety Effectiveness of Intersection Left- and Right-Turn Lanes*. Report No. FHWA-RD-02-089, Federal Highway Administration, U.S. Department of Transportation, April 2002.

2820

2821

2822

2823

8. Harwood, D. W., K. M. Bauer, K. R. Richard, D. K. Gilmore, J. L. Graham, I. B. Potts, D. J. Torbic, and E. Hauer. *Methodology to Predict the Safety Performance of Urban and Suburban Arterials*. National Cooperative Highway Research Program Web-Only Document 129, Phases I and II, NCHRP, TRB, Washington, DC, March 2007.

2824

2825

2826

2827

2828

9. Harwood, D. W., D. J. Torbic, D. K. Gilmore, C. D. Bokenkroger, J. M. Dunn, C. V. Zegeer, R. Srinivasan, D. Carter, and C. Raborn. *Methodology to Predict the Safety Performance of Urban and Suburban Arterials: Pedestrian Safety Prediction Methodology*. National Cooperative Highway Research Program Web-Only Document 129, Phase III, NCHRP, Transportation Research Board, Washington, DC, March, 2008.

2829

2830

2831

2832

2833

2834

10. Hauer, E. *Left-Turn Protection, Safety, Delay and Guidelines: A Literature Review*. Federal Highway Administration, U.S. Department of Transportation, October, 2004. Available from <http://www.roadssafetyresearch.com>.

2835

2836

2837

11. Lyon, C., A. Haq, B. Persaud, and S. T. Kodama. *Development of Safety Performance Functions for Signalized Intersections in a Large Urban Area and Application to Evaluation of Left-Turn Priority Treatment*. Presented at the 84th Annual Meeting of the Transportation Research Board, Washington, DC, January, 2005.

2838

2839

2840

2841

2842

12. Persaud, B., F. M. Council, C. Lyon, K. Eccles, and M. Griffith. *A Multi-Jurisdictional Safety Evaluation of Red Light Cameras*. 84th Transportation Research Board Annual Meeting, Washington, DC, 2005. pp. 1-14.

2843

2844

2845

13. Srinivasan, R., C. V. Zegeer, F. M. Council, D. L. Harkey, and D. J. Torbic. *Updates to the Highway Safety manual Part D AMFs*. Unpublished

2846

- 2847 memorandum prepared as part of the FHWA Highway Safety Information
2848 System project. Highway Safety Research Center, University of North
2849 Carolina, Chapel Hill, NC, July, 2008.
- 2850 14. Srinivasan, R., F. M. Council, and D. L. Harkey. *Calibration Factors for HSM*
2851 *Part C Predictive Models*. Unpublished memorandum prepared as part of the
2852 FHWA Highway Safety Information System project. Highway Safety
2853 Research Center, University of North Carolina, Chapel Hill, NC, October,
2854 2008
- 2855 15. Zegeer, C. V., and M. J. Cynecki. Determination of Cost-Effective Roadway
2856 Treatments for Utility Pole Accidents. In *Transportation Research Record 970*.
2857 TRB, National Research Council, 1984.
- 2858
- 2859
- 2860

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**APPENDIX A - WORKSHEETS FOR
PREDICTIVE METHOD FOR URBAN AND
SUBURBAN ARTERIALS**

Worksheet 1A – General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Roadway Section	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data	Base Conditions	Site Conditions	
Road type (2U, 3T, 4U, 4D, 5T)	-		
Length of segment, L (mi)	-		
AADT (veh/day)	-		
Type of on-street parking (none/parallel/angle)	none		
Proportion of curb length with on-street parking	-		
Median width (ft)	15		
Lighting (present / not present)	not present		
Auto speed enforcement (present/not present)	not present		
Major commercial driveways (number)	-		
Minor commercial driveways (number)	-		
Major industrial/institutional driveways (number)	-		
Minor industrial/institutional driveways (number)	-		
Major residential driveways (number)	-		
Minor residential driveways (number)	-		
Other driveways (number)	-		
Speed Category	-		
Roadside fixed object density (fixed objects/mi)	not present		
Offset to roadside fixed objects (ft)	not present		
Calibration Factor, C _r	1.0		

2865

Worksheet 1B – Accident Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
AMF for On-Street Parking	AMF for Roadside Fixed Objects	AMF for Median Width	AMF for Lighting	AMF for Auto Speed Enforcement	Combined AMF
AMF _{1r}	AMF _{2r}	AMF _{3r}	AMF _{4r}	AMF _{5r}	AMF _{COMB}
from Equation 12-32	from Equation 12-33	from Exhibit 12-39	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)

2866

Worksheet 1C – Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)						
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N _{brmv}	Proportion of total crashes	Adjusted N _{brmv}	Combined AMFs	Calibration factor	Predicted N _{brmv}						
	from Exhibit 12-5									from Exhibit 12-5	from Equation 12-10	(4) _{TOTAL} * (5)	(6) from Worksheet 1B	C _r	(6)*(7)*(8)
	a	b													
Total															
Fatal and injury (FI)					(4) _{FI} / ((4) _{FI} + (4) _{PDO})										
Property damage only (PDO)					(5) _{TOTAL} - (5) _{FI}										

2867

Worksheet 1D – Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type ^(F1)	Predicted N _{brmv} ^(F1) (crashes/year)	Proportion of Collision Type ^(PDO)	Predicted N _{brmv} ^(PDO) (crashes/year)	Predicted N _{brmv} ^(TOTAL) (crashes/year)
	from Exhibit 12-7	(9) _{F1} from Worksheet 1C	from Exhibit 12-7	(9) _{PDO} from Worksheet 1C	(9) _{TOTAL} from Worksheet 1C
Total	1.000		1.000		
		(2) * (3) _{F1}		(4) * (5) _{PDO}	(3) + (5)
Rear-end collision					
Head-on collision					
Angle collision					
Sideswipe, same direction					
Sideswipe, opposite direction					
Other multiple-vehicle collision					

2868

Worksheet 1E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity level	SPF Coefficients		Overdispersion Parameter, k	Initial N _{brsv}	Proportion of total crashes	Adjusted N _{brsv}	Combined AMFs	Calibration factor	Predicted N _{brsv}
	from Exhibit 12-8	from Exhibit 12-8							
	a	b							
Total									
Fatal and injury (F1)					(4) _{F1} / ((4) _{F1} + (4) _{PDO})				
Property damage only (PDO)					(5) _{TOTAL} - (5) _{F1}				

2869

Worksheet 1F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision type	Proportion of Collision Type _(F1)	Predicted N _{brsv (F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{brsv (PDO)} (crashes/year)	Predicted N _{brsv (TOTAL)} (crashes/year)
	from Exhibit 12-10	(9) _{F1} from Worksheet 1E	from Exhibit 12-10	(9) _{PDO} from Worksheet 1E	(9) _{TOTAL} from Worksheet 1E
Total	1.000		1.000		
		(2) * (3) _{F1}		(4) * (5) _{PDO}	(3) + (5)
Collision with animal					
Collision with fixed object					
Collision with other object					
Other single-vehicle collision					

2870

Worksheet 1G – Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway type	Number of driveways, n _j	Crashes per driveway per year, N _j	Coefficient for traffic adjustment, t	Initial N _{brdwy}	Overdispersion parameter, k
		from Exhibit 12-11	from Exhibit 12-11	Equation 12-16 n _j *N _j *(AADT/15,000) ^t	from Exhibit 12-11
Major commercial					
Minor commercial					
Major industrial/institutional					
Minor industrial/institutional					
Major residential					
Minor residential					
Other					
Total		-	-	-	

2871

Worksheet 1H – Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Initial N_{brdwy}	Proportion of total accidents (f_{dwy})	Adjusted N_{brdwy}	Combined AMFs	Calibration factor, C_r	Predicted N_{brdwy}
	(5) _{TOTAL} from Worksheet 1G	from Exhibit 12-11	(2) _{TOTAL} * (3)	(6) from Worksheet 1B		(4) * (5) * (6)
Total						
Fatal and injury (FI)	-					
Property damage only (PDO)	-					

2872

Worksheet 1I – Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{pedr}	Calibration factor, C_r	Predicted N_{pedr}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-17		(5) * (6) * (7)
Total							
Fatal and injury (FI)	-	-	-	-	-		

2873

Worksheet 1J – Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash severity level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{biker}	Calibration factor, C_r	Predicted N_{biker}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Exhibit 12-18		(5) * (6) * (7)
Total							
Fatal and injury	-	-	-	-	-		

2874

Worksheet 1K – Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H;	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)			
Head-on collisions (from Worksheet 1D)			
Angle collisions (from Worksheet 1D)			
Sideswipe, same direction (from Worksheet 1D)			
Sideswipe, opposite direction (from Worksheet 1D)			
Driveway-related collisions (from Worksheet 1H)			
Other multiple-vehicle collision (from Worksheet 1D)			
Subtotal			
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)			
Collision with fixed object (from Worksheet 1F)			
Collision with other object (from Worksheet 1F)			
Other single-vehicle collision (from Worksheet 1F)			
Collision with pedestrian (from Worksheet 1I)			
Collision with bicycle (from Worksheet 1J)			
Subtotal			
Total			

2875

Worksheet 1L – Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash severity level	Predicted average crash frequency, $N_{predicted}$ (crashes/year)	Roadway segment length, L (mi)	Crash rate (crashes/mi/year)
	(Total) from Worksheet 1K		(2)/(3)
Total			
Fatal and injury (FI)			
Property damage only (PDO)			

2876

Worksheet 2A – General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		Location Information	
Analyst		Roadway	
Agency or Company		Intersection	
Date Performed		Jurisdiction	
		Analysis Year	
Input Data		Base Conditions	Site Conditions
Intersection type (3ST, 3SG, 4ST, 4SG)		-	
AADT _{major} (veh/day)		-	
AADT _{minor} (veh/day)		-	
Intersection lighting (present/not present)		not present	
Calibration factor, C _i		1.00	
Data for unsignalized intersections only:		-	
Number of major-road approaches with left-turn lanes (0,1,2)		0	
Number of major-road approaches with right-turn lanes (0,1,2)		0	
Data for signalized intersections only:		-	
Number of approaches with left-turn lanes (0,1,2,3,4)		0	
Number of approaches with right-turn lanes (0,1,2,3,4)		0	
Number of approaches with left-turn signal phasing		-	
Type of left-turn signal phasing		permissive	
Intersection red light cameras (present/not present)		not present	
Sum of all pedestrian crossing volumes (PedVol)		-	
Maximum number of lanes crossed by a pedestrian (n _{lanes})		-	
Number of bus stops within 300 m (1,000 ft) of the intersection		0	
Schools within 300 m (1,000 ft) of the intersection (present/not present)		not present	
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	

Worksheet 2B – Accident Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AMF for Left-Turn Lanes	AMF for Left-Turn Signal Phasing	AMF for Right-Turn Lanes	AMF for Right Turn on Red	AMF for Lighting	AMF for Red Light Cameras	Combined AMF
AMF _{1i}	AMF _{2i}	AMF _{3i}	AMF _{4i}	AMF _{5i}	AMF _{6i}	AMF _{COMB}
from Exhibit 12-41	from Exhibit 12-42	from Exhibit 12-43	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)

2878

Worksheet 2C – Multiple-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections										
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N _{bimv}	Proportion of total crashes	Adjusted N _{bimv}	Combined AMFs	Calibration Factor, C _i	Predicted N _{bimv}
	from Exhibit 12-19									
	a	b	c							
Total										
Fatal and injury (FI)						(4) _{FI} / ((4) _{FI} + (4) _{PDO})				
Property damage only (PDO)						(5) _{TOTAL} - (5) _{FI}				

2879

Worksheet 2D – Multiple-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections

(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(FI)	Predicted N _{bimv (FI)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{bimv (PDO)} (crashes/year)	Predicted N _{bimv (TOTAL)} (crashes/year)
	from Exhibit 12-24	(9) _{FI} from Worksheet 2C	from Exhibit 12-24	(9) _{PDO} from Worksheet 2C	(9) _{PDO} from Worksheet 2C
Total	1.000		1.000		
		(2)* (3) _{FI}		(4)* (5) _{PDO}	(3) + (5)
Rear-end collision					
Head-on collision					
Angle collision					
Sideswipe					
Other multiple-vehicle collision					

2880

Worksheet 2E – Single-Vehicle Collisions by Severity Level for Urban and Suburban Arterial Intersections

(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash severity Level	SPF Coefficients			Overdispersion Parameter, k	Initial N _{bisv}	Proportion of total crashes	Adjusted N _{bisv}	Combined AMFs	Calibration Factor, C _i	Predicted N _{bisv}
	from Exhibit 12-25			from Exhibit 12-25	from Equation 12-25: (FI) from Equation 12-25 or 12-27		(4) _{TOTAL} * (5)	(7) from Worksheet 2B		(6) * (7) * (8)
a	b	c								
Total										
Fatal and injury (FI)						(4) _{FI} / ((4) _{FI} + (4) _{PDO})				
Property damage only (PDO)						(5) _{TOTAL} - (5) _{FI}				

2881

Worksheet 2F – Single-Vehicle Collisions by Collision Type for Urban and Suburban Arterial Intersections					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	Proportion of Collision Type _(F1)	Predicted N _{b_{sv}(F1)} (crashes/year)	Proportion of Collision Type _(PDO)	Predicted N _{b_{sv}(PDO)} (crashes/year)	Predicted N _{b_{sv}(TOTAL)} (crashes/year)
	Exhibit 12-30	(9) _{F1} from Worksheet 2E	Exhibit 12-30	(9) _{PDO} from Worksheet 2E	(9) _{PDO} from Worksheet 2E
Total	1.000		1.000		
		(2) * (3) _{F1}		(4) * (5) _{PDO}	(3) + (5)
Collision with parked vehicle					
Collision with animal					
Collision with fixed object					
Collision with other object					
Other single-vehicle collision					
Single-vehicle noncollision					

2882

Worksheet 2G – Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Stop-Controlled Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Predicted N _{b_{imv}}	Predicted N _{b_{sv}}	Predicted N _{bi}	f _{pedi}	Calibration factor, C _i	Predicted N _{pedi}
	(9) from Worksheet 2C	(9) from Worksheet 2E	(2) + (3)	from Exhibit 12-33		(4) * (5) * (6)
Total						
Fatal and injury (FI)	-	-	-	-		

2883

Worksheet 2H – Accident Modification Factors for Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections			
(1)	(2)	(3)	(4)
AMF for Bus Stops	AMF for Schools	AMF for Alcohol Sales Establishments	Combined AMF
AMF _{1p}	AMF _{2p}	AMF _{3p}	
from Exhibit 12-45	from Exhibit 12-46	from Exhibit 12-47	(1) * (2) * (3)

2884

Worksheet 2I – Vehicle-Pedestrian Collisions for Urban and Suburban Arterial Signalized Intersections

(1)	(2)					(3)	(4)	(5)	(6)	(7)
Crash severity level	SPF Coefficients					Overdispersion Parameter, k	$N_{pedbase}$	Combined AMF	Calibration factor, C_i	Predicted N_{pedi}
	from Exhibit 12-31						from Equation 12-30			
	a	b	c	d	e					
Total										
Fatal and injury (FI)	-	-	-	-	-	-	-	-		(8)*(9)*(10)

2885

Worksheet 2J – Vehicle-Bicycle Collisions for Urban and Suburban Arterial Intersections

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash severity level	Predicted N_{bimv}	Predicted N_{bisv}	Predicted N_{bi}	f_{bikei}	Calibration factor, C_i	Predicted N_{pedi}
	(9) from Worksheet 2C	(9) from Worksheet 2E	(2) + (3)	from Exhibit 10-34		(4) * (5) * (6)
Total						
Fatal and injury (FI)	-	-	-	-		

2886

Worksheet 2K– Crash Severity Distribution for Urban and Suburban Arterial Intersections			
(1)	(2)	(3)	(4)
Collision type	Fatal and injury (FI)	Property damage only (PDO)	Total
	(3) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J	(5) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J	(6) from Worksheet 2D and 2F; (7) from 2G or 2I and 2J
MULTIPLE-VEHICLE COLLISIONS			
Rear-end collisions (from Worksheet 2D)			
Head-on collisions (from Worksheet 2D)			
Angle collisions (from Worksheet 2D)			
Sideswipe (from Worksheet 2D)			
Other multiple-vehicle collision (from Worksheet 2D)			
Subtotal			
SINGLE-VEHICLE COLLISIONS			
Collision with parked vehicle (from Worksheet 2F)			
Collision with animal (from Worksheet 2F)			
Collision with fixed object (from Worksheet 2F)			
Collision with other object (from Worksheet 2F)			
Other single-vehicle collision (from Worksheet 2F)			
Single-vehicle noncollision (from Worksheet 2F)			
Collision with pedestrian (from Worksheet 2G or 2I)			
Collision with bicycle (from Worksheet 2J)			
Subtotal			
Total			

2887

Worksheet 2L – Summary Results for Urban and Suburban Arterial Intersections	
(1)	(2)
Crash severity level	Predicted average crash frequency, $N_{predicted int}$ (crashes/year)
	(Total) from Worksheet 2K
Total	
Fatal and injury (FI)	
Property damage only (PDO)	

Worksheet 3A – Predicted Crashes by Collision and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type/ site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion parameter, k	Weighted adjustment, w Equation A-5 from Part C Appendix	Expected average crash frequency, $N_{expected}$ (VEHICLE) Equation A-4 from Part C Appendix
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (F1)	$N_{predicted}$ (PDO)				
ROADWAY SEGMENTS							
Multiple-vehicle nondriveway							
Segment 1							
Segment 2							
Segment 3							
Segment 4							
Single-vehicle							
Segment 1							
Segment 2							
Segment 3							
Segment 4							
Multiple-vehicle driveway-related							
Segment 1							
Segment 2							
Segment 3							
Segment 4							
INTERSECTIONS							
Multiple-vehicle							
Intersection 1							
Intersection 2							
Intersection 3							
Intersection 4							
Single-vehicle							
Intersection 1							
Intersection 2							
Intersection 3							
Intersection 4							
COMBINED (sum of column)					-	-	

Worksheet 3B – Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials		
(1)	(2)	(3)
Site Type	N _{ped}	N _{bike}
ROADWAY SEGMENTS		
Segment 1		
Segment 2		
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1		
Intersection 2		
Intersection 3		
Intersection 4		
COMBINED (sum of column)		

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Worksheet 3C – Site-Specific EB Method Summary Results for Urban and Suburban Arterials					
(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	N _{predicted}	N _{ped}	N _{bike}	N _{expected} (VEHICLE)	N _{expected}
Total	(2) _{COMB} Worksheet 3A	(2) _{COMB} Worksheet 3B	(3) _{COMB} Worksheet 3B	(13) _{COMB} Worksheet 3A	(3) + (4) + (5)
Fatal and injury (FI)	(3) _{COMB} Worksheet 3A	(2) _{COMB} Worksheet 3B	(3) _{COMB} Worksheet 3B	(5) _{TOTAL} * (2) _{FI} / (2) _{TOTAL}	(3) + (4) + (5)
Property damage only (PDO)	(4) _{COMB} Worksheet 3A	-	-	(5) _{TOTAL} * (2) _{PDO} / (2) _{TOTAL}	(3) + (4) + (5)
		0.000	0.000		

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Worksheet 4A – Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Collision type/ site type	Predicted crashes			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion parameter, k	$N_{predicted\ w0}$	$N_{predicted\ w1}$	w_o	N_o	w_1	N_1	$N_{expected/comb}$ (VEHICLE)
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-8 $(6) * (2)^2$	Equation A-9 $(\sqrt{(6) * (2)})$	Equation A-10	Equation A-11	Equation A-12	Equation A-13	Equation A-14
ROADWAY SEGMENTS												
Multiple-vehicle nondriveway												
Segment 1				-				-	-	-	-	-
Segment 2				-				-	-	-	-	-
Segment 3				-				-	-	-	-	-
Segment 4				-				-	-	-	-	-
Single-vehicle												
Segment 1				-				-	-	-	-	-
Segment 2				-				-	-	-	-	-
Segment 3				-				-	-	-	-	-
Segment 4				-				-	-	-	-	-
Multiple-vehicle driveway-related												
Segment 1				-				-	-	-	-	-
Segment 2				-				-	-	-	-	-
Segment 3				-				-	-	-	-	-
Segment 4				-				-	-	-	-	-
INTERSECTIONS												
Multiple-vehicle												
Intersection 1				-				-	-	-	-	-
Intersection 2				-				-	-	-	-	-
Intersection 3				-				-	-	-	-	-
Intersection 4				-				-	-	-	-	-
Single-vehicle												
Intersection 1				-				-	-	-	-	-
Intersection 2				-				-	-	-	-	-
Intersection 3				-				-	-	-	-	-
Intersection 4				-				-	-	-	-	-
COMBINED (sum of column)												

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Worksheet 4B – Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials		
(1)	(2)	(3)
Site Type	N _{ped}	N _{bike}
ROADWAY SEGMENTS		
Segment 1		
Segment 2		
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1		
Intersection 2		
Intersection 3		
Intersection 4		
COMBINED (sum of column)		

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Worksheet 4C – Project-Level EB Method Summary Results for Urban and Suburban Arterials					
(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	N _{predicted}	N _{ped}	N _{bike}	N _{expected/comb} (VEHICLE)	N _{expected}
Total	(2) _{COMB} Worksheet 4A	(2) _{COMB} Worksheet 4B	(3) _{COMB} Worksheet 4B	(13) _{COMB} Worksheet 4A	(3) + (4) + (5)
Fatal and injury (FI)	(3) _{COMB} Worksheet 4A	(2) _{COMB} Worksheet 4B	(3) _{COMB} Worksheet 4B	(5) _{TOTAL} * (2) _{FI} / (2) _{TOTAL}	(3) + (4) + (5)
Property damage only (PDO)	(4) _{COMB} Worksheet 4A	-	-	(5) _{TOTAL} * (2) _{PDO} / (2) _{TOTAL}	(3) + (4) + (5)
		0.000	0.000		

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