CHAPTER 4

DETERMINATION OF COUNTERMEASURES, CRASH-REDUCTION FACTORS AND COSTS

Obtaining the greatest traffic safety improvement possible with limited funds requires crash countermeasures well-matched to the physical features, traffic characteristics and most troublesome crash types present at specific locations. This chapter describes a methodology for identifying a location's crash patterns and possible causes and countermeasures related to those patterns. The methodology is illustrated with a continuation of the intersection example begun in Chapter 3.

Numerous specific countermeasures are listed for consideration, generally involving traffic engineering, highway design, maintenance and law enforcement. Representative data for the benefit/cost (B/C) analysis of the traffic engineering countermeasures are also presented. These data include anticipated countermeasure crash-reduction factors, service life estimates and costs.

CRASH PATTERN IDENTIFICATION

When crashes of a particular type constitute an unexpectedly large proportion of a location's reported crashes, a significant crash pattern is said to exist. Examining the pattern can identify possible causes susceptible to correction. (Causes may be accurately characterized as "probable" only after follow-up engineering studies have tended to support suspected cause-and-effect relationships.)

SEMCOG staff has studied several commonly recurring crash patterns and linked them with their typical (and therefore possible) causes. This manual presents these linkages in a form easily applied by others in evaluating crash patterns occurring at specific locations of concern.

There are numerous crash patterns of potential interest in identifying possible causes. In a manual published by the Federal Highway Administration (FHWA, 1981a), tables relating crash patterns, causes and countermeasures covered twelve crash patterns categorized by SEMCOG as follows:

- multiple-vehicle crashes:
  - head-on and sideswipe/opposite-direction (SS/OD),
  - head-left/rear-left,
  - angle,
  - rear-left/rear-right and sideswipe/ same direction (SS/SD);

- object involved:
  - train,
  - fixed object,
  - parked/parking vehicle,
  - pedestrian/bicyclist;

- driving situation:
  - driveway use,
  - running-off-road,
  - nighttime,
  - wet pavement.

Note that many of these patterns overlap each other in terms of their ability to accurately characterize a given crash; for example, a crash could involve a driver running off the road due to darkness and wet pavement. The patterns one chooses to search for in crash data depend on one's particular safety concerns regarding the location being studied. If there are concerns not addressed by the above list of patterns — such as single-vehicle rollover crashes or crashes involving alcohol and drug-influenced drivers — additional crash patterns can be defined for evaluation.

To identify significant crash patterns for a given location, use a worksheet of the type presented in Figure 4-1 to complete the following steps:

Figure 4-1.
Crash Pattern Identification and Prioritization at

Average Daily Traffic (ADT) Range ___________________

Evaluation Criteria		**Possible Crash Pattern**			
		Head-On & SS/OD	**Head-Left/ Rear-Left**	**Angle**	**Rear-End/ Rear-Right & SS/SD**
Location's Crashes	No. by Type / Total No.	/	/	/	/
	Location's %				
Regional Crash % (table or computation)	4-1. Area Type:				
	4-2. Functional Class:				
	4-3. No. of Lanes: ___				
	4-4. Sig. ___ Unsig. ___				
	Computed (attach details)				
Significant Pattern?	Enter YES if Location's % Exceeds At Least One of the Above Regional %s				
Pattern Priority[1]	Average Regional % [2]				
	Over-Representation Ratio (ORR) = Location's % / Average Regional %				
	Severity Weighting (SW)				
	Pattern Priority Index (PPI) = 10 / (ORR x SW)				

[1] Complete this block only for significant patterns.
[2] Circle or highlight, and then average, only those regional %s which are less than the location's %. This is necessary to guarantee an ORR greater than 1.0.
[3]See Figure 4-6 for a completed example of worksheet.

1. Compute the location's crash percentage for each possible crash pattern. Assume for purposes of this discussion that there is a desire to evaluate a location's crash data for the multiple-vehicle crash patterns listed above and shown again as column headings in Figure 4-1. A reproducible copy of this figure can be found in Appendix F. Enter in each box of the worksheet's first row the number of crashes of the corresponding type, separated by a slash from the total number of crashes at the location. Then enter in each box of the second row the location's crash percentage (100 times the number of crashes of the corresponding type divided by the total number of crashes).

2. Define the location type. In the manner described in Chapter 3, categorize the location by as many of the following features as possible:

   a. area type (urban/rural);

   b. roadway functional class (arterial/collector/local) — for an intersection, the higher or highest functional class of the intersecting roadways, where an arterial is the highest class (meant primarily to carry through traffic) and a local is the lowest class (meant primarily to provide access to abutting properties);

   c. number of lanes — for an intersection, the number of through lanes on the widest approach;

   d. predominant traffic control — for an intersection, the presence or absence of signalization and for a segment, the speed limit; and

   e. average daily traffic (ADT) volume (the 10,000 vehicle per day range within which the location's ADT falls; e.g., 0 to 10,000, 10,001 to 20,000, etc.) — for an intersection, the sum of the volumes on all approaches.

   Enter the categorizations according to criteria "a" to "d" in the corresponding worksheet blanks labeled "4-1" to "4-4." Enter the ADT from criterion "e" in the blank provided just above the body of the worksheet.

3. Determine regional crash percentages for each possible crash pattern. Look up one to four regional crash percentages for each pattern, using tables developed by SEMCOG for intersections in Southeast Michigan (Tables 4-1 to 4-4) and enter them into the appropriate cells of the worksheet. Draw a horizontal line through the row of cells corresponding to any of the four tables not consulted for regional values.

These regional crash percentages were computed with crash data for the entire SEMCOG region. Alternative crash percentages may be calculated for the local level using the appropriate statistical method discussed in Appendix A. If a local crash percentage is derived, it is important to verify that the sample size is sufficient for the community.

4. Compare each crash percentage computed for the location to the corresponding regional crash percentages. If the location's crash percentage exceeds one or more of the regional crash percentages entered in the same column, the location has an above-average proportion of crashes of the indicated type and can be said to have exhibited a significant crash pattern of that type. Indicate significant crash patterns by entering "YES" into the appropriate columns of the worksheet.

To prioritize a location's significant crash patterns for further evaluation, continue using the Figure 4-1 worksheet to complete the following additional steps:

Table 4-1.
Regional Crash Percentages at Intersections by Crash Types: By Area Type

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear-Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
URBAN AREA[2]	**6.7**	**2.1**	**4.4**	**20.3**	**60.7**	**5.4**	**7,129**
1 - 10,000	17	4	4	26	42	8	2,041
10,001 - 20,000	11	3	5	24	50	6	1,960
20,001 - 30,000	7	2	5	22	58	6	1,467
30,001 - 40,000	5	2	5	21	61	5	921
40,001 - 50,000	5	2	5	19	63	5	419
50,001 - 60,000	4	2	6	19	65	5	193
60,001 - 70,000	3	2	6	19	65	4	94
70,001 - 80,000	3	2	3	17	70	5	24
over 80,000	5	0	1	16	72	5	10
RURAL AREA[2]	**36**	**3**	**4.7**	**17.7**	**35**	**4**	**729**
1 - 10,000	48	4	4	21	19	5	536
10,001 - 20,000	25	3	6	20	42	4	115
over 20,000	35	2	4	12	44	3	78

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-2.
Regional Crash Percentages at Intersections by Crash Types: By Higher Functional Class of Roadway

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear- Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
ARTERIAL[2]	**6.1**	**2.2**	**4.8**	**20.9**	**60.4**	**5.3**	**5,824**
1 - 10,000	18	4	5	26	40	7	1,175
10,001 - 20,000	11	3	5	24	50	6	1,834
20,001 - 30,000	7	2	5	22	57	6	1,387
30,001 - 40,000	5	2	6	21	61	5	839
40,001 - 50,000	4	2	6	20	63	5	341
50,001 - 60,000	3	2	6	19	65	5	156
60,001 - 70,000	2	2	6	20	65	4	69
70,001 - 80,000	2	2	3	18	70	5	17
over 80,000	3	1	1	18	73	5	6
COLLECTOR OR LOCAL[2]	**75**	**0**	**0**	**9**	**9**	**0**	**45**
1 - 10,000	75	0	0	9	9	0	45
Major Collector on Next Page							

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-2.
Regional Crash Percentages at Intersections by Crash Types: By Higher Functional Class of Roadway (cont'd)

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear-Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
MAJOR COLLECTOR[2]	**14**	**4.3**	**5.5**	**22.8**	**47.3**	**6.3**	**6,191**
1 - 10,000	25	4	3	28	34	7	5,152
10,001 - 20,000	9	3	5	29	47	6	948
20,001 - 30,000	12	0	6	19	62	2	52
over 30,000	10	10	8	15	46	10	39

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-3.
Regional Crash Percentages at Intersections by Crash Types:
By Number of Through Lanes on Widest Approach

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear- Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
ONE LANE[2]	**15.7**	**2.3**	**2.3**	**9.7**	**67.7**	**2.3**	**48**
1 - 10,000	29	3	3	18	39	7	41
10,001 - 20,000	18	4	4	11	64	0	6
over 20,000	0	0	0	0	100	0	1
TWO LANES[2]	**11.4**	**2.4**	**3.7**	**18.7**	**59.0**	**5.0**	**2,291**
1 - 10,000	24	4	4	25	37	7	1,171
10,001 - 20,000	14	4	6	24	47	6	599
20,001 - 30,000	10	2	5	19	59	5	283
30,001 - 40,000	8	2	4	19	61	5	139
40,001 - 50,000	8	2	5	19	61	5	64
50,001 - 60,000	9	2	1	14	70	4	17
over 60,000	7	1	1	11	78	3	18
Three and Four or More Lanes on Next Page							

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-3.
Regional Crash Percentages at Intersections by Crash Types:
By Number of Through Lanes on Widest Approach (cont'd)

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear- Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
THREE LANES[2]	**8.5**	**2**	**2.9**	**17.5**	**63.5**	**5.4**	**1,619**
1 - 10,000	19	3	3	25	42	7	523
10,001 - 20,000	12	3	5	24	50	6	499
20,001 - 30,000	7	2	4	20	60	6	294
30,001 - 40,000	6	2	4	18	65	5	187
40,001 - 50,000	8	2	3	15	66	7	68
50,001 - 60,000	4	1	3	16	71	5	32
60,001 - 70,000	8	1	1	14	72	3	12
over 70,000	4	2	0	8	82	4	4
FOUR OR MORE LANES[2]	**7.8**	**1.9**	**3.4**	**18.5**	**62.8**	**5.6**	**1,909**
1 - 10,000	20	3	4	26	38	8	510
10,001 - 20,000	10	3	5	24	50	7	549
20,001 - 30,000	7	2	5	21	57	7	428
30,001 - 40,000	6	2	4	20	63	6	256
40,001 - 50,000	5	2	4	16	67	6	107
50,001 - 60,000	5	1	2	19	69	4	35
60,001 - 70,000	5	1	1	9	81	3	20
over 70,000	4	1	2	13	77	4	4

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-3.
Regional Crash Percentages at Intersections by Crash Types:
By Number of Through Lanes on Widest Approach (cont'd)

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear-Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
FIVE OR MORE LANES[2]	**6.5**	**2.3**	**5.6**	**22.5**	**57.4**	**5.4**	**1,991**
1 - 10,000	18	3	4	28	38	8	332
10,001 - 20,000	10	3	5	25	52	5	422
20,001 - 30,000	7	2	6	24	56	5	518
30,001 - 40,000	5	3	7	23	58	5	360
40,001 - 50,000	4	2	6	21	61	5	180
50,001 - 60,000	3	2	7	19	64	5	109
60,001 - 70,000	2	2	7	21	62	5	49
over 70,000	3	1	3	19	68	5	21

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-4.
Regional Crash Percentages at Intersections by Crash Types:
By Presence or Absence of Signalization

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear- Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
SIGNALIZED[2]	**4.8**	**2.2**	**5**	**21.4**	**61**	**5.7**	**3,901**
1 - 10,000	9	4	5	29	45	9	721
10,001 - 20,000	9	3	6	25	51	7	1132
20,001 - 30,000	6	2	6	22	57	6	962
30,001 - 40,000	5	2	6	22	60	5	580
40,001 - 50,000	4	2	6	20	63	5	281
50,001 - 60,000	3	2	6	19	65	5	139
60,001 - 70,000	2	2	6	20	65	4	63
70,001 - 80,000	2	2	3	18	70	5	17
over 80,000	3	1	1	18	73	5	6
Unsignalized on Next Page							

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

Table 4-4.
Regional Crash Percentages at Intersections by Crash Types:
By Presence or Absence of Signalization (cont'd)

Average Daily Traffic Volume Entering Intersection	% Single-Vehicle	% Head-On & Sideswipe/ Opp.-Dir.	% Head-Left/ Rear-Left	% Angle	% Rear-End/ Rear-Right & Sideswipe/ Same-Dir.	% Other & Uncoded	Number of Intersections Sampled[1]
UNSIGNALIZED[2]	**16.3**	**2.1**	**2.6**	**15.4**	**58.7**	**5.4**	**3,957**
1 - 10,000	31	4	3	23	34	6	1,856
10,001 - 20,000	17	3	4	23	47	6	943
20,001 - 30,000	14	2	3	17	59	6	561
30,001 - 40,000	11	2	3	16	63	5	362
40,001 - 50,000	14	1	2	12	65	6	139
50,001 - 60,000	9	1	2	13	70	5	54
over 60,000	18	2	1	4	73	4	42

[1] Size of sample taken from SEMCOG crash data for Southeast Michigan, 2012-2014.
[2] Values on this line are volume-independent. All percentages are distributional averages.

5. Compute the average of all regional crash percentages which are less than the location's crash percentage. Enter the computed value in the corresponding box of the worksheet row labeled "Average Regional Percentage". Circle or highlight the regional values averaged.

6. Compute an over-representation ratio (ORR). Divide the location's crash percentage by the corresponding average regional crash percentage and enter the ratio in the appropriate box of the worksheet. The ORR should be greater than 1.0.

7. Determine a severity weighting (SW). Some crash types are typically more severe than others; for example, angle crashes result in more serious personal injuries, on average, than do rear-end crashes. To reflect this difference, determine a pattern's severity weighting by taking one of the following two approaches:

   a. Use "1" for patterns predominated by rear-end or either direction of sideswipe crash and "2" for all other crash types or, in the event that different crash types are being evaluated, adopt a similar set of simple subjective severity weightings.

   b. If sufficient crash data exist, compute and use the casualty ratio for the crash type(s) in question. Refer to Step 1 of the CPI Method, in Chapter 3, for the definition and equation used to compute a casualty ratio.

   Enter the SW(s) in the appropriate row of the worksheet.

8. Determine pattern priority. Compute a pattern priority index (PPI) for each significant crash pattern by substituting the values of ORR and SW determined in Steps 6 and 7, respectively, into the following equation and solving:

   Eq. (4-1)

$$PPI=\frac{10}{ORRxSW}$$

   Once computed (to one decimal place) for every significant crash pattern and entered in the last row of the worksheet, the PPI values will indicate the relative priorities for further evaluating and potentially treating significant crash patterns. The pattern with the smallest value of PPI should receive the highest priority, and the pattern with the largest value of PPI, the lowest priority. PPI values will function in a manner similar to normal priority rankings, but they will not be whole consecutive numbers. (See Figure 4-6 for a completed example of worksheet.)

DETERMINATION OF POSSIBLE CAUSES

Possible causes may be determined for just one, a few or all significant crash patterns found at a location. The scheme described in the preceding section for prioritizing crash patterns will help analysts make more cost-effective use of their time. Focusing first on the more highly over-represented and severe crash patterns will speed up the process of isolating those causes responsible for the greatest crash losses occurring at a high-crash location.
Figure 4-2 presents 21 possible causes for crash patterns categorized by the multiple-vehicle crash type.

Most of the causes listed deal with some aspect of the driving environment which can influence the probability of a crash. While driver error is invariably cited as the most common cause of crashes, the likelihood of an error occurring can be heavily influenced by the design, operation and maintenance of the roadway — typical responsibilities of local agencies. Other than speed limit posting and enforcement, there is relatively little that such agencies can do to directly modify driver behavior; hence, the only driver error listed here as a crash cause is Excessive Speed.

Possible Causes for Multiple-Vehicle Crash Patterns at ____________________________

Possible Cause	Crash Pattern					
	Head-On & SS/OD	Head-Left/ Rear-Left	Angle		Rear-End/ Rear-Right & SS/SD	
			Sig	Unsig	Sig	Unsig
Pattern Priority Index (PPI)						
Excessive Speed	o	o	o	o	o	o
Restricted Sight Distance	o	o	o	o		o
Slippery Surface			o	o	o	o
Narrow Lanes	o				o	o
Inadequate Signal Change Interval		o	o			
Turning Vehicles Slowing or Stopping in Through Lanes					o	o
Unexpected Slowing and Lane Changing					o	o
Poor Visibility of Traffic Signal			o		o	
Unexpected/Unnecessary Stops Due to Signal			o		o	
Unsafe Right-Turns-on-Red			o		o	
Crossing Pedestrians					o	o
Poor Visibility of STOP/YIELD Signs				o		o
Proper Stopping Position Unclear			o	o		
Inadequate Pavement Markings	o					
Inadequate Roadway Shoulders	o					
Inadequate Maintenance	o					
Severe Curves	o					
Inadequate Gaps in Oncoming Traffic		o				
Inadequate Signalization for Left-Turn Volume		o				
Inadequate Gaps for Turning and Accelerating						o
Unexpected Cross Traffic				o		

See Figure 4-7 for a completed example of worksheet.

Figure 4-2 has been designed to be used as a worksheet in identifying and prioritizing a location's possible crash causes. A reproducible copy of this figure can be found in Appendix F. To apply it as a worksheet, fill in the location name or code in the title block and complete the following steps:

1. Highlight the columns associated with significant crash patterns. Using the results from the Figure 4-1 worksheet, highlight the columns representing significant crash patterns in the current worksheet. Ensure that the columns chosen for angle, rear-end/rear-right & sideswipe/same-direction crash patterns accurately reflect the presence or absence of signalization.

2. Enter the PPI values. Transfer these values from the last row of the Figure 4-1 worksheet to the first row of the Figure 4-2 worksheet, again accounting for the presence or absence of signalization. Indices should be available for entry only in highlighted columns. Draw a horizontal line through the PPI cells in other columns.

3. Highlight possible causes for the highest priority crash pattern. To complete this step:

   a. Locate the pattern having the smallest value of PPI.

   b. Scan the highlighted column associated with this pattern for bullets.

   c. When a bullet is encountered, highlight the possible cause directly to the left.

4. Highlight possible causes for multiple significant crash patterns. Scan all highlighted columns collectively for two or more bullets in the same row of the worksheet and whenever such a situation is found, highlight the possible cause directly to the left of the bullets (if not already highlighted in Step 3).

5. Compile a separate list of the possible causes highlighted in Steps 3 and 4 and declare them to be "higher-priority" possible causes. Use the format shown in Figure 4-3. A full-size reproducible copy of this figure can be found in Appendix F. A possible cause of multiple crash patterns should be listed separately under each related pattern. This is necessary in order to use this list to identify all possible countermeasures (appropriate countermeasures for the same cause will vary with crash pattern).

Figure 4-3.
Higher-Priority Possible Causes for Crash Patterns at ______________________________

Crash Pattern	Possible Cause	Applicable? (Step 7)		Comments
		Yes	**No**	
Causes Associated with Highest Priority Pattern (Step 3)				
Causes Associated with Multiple Patterns (Step 4)				

See Figure 4-8 and Figure 4-9 for completed examples of worksheet.

Addressing these higher-priority causes first should aid in the early consideration of more broadly effective crash countermeasures.

6. Highlight and/or list other possible causes. Review the Figure 4-2 worksheet for possible causes of single significant crash patterns other than the one identified in Step 3. Consider highlighting the names of these causes in the first column using a different color or shading than used in previous steps. Then compile a separate list entitled "Other Possible Causes for Crash Patterns" using the column headings shown in Figure 4-3. A reproducible copy of this form can be found in Appendix F. Your agency may want to address the possible causes on this list at a later time, after first addressing the higher-priority possible causes.

7. Review the lists compiled in Steps 5 and 6 and rule out possible causes which are inconsistent with basic location features. For example, if the travel lanes are all 11 feet or wider, "narrow lanes" should probably not be cited as a possible crash cause. Other obviously inconsistent causes, such as "severe curves" on a perfectly straight road, should also be ruled out.

   Use the "Comments" column of the listing to explain why certain possible causes are being ruled out (or ruled in). Reinforce the sorting process by highlighting causes that are not ruled out. (See Figures 4-7 through 4-9 for completed examples of worksheets.)

DETERMINATION OF POSSIBLE COUNTERMEASURES

Having identified the possible causes of a location's most troublesome crash types, the next logical step is to determine possible countermeasures. Such countermeasures can be determined for a specific multiple-vehicle crash pattern and cause by consulting one of the following tables:

- Head-on and sideswipe/opposite-direction crashes -- Table 4-5;
- Head-left/rear-left crashes: Table 4-6;
- Angle crashes -- signalized: Table 4-7 and unsignalized: Table 4-8;
- Rear-end/rear-right and sideswipe/same-direction crashes -- signalized: Table 4-9 and unsignalized: Table 4-10.

Note that two patterns, angle crashes and the combination of rear-end/rear-right & sideswipe/same-direction crashes, are each treated in a pair of tables differentiated by the form of intersection traffic control (i.e., signalized or unsignalized). Both the analysis of possible causes and the selection of appropriate countermeasures depend on whether or not the location is signalized. It is important to know not only the present form of control, but also that this form was in place throughout the crash data analysis period. For causal analysis to be meaningful and reliable, a signal should not have been added or removed during this analysis period.

Tables 4-5 to 4-10 are intended to be used as a guide in performing B/C analyses and are not to be considered all-inclusive. Users of this manual may add to the tables any crash causes and/or countermeasures unique to local conditions which they have successfully identified in past traffic safety analyses.

The code given in the last column of the tables cross-references each specific countermeasure to a more detailed table used for costing purposes (as discussed later in this chapter). Please note that not all countermeasures include benefit and cost data. Countermeasures for which such data can be obtained can be used in the analysis. Other countermeasures can be studied or researched to obtain such data for future reference. The alphabetic prefix indicates one of the following 11 countermeasure categorizations:

- Signs (SN) -- standard traffic signs for regulating, warning and guiding;
- Signals (SG) -- vehicle and pedestrian signals, intersection warning flashers;
- Markings (MK) -- pavement striping/markers, post delineators, chevrons;
- Channelization (CH) -- channelizing islands, median strips, turning radii;
- Pavement (PV) -- drainage, skid resistance, maintenance, rumble strips;
- Roadway (RD) -- widening lanes/shoulders, banking, realigning, flattening;
- Pedestrian (PE) -- crosswalks, signs, signals, refuge islands, lighting, routing;
- Barriers (BA) -- guardrails, median barriers, impact attenuators;
- Driveways (DY) -- definition, geometry, spacing, corner setback, turning rules;
- Railroad Crossing (RR) -- sight distance, signs, markings, flashers, gates; and
- Miscellaneous (MS) -- sight lines, object hazards, lighting, enforcement, etc.

It must be emphasized that the methodology presented in this chapter for identifying crash causes and countermeasures should generally be limited in its application to the preliminary planning and budgeting of a safety improvement program. This is especially important for the more costly countermeasures and those which may have unexpected or undesirable side-effects at particular locations (e.g., an unwarranted traffic signal may have a net negative effect on safety if increased rear-end crashes greatly outnumber decreased angle crashes).

Table 4-5.
Possible Causes and Countermeasures for Head-On and Sideswipe/Opposite-Direction Crashes

Possible Cause	Possible Countermeasure: Specific Name [1]	Code
Restricted Sight Distance	Install No Passing Zones	MK-10
	Add NO PASSING ZONE Pennant Signs	SN-19
	Reduce Obstructions on Insides of Curves	MS-2
	Lower Roadbed on Hill Crests	RD-7
Inadequate Pavement Markings	Supplement Centerline with RPMs	MK-9
	Upgrade Markings (Halve Maint. Cycle)[2]	MK-1
	Add Ctr + Lanelines to Unstriped Street	MK-4
	Add Ctr + Edgelines to Unstriped Road	MK-6
	Add Centerline to Unstriped Pavement	MK-5
	Install Flush Median	CH-2
	Install Raised Median	CH-1
Narrow Lanes	Eliminate Parking	SN-14
	Widen Lanes	RD-2
Inadequate Roadway Shoulders	Upgrade Roadway Shoulders	RD-1
	Remove/Relocate Obstacles Close to Road	MS-3
Inadequate Maintenance	Repair/Replace Roadway Surface	PV-4
	Repair/Replace Shoulder Surface	PV-5
Severe Curves	Realign Opposing Intersection Legs	RD-4
	Flatten Roadway Curves	RD-6
	Provide Proper Superelevation (Banking)	RD-5
	Post Curve Warnings / Advisory Speeds	SN-20
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9

[1] RPM = Reflective Pavement Marker and Ctr = Centerline.

[2] In other words, reduce the time between repainting to one half of its present value (e.g., repaint every six months instead of annually).

Table 4-6.
Possible Causes and Countermeasures for Head-Left/Rear-Left Crashes

Possible Cause	Possible Countermeasure	
	Specific Name[3]	**Code**
Inadequate Gaps in Oncoming Traffic	Add 2-Way STOP/YIELD at Urban I/S	SN-11
	Add 2-Way STOP at Rural I/S	SN-12
	Change from 2-Way to 4-Way STOP	SN-13
	Signalize Intersection	SG-1
Inadequate Signalization for Left-Turn (LT) Volume	Retime Traffic Signal	SG-2
	Provide Lead/Lag or Split Phasing	SG-9
	Add Pretimed, Protected LT Signals	SG-8
	Install Signal Actuation	SG-12
	Upgrade Signal Controller	SG-15
	Upgrade Signalization	SG-14
	Install Dual LT Lanes, Signs, & Signals	SG-7
	Prohibit Turns	SN-25
	Reroute Left-Turn Traffic	SN-24
	Sign One-Way Street Operation	SN-22
Inadequate Signal Change Interval	Increase Yellow Change Interval	SG-3
	Add All-Red Clearance Interval	SG-4
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9
Restricted Sight Distance	Reduce Obstructions in Median	MS-1
	Favorably Offset Opposing LT Lanes	CH-5
	Move Intersection Away from Curves/Crests	RD-3
	Reduce Obstructions on Insides of Curves	MS-2
	Flatten Curves	RD-6
	Lower Roadbed on Hill Crests	RD-7

[3] I/S = Intersection

Table 4-7.
Possible Causes and Countermeasures for Angle Crashes at Signalized Intersections

Possible Cause	Possible Countermeasure	
	Specific Name	**Code**
Poor Visibility of Traffic Signal	Remove Signal Sight Obstructions	MS-7
	Post SIGNAL AHEAD Warning Signs/Urban	SN-3
	Post SIGNAL AHEAD Warning Signs/Rural	SN-4
	Install/Replace Signal Visors	SG-19
	Add Signal Back Plates	SG-18
	Add/Relocate Signal Head	SG-17
	Install 12-inch Signal Lenses	SG-16
	Install Advance Flasher-Signs	SG-21
	Upgrade Signalization	SG-14
Unexpected/Unnecessary Stops Due to Signal	Retime Traffic Signal	SG-2
	Upgrade Signal Controller	SG-15
	Provide Signal Progression	SG-13
	Install Signal Actuation	SG-12
Inadequate Signal Change Interval	Increase Yellow Change Interval	SG-3
	Add All-Red Clearance Interval	SG-4
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9
Slippery Surface	Post SLIPPERY WHEN WET Signs / Urban	SN-9
	Post SLIPPERY WHEN WET Signs / Rural	SN-10
	Improve Drainage	PV-2
	Groove Pavement	PV-1
	Resurface Roadway	PV-3
Proper Stopping Position Unclear	Add Stop Bars/Crosswalks	MK-2
	Add/Improve Intersection Lighting	MS-8

**Table 4-7.
Possible Causes and Countermeasures for Angle Crashes
at Signalized Intersections (cont'd)**

Possible Cause	Possible Countermeasure	
	Specific Name	**Code**
Unsafe Right-Turns-on-Red (RTOR)	Reduce RTOR Sight Obstructions	MS-6
	Add Right-Turn Lane Channelization	CH-3
	Provide Right-Turn Overlap (Green Arrow)	SG -6
	Prohibit RTOR	SN-23
Restricted Sight Distance	Eliminate Parking Near Intersection	SN-14
	Remove Obstructions from Sight Triangle	MS-4
	Close/Relocate Driveways Near Intersection	DY-1

Table 4-8.
Possible Causes and Countermeasures for Angle Crashes at Unsignalized Intersections

Possible Cause	Possible Countermeasure	
	Specific Name[4]	**Code**
Unexpected Cross Traffic	Install Intersection Warning Signs / Urban	SN-5
	Install Intersection Warning Signs / Rural	SN-6
	Move Intersection Away from Curves/Crests	RD-3
Restricted Sight Distance	Eliminate Parking Near Intersection	SN-14
	Remove Obstructions from Sight Triangle	MS-4
	Close/Relocate Driveways Near Intersection	DY-1
	Add 2-Way STOP/YIELD at Urban I/S	SN-11
	Add 2-Way STOP at Rural I/S	SN-12
	Change from 2-Way to 4-Way STOP	SN-13
	Signalize Intersection	SG-1
Poor Visibility of STOP/YIELD Signs	Remove Sign Sight Obstructions	MS-5
	Install Larger Signs	SN-17
	Install STOP/YIELD AHEAD Signs / Urban	SN-1
	Install STOP AHEAD Signs / Rural	SN-2
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9
Slippery Surface	Post SLIPPERY WHEN WET Signs / Urban	SN-9
	Post SLIPPERY WHEN WET Signs / Rural	SN-10
	Improve Drainage	PV-2
	Groove Pavement	PV-1
	Resurface Roadway	PV-3
Proper Stopping Position Unclear	Add Stop Bars/Crosswalks	MK-2
	Add/Improve Intersection Lighting	MS-8

4 I/S = Intersection

Table 4-9.
Possible Causes and Countermeasures for Rear-End/Rear-Right and Side-Swipe/Same-Direction Crashes at Signalized Intersections

Possible Cause	Possible Countermeasure: Specific Name [5]	Code
Turning Vehicles Slowing or Stopping in Through Lanes	Mark/Lengthen Exclusive Turn Lanes	MK-7
	Install Two-Way Left-Turn Lane	MK-8
	Widen Approaches to Handle Turn Lanes	CH-4
	Increase Curb/Edge-of-Pavement Radius	CH-6
	Add Pretimed, Protected LT Signals	SG-8
	Install Signal Actuation	SG-12
	Install Dual LT Lanes, Signs, & Signals	SG-7
	Provide Split Phasing	SG-9
	Prohibit Turns	SN-25
	Reroute Left-Turn Traffic	SN-24
Unexpected Slowing and Lane Changing	Install Guide Signs	SN-15
	Install Larger Signs	SN-17
	Install Lane-Use Control (Metal) Signs	SN-16
	Install Internally Illuminated Signs	SN-21
Narrow Lanes	Eliminate Parking	SN-14
	Widen Lanes	RD-2
Poor Visibility of Traffic Signal	Remove Signal Sight Obstructions	MS-7
	Post SIGNAL AHEAD Warning Signs/Urban	SN-3
	Post SIGNAL AHEAD Warning Signs/Rural	SN-4
	Install/Replace Signal Visors	SG-19
	Add Signal Back Plates	SG-18
	Add/Relocate Signal Head	SG-17
	Install 12-inch Signal Lenses	SG-16
	Install Advance Flasher-Signs	SG-21
	Upgrade Signalization	SG-14

[5] LT = Left-Turn

Table 4-9.
Possible Causes and Countermeasures for Rear-End/Rear-Right and Side-Swipe/Same-Direction Crashes at Signalized Intersections (cont'd)

Possible Cause	Possible Countermeasure	
	Specific Name	**Code**
Unexpected/Unnecessary Stops Due to Signal	Revise Signal Phasing/Sequence	SG-15
	Retime Traffic Signal	SG-2
	Upgrade Signal Controller	SG-15
	Provide Signal Progression	SG-13
	Install Signal Actuation	SG-12
	Remove Unwarranted Signalization	SG-20
Unsafe Right-Turns-on-Red (RTOR)	Reduce RTOR Sight Obstructions	MS-6
	Add Right-Turn Lane Channelization	CH-3
	Provide Right-Turn Overlap (Green Arrow)	SG-6
	Prohibit RTOR	SN-23
Crossing Pedestrians	Add Stop Bars/Crosswalks	MK-2
	Post Ped Xing/Advance Xing Signs / Urban	SN-7
	Post Ped Xing/Advance Xing Signs / Rural	SN-8
	Place Advance Pavement Messages	MK-3
	Install WALK-DON'T WALK Signals	SG-10
	Add/Improve Intersection Lighting	MS-8
	Reroute Pedestrians to Safer Crossing	PE-1
Slippery Surface	Post SLIPPERY WHEN WET Signs / Urban	SN-9
	Post SLIPPERY WHEN WET Signs / Rural	SN-10
	Improve Drainage	PV-2
	Groove Pavement	PV-1
	Resurface Roadway	PV-3
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9

Table 4-10.
Possible Causes and Countermeasures for Rear-End/Rear-Right and Side-Swipe/Same-Direction Crashes at Unsignalized Intersections

Possible Cause	Possible Countermeasure: Specific Name	Code
Stopping in Through Lanes	Mark/Lengthen Exclusive Turn Lanes	MK-7
	Install Two-Way Left-Turn Lane	MK-8
	Widen Approaches to Handle Turn Lanes	CH-4
	Increase Curb/Edge-of-Pavement Radius	CH-6
	Prohibit Turns	SN-25
	Reroute Left-Turn Traffic	SN-24
Unexpected Slowing and Lane Changing	Install Guide Signs	SN-15
	Install Larger Signs	SN-17
	Install Lane-Use Control (Metal) Signs	SN-16
Narrow Lanes	Eliminate Parking	SN-14
	Widen Lanes	RD-2
Poor Visibility of STOP/YIELD Signs	Remove Sign Sight Obstructions	MS-5
	Install Larger Signs	SN-17
	Install STOP/YIELD AHEAD Signs / Urban	SN-1
	Install STOP AHEAD Signs / Rural	SN-2
Inadequate Gaps for Turning and Accelerating	Change from 2-Way to 4-Way STOP	SN-13
	Signalize Intersection	SG-1
Crossing Pedestrians	Add Stop Bars/Crosswalks	MK-2
	Post Ped Xing/Advance Xing Signs / Urban	SN-7
	Post Ped Xing/Advance Xing Signs / Rural	SN-8
	Place Advance Pavement Messages	MK-3
	Add/Improve Intersection Lighting	MS-8
	Reroute Pedestrians to Safer Crossing	PE-1
	Signalize Pedestrian Crossing	SG-11

Table 4-10.
Possible Causes and Countermeasures for Rear-End/Rear-Right and Side-Swipe/Same-Direction Crashes at Unsignalized Intersections (cont'd)

Possible Cause	Possible Countermeasure	
	Specific Name	**Code**
Slippery Surface	Post SLIPPERY WHEN WET Signs / Urban	SN-9
	Post SLIPPERY WHEN WET Signs / Rural	SN-10
	Improve Drainage	PV-2
	Groove Pavement	PV-1
	Resurface Roadway	PV-3
Excessive Speed	Post/Reduce Speed Limit	SN-19
	Increase Traffic/Speed Enforcement	MS-9
Restricted Sight Distance	Install Intersection Warning Signs / Urban	SN-5
	Install Intersection Warning Signs / Rural	SN-6
	Move Intersection Away from Curves/Crests	RD-3

Additional field surveys and engineering studies will often be necessary to properly justify and design the countermeasures preliminarily selected here (FHWA, 1981b; FHWA, 1986b). Also, any traffic control devices (i.e., signs, signals and markings) involved in proposed countermeasures should be evaluated against applicable warrants in the *Michigan Manual of Uniform Traffic Control Devices* (Michigan, 1994).

The possible countermeasures extracted from Tables 4-5 to 4-10 should be consistent with existing conditions, policies and agency capabilities. To document the systematic review of possible countermeasures, complete the following steps:

1. Identify possible countermeasures. Review Tables 4-5 to 4-10 for selected (higher-priority or other) pattern/cause combinations. Note all possible countermeasures associated with these combinations, regardless of individual countermeasure feasibility or duplication.

2. Compile a separate list of the possible countermeasures identified in Step 1. Use the format shown in Figure 4-4. A full-size reproducible copy of this figure can be found in Appendix F.

3. Review the list compiled in Step 2 and rule out inapplicable countermeasures. Classify as inapplicable any counter-measure that:

   a. duplicates one listed earlier,

   b. is inconsistent with basic location features, or

Figure 4-4.
Possible Countermeasures for Crash Patterns at ____________________________

Crash Pattern	Possible Cause	Possible Countermeasure (Step 1)		Applicable? (Step 3)		Comments
		Specific Name	Generic Code	Yes	No	

See Figure 4-9 for a completed example of worksheet.

   c. would violate agency policy or otherwise be very difficult to implement due to legal, technical, staffing, administrative or budgetary constraints.

For example, assume that a conventionally striped and lighted urban intersection is being evaluated, and that one of the possible crash causes of interest is Inadequate Pavement Markings. Table 4-5 indicates that one of the possible countermeasures for this cause would add reflective pavement markers (RPMs), and three other possible countermeasures would add a centerline. A suitable comment to include in Figure 4-4 for the RPM countermeasure would be: "Unwarranted given existing intersection lighting." A suitable comment for each of the centerline countermeasures would be: "Inapplicable given existing centerline." The "No" column in the figure would be checked for all four inappropriate countermeasures.

Use the "Comments" column of the listing to explain why certain possible countermeasures are being ruled out (or ruled in). Reinforce the sorting process by highlighting counter-measures that are not ruled out. (See Figure 4-10 for a completed example of worksheet.)

DATA FOR B/C ANALYSIS

To compute the B/C ratios used to compare the relative economic attractiveness of alternative crash countermeasures, an interest rate and the following countermeasure-specific inputs must be determined:

- benefits in terms of overall crash-reduction potential, and

- various cost-related parameters, including:

  - implementation cost,
  - operating and maintenance (O&M) cost,
  - service life and
  - salvage value.

Crash-Reduction Potential

Chapter 5's B/C methodology estimates the benefits of a countermeasure as the monetary value of the reduced crashes expected at a location due to countermeasure implementation. A SEMCOG search for relevant technical literature produced several sources of data on countermeasure crash-reduction potential. The results of this search are synthesized in Appendix B. Judgment was applied to the synthesized data in choosing the single default value shown in Tables 4-11 to 4-13 as each countermeasure's Total Crash Reduction Factor (CRF) for the Signs, Signals, and Markings countermeasure categories. Appendix D contains tables of CRF values for these counter-measures for which no associated cost data was available — Channelization, Pavement, Roadway, Pedestrian, Driveway, and Miscellaneous countermeasure categories. These values are rough (certainly unguaranteed) estimates.

The B/C analysis worksheet presented in the next chapter allows the user or the analyst to input alternative CRFs at their discretion. If this is done, care should be exercised in documenting both the action and the basis for the action. Subsequent editions of this manual are likely to include updated values for various CRFs; hence, SEMCOG would appreciate learning about alternative values being used or proposed for use (especially in Southeast Michigan).

The CRFs given in Tables 4-11 to 4-13 and in Appendix D are for the application of a single countermeasure at a location. When a combination of countermeasures is under consideration (see next section), a combined CRF must be estimated. This combined factor is not, however, simply the sum of the individual CRFs, since the effects of multiple countermeasures often interact and overlap. Compute the CRF for a countermeasure combination by completing the following steps:

1. Express the CRF for each countermeasure in the combination as a value, CRF_i, between 0 and 1 (i.e., tabled value/100).

Table 4-11.
Countermeasure Default Values: SIGNS (SN)

Countermeasure[6]	Service Life (yrs)	Costing Unit[1]	Unit Costs ($)		Units/ Project	Project Costs ($)		Total CRF (%)
			Implementation	O&M /yr		Implementation	O&M/ yr	
1-Install STOP/YIELD AHEAD Signs/Urban	7	Sign	225	0	4	900	0	30
2-Install STOP/YIELD AHEAD Signs/Rural	7	Sign	225	0	4	900	0	35
3-Install SIGNAL AHEAD Warning Signs/Urban	7	Sign	225	0	4	900	0	30
4-Install SIGNAL AHEAD Warning SIgns/Rural	7	Sign	225	0	4	900	0	35
5-Install I/S Warning Signs / Urban	7	Sign	225	0	4	900	0	30
6-Install I/S Warning Signs / Rural	7	Sign	225	0	4	900	0	35
7-Post Ped Xing/Advance Xing Signs/Urban	7	Sign	225	0	4	900	0	20
8-Post Ped Xing/Advance Xing Signs/Rural	7	Sign	225	0	4	900	0	25
9-Post SLIPPERY WHEN WET Signs/Urban	7	Sign	225	0	4	900	0	15
10-Post SLIPPERY WHEN WET Signs/Rural	7	Sign	225	0	4	900	0	20
11-Add 2-Way STOP/YIELD at Urban I/S	7	I/S	450	0	1	450	0	35
12-Add 2-Way STOP at Rural I/S	7	I/S	450	0	1	450	0	40
13-Change from 2-Way to 4-Way STOP	7	I/S	600	0	1	600	0	50
14-Eliminate Parking (w/signs @ 200 ft)	10	Sign	85	0	50	4,250	0	30

6 I/S = Intersection

Table 4-11.
Countermeasure Default Values: SIGNS (SN) (cont'd)

Countermeasure[7]	Service Life (yrs)	Costing Unit[1]	Unit Costs ($)		Units/ Project	Project Costs ($)		Total CRF (%)
			Implementation	O&M /yr		Implementation	O&M/ yr	
15-Install Guide Signs	7	Sign	225	0	4	900	0	15
16-Install Lane-Use Control Signs (Metal)	7	Sign						
17-Install Larger Signs	7	Sign	300	0	4	1,200	0	
18-Install NO PASSING ZONE Pennant Signs	7	Sign						20
19-Post/Reduce Speed Limit	7	Sign	225	0	4	900	0	25
20-Post Curve Warnings/Advisory Speeds	7	Sign	300	0	2	600	0	30
21-Install Internally Illuminated Signs	7	Sign						
22-Sign One-Way Street Operation	7	Sign						35
23-Prohibit RTOR	7	Sign	225	0	4	900	0	45
24-Reroute LT Traffic	7	Sign						45
25-Prohibit Turns (at I/S or between I/Ss)	7	Sign	225	0	4	900	0	40

[7] **I/S = Intersection**

Table 4-12.
Countermeasure Default Values: Signals (SG)

Countermeasure[1]	Service Life (yrs)	Costing Unit[1]	Unit Costs ($)		Units/ Project	Project Costs ($)		Total CRF (%)
			Implementation	O&M/yr		Implementation	O&M/yr	
1-Signalize Intersection	15	I/S	45,000	2,600	1	45,000	2,600	20
2-Retime Traffic Signal	1	I/S	900	0	1	900	0	10
3-Increase Yellow Change Interval	1	I/S	900	0	1	900	0	15
4-Add All-Red Clearance Interval	1	I/S	900	0	1	900	0	15
5-Revise Signal Phasing/Sequence	3	I/S	1,600	0	1	1,600	0	25
6-Provide RT Overlap (Green Arrow)	3	I/S	1,600	0	1	1,600	0	25
7-Install Dual LT Lanes, Signs and Signals		I/S						
8-Add Pretimed/Protected LT Signals	15	Street	4,500	800	1	4,500	800	25
9-Provide Lead/Lag or Split Phasing	3	I/S	1,600	0	1	1,600	0	25
10-Install WALK-DON'T WALK Signals	15	I/S	8,000	1,000	1	8,000	1,000	20
11-Signalize Pedestrian Crossing	15	Each	22,500	1,000	1	22,500	1,000	20
12-Install Signal Actuation	10	I/S	25,000	1,800	1	25,000	1,800	20
13-Provide Signal Progression (3 I/Ss)	11	I/S	1,400	0	1	1,400	0	10
14-Upgrade Signalization	15	I/S	37,500	0	1	37,500	0	20
15-Upgrade Signal Controller	15	I/S	2,500	0	1	2,500	0	20
16-Install 12-inch Signal Lenses	15	I/S	5,000	0	1	5,000	0	10
17-Add/Relocate Signal Head	15	Each	1,000	0	1	1,000	0	
18-Add Signal Back Plates	15	Appr	400	0	2	800	0	20
19-Install/Replace Signal Visors	15	Appr	500	0	1	500	0	
20-Remove Unwarranted Signalization	15	I/S	3,500	(2,500)	1	3,500	(2,500)	55
21-Install Advance Flasher-Signs	15	Each	5,000	150	2	10,000	300	25

[1] I/S=Intersection, LT=Left-Turn, and Appr=Approach

Table 4-13.
Countermeasure Default Values: MARKINGS (MK)

Countermeasure[8]	Service Life (yrs)	Costing Unit[1]	Unit Costs ($)		Units/ Project	Project Costs ($)		Total CRF (%)
			Implementation	O&M /yr		Implementation	O&M/yr	
1-Upgrade Markings (Halve Maint. Cycle)[9]	1	LF	0.04	0	13,200	525	0	15
2-Add Stop Bars/Crosswalks	3	I/S	1,200.00	0	1	1,200	0	15
3-Place Advance Pavement Messages	5	Each	200.00	0	2	400	0	15
4-Add Ctr + Lanelines to Unstriped Street	1	LF	0.04	0	13,200	525	0	35
5-Add Centerline to Unstriped Pavement	1	LF	0.04	0	1,320	50	0	35
6-Add Ctr + Edgelines to Unstriped Road	1	LF	0.04	0	11,880	475	0	40
7-Mark/Lengthen Exclusive Turn Lanes	3	Lane	400.00	0	2	800	0	30
8-Install Two-Way Left-Turn Lane	1	LF	0.04	0	13,200	525	0	35
9-Supplement Centerline with RPMs	10	RPM	27.00	1	65	1,750	65	15
10-Install No Passing Zones (33% need)[10]	6	LF	0.60	0	3,500	2,100	0	40

[8] RPM = Reflective Pavement Marker, I/S = Intersection and LF = Lineal Feet.

[9] In other words, reduce the time between repainting to one half of its present value (e.g., repaint every six months instead of annually).

[10] Assumes that passing will be prohibited over 33% of the travel distance in each direction on a representative rural two-lane highway. This requires a total of 0.33 x 5,280 feet per mile x 2 directions of travel = 3,485 (or approximately 3,500) feet of yellow striping per mile.

2. List the proposed countermeasures in the combination in order of decreasing priority. Consider basing countermeasure priority on the:

   a. crash reduction (e.g. $CRF_1 > CRF_2 > CRF_3$) or the

   b. ease and/or immediacy of implementation (logical for phased countermeasures introductions).

3. Compute the combined CRF with the following equation (FHWA, 1991):

$$CRF_{com} = 1 - [(1 - CRF_1) x (1 - CRF_2) x (1 - CRF_3) ...] \quad \text{Eq.(4-2)}$$

While using Eq.(4-2) guarantees that the combined factor does not exceed 1.0, judgment is still required to avoid adopting values that may be unrealistically high (e.g. > 0.75). (See page 4-37 for an example of computation.)

Cost-Related Parameters

Considering the expected geographic sensitivity of countermeasure cost and service life data, SEMCOG surveyed a variety of Southeastern Michigan sources for such data. The results of this survey are synthesized in Appendix C. Judgment was applied to the synthesized data in choosing default values for each countermeasure's "Service Life" and "Unit Costs" (Tables 4-11 to 4-13).

Unit costs for "O&M" have been set to zero for all countermeasures in the SIGNS category involving conventional sign panels (Table 4-11). This reflects the fairly common practice of simply replacing signs rather than washing or otherwise maintaining them in place.

Traffic engineering countermeasures appear to be rarely assigned a salvage value in economic analyses, and no attempt to do so occurred in the preparation of this manual. A relatively large proportion of the implementation cost of most such measures is for labor. Also, some of the more costly pieces of hardware (such as signal controllers) typically reach technological obsolescence at or before the time they are replaced due to their physical condition. These considerations notwithstanding, individual agencies may wish to adopt their own (non-zero) salvage values for countermeasures involving such items as sign blanks to be recycled or signal heads to be reused after their removal from a location where traffic controls are being upgraded.

The most difficult generalization in putting together Tables 4-11 to 4-13 was the assumed project size (i.e., "Units/Project"). Prior to starting the B/C analysis, users should carefully consider the appropriateness of each such value for the actual location(s) under study. Any adopted revisions to tabled values should be highlighted in revised tables of the same format. Currently tabled values assume that:

- For treatments not applied only at an intersection or a curve, the typical project length for planning purposes is one mile and the typical quantity of required signs is four per mile (i.e., two per direction per mile).

- Effective enforcement of a continuous No Parking zone which previously accommodated parking requires signs to be placed at intervals not exceeding about 200 feet (see countermeasure SN-14.

- While warning signs and signal back plates may be needed on only one approach to an intersection or curve due to driver expectancy and visibility problems, a common (generally inexpensive and liabilitysensitive) practice is to treat both approaches on a given roadway even if only one is warranted.

- Special signal visors, on the other hand, are used to restrict the viewing of treated signal indications to a single intersection approach.

COUNTERMEASURE PACKAGING

The last step before proceeding to counter-measure B/C analysis is to consider how the individual countermeasures identified earlier might be logically combined or "packaged." Packaging countermeasures both simplifies and enhances the value of the B/C analyses. It accomplishes this by limiting the alternatives evaluated to complementary combinations of countermeasures which are practical to implement together at various stages in the long-term safety improvement of a given location.

As an example of countermeasure packaging, assume that a signalized intersection on a five-lane street suffers from excessive left-turn crashes. Preliminary observation and analysis indicate that the two leading possible crash causes are excessive speed and restricted sight distance, the latter due to the frequency of simultaneously opposing left-turns. A plausible countermeasure combination for near-term (if not immediate) implementation would be the introduction of a new speed limit and a complementary increase in speed enforcement.

The most likely countermeasure for longer-term implementation would probably be the addition of protected left-turn signal phasing. However, a viable alternative or predecessor to such phasing may be the removal of on-street parking to make room on the intersection approach for the insertion of raised median channelization. The objective of such channelization would be to offset opposing left-turn lanes to the left of each other for improved visibility of oncoming through traffic. Such a channelization package may provide a cost-effective safety improvement for an extended period without the need for capacity-reducing turn phases.

The process of packaging countermeasures provides analysts a good opportunity to exercise their own discretion as to which possible countermeasures they wish to evaluate further and which ones they wish to "set aside." This is also a convenient time to check the availability of data needed for the B/C analysis. Use a checklist having the format shown in Figure 4-5 to document the preparation of countermeasure packages. A full-size reproducible copy of this figure can be found in Appendix F. (See Figure 4-11 for completed example of worksheet.)

Figure 4-5.
Countermeasure Packaging at ________________________

Countermeasure		Check Data Available				Comments
Package	**Specific Name (& Generic Code)**	**Service Life**	**Unit Costs**	**Units/ Project**	**CRF**	
Set-Asides (Explain to right)						

See Figure 4-11 for completed example of worksheet.

EXAMPLE OF PATTERN/CAUSE/COUNTERMEASURE IDENTIFICATION

This final section continues the example problem started in Chapter 3. In that chapter, it was shown using several methods that the Sem-Cog intersection was a high-crash location for the calendar years 1993 to 1995. Now it is possible to determine the crash patterns causing that condition and the various countermeasures that might be pursued to alleviate those crash patterns. The earlier retrieval of crash data for this location revealed that of the 141 total crashes reported over the three-year analysis period, none were head-on crashes, 21 were sideswipe/opposite-direction crashes, 18 were head-left/rear-left crashes, 39 were angle crashes, 24 were rear-end/rear-right crashes and 12 were sideswipe/same-direction crashes. The remaining 27 crashes were single-vehicle crashes or other types not relevant to evaluating crash patterns categorized by multiple-vehicle crash type (the patterns for which this edition of the manual includes pattern/cause/ countermeasure tables).

Crash Patterns

The results from applying the crash pattern identification and prioritization method to the sample intersection are indicated below under each of the method's steps. These steps apply to the Figure 4-1 worksheet (repeated for the example as Figure 4-6) and require the analyst to:

1. <u>Compute the location's crash percentage for each possible crash pattern</u>. The numbers of multiple-vehicle crashes by type given above are entered in the appropriate boxes in the first row of Figure 4-6. The corresponding percentages are then computed to one decimal place and entered in the second row.

2. <u>Define the location type</u>. Information defining the location type is entered in Figure 4-6. The ADT range is indicated in the figure's title block and the area type, roadway functional class, number of

lanes and predominant traffic control are indicated opposite the corresponding regional percentage value look-up table numbers.

3. Determine regional crash percentages for each possible crash pattern. The method used to complete this step is described on page 4-3 (Step 3 under CRASH PATTERN IDENTIFICATION). Four regional crash percentages for each pattern, one from each of the SEMCOG tables (Tables 4.1 to 4.4), are entered in the corresponding cells of the worksheet.

4. Compare each crash percentage computed for the location to the corresponding regional crash percentages. Note in Figure 4-6 that for each of the first three crash patterns, the location's percentage exceeds each of the corresponding four regional percentages; hence, these patterns are significant and the word "YES" is entered in the appropriate column in the "Significant Pattern?" row. For rear-end/rear-right & sideswipe/same-direction crashes, the location's percentage fails to exceed even one regional percentage. There is no significant pattern associated with these latter crash types since they are under-represented at the sample intersection.

5. Compute the average of all regional crash percentages which are less than the location's crash percentage. Averages for the three significant patterns are computed and entered in the worksheet. All values averaged are highlighted through the use of boldface type (in manually completing the worksheet, these values would be circled).

6. Compute an ORR. The location's crash percentage for each significant pattern is divided by the corresponding average regional percentage, expressed to one decimal place and entered in the ORR row of the worksheet. The results show that head-on and sideswipe/opposite-direction crashes were over-represented by a factor of 2.8, head-left/rear-left crashes by a factor of 1.2 and angle crashes by a factor of 1.1.

7. Determine a SW. Severity weightings are used to attach higher priority to those crash patterns producing higher average losses. Weightings are determined in this example using the method described in sub-step 7a on page 4-10. Since sideswipe crashes predominate the first pattern (there were no head-on crashes), this pattern receives a SW of 1.

8. Determine pattern priority. Eq.(4-1) is applied to the values of ORR and SW determined in Steps 6 and 7, respectively, and the results are shown to one decimal place in the last row of the worksheet. The PPIs show that the combination of head-on and sideswipe/opposite-direction crashes should receive the greatest attention in identifying possible causes and counter- measures.

Possible Causes

The results from applying the above method for identifying possible causes to the sample intersection are indicated below under each of the method's steps. These steps apply to the Figure 4-2 and Figure 4-3 worksheets (repeated for the example as Figure 4-7 through Figure 4-9) and require the analyst to:

1. Highlight the columns associated with significant crash patterns. As revealed in Figure 4-6, the Sem-Cog intersection displayed significant patterns of head-on & sideswipe/opposite-direction crashes, left-turn crashes and angle crashes between 1993 and 1995. The corresponding columns are highlighted in Figure 4-7 by darkening in the previously hollow bullets (although shading the full width of the columns with highlighting ink would be a good alternative). In highlighting these columns, recognition is given to the fact that the location being evaluated is signalized (i.e., the

"Angle-Sig" column is highlighted).

2. Enter the PPIs. The values of PPI for the three significant crash patterns (3.6, 4.2 and 4.5, respectively) are taken from Figure 4-6 and entered in the current worksheet.

3. Highlight possible causes for the highest priority crash pattern. With a PPI of 3.6, the combination of head-on & sideswipe/opposite-direction crashes should receive the highest priority. Scanning down this pattern column for bullets and then reading across to the left reveals seven possible causes: Excessive Speed, Restricted Sight Distance, Narrow Lanes, Inadequate Pavement Markings, Inadequate Roadway Shoulders, Inadequate Maintenance and Severe Curves. These possible causes are highlighted in Figure 4-7 using bold-face type (highlighting ink is used when done manually).

4. Highlight possible causes for multiple significant crash patterns. Scanning the highlighted columns for two or more bullets in the same row and then reading across to the left reveals three possible crash causes common to multiple patterns: Excessive Speed, Restricted Sight Distance and Inadequate Signal Change Interval. Since the first two of these possible causes were already highlighted in Step 3, only Inadequate Signal Change Interval needs to be highlighted now.

5. Compile a separate list of the possible causes highlighted in Steps 3 and 4 and declare them to be "higher-priority" possible causes. Every pattern/cause combination needs to be listed, even when this results in the same cause appearing more than once in the list. (See Figure 4-8) This is necessary in order to later identify all applicable countermeasures in pattern-specific tables.

6. Highlight and/or list other possible causes. A review of the Figure 4-7 worksheet shows that other possible causes for this location's significant crash patterns (i.e., those having a single bullet in the second or third column) are the seven listed in Figure 4-9. To simplify the completion of this example, these possible causes and countermeasures are not discussed further.

7. Review the lists compiled in Steps 5 and 6 and rule out possible causes which are inconsistent with basic location features. As explained in the last column of Figure 4-8, three possible causes can be ruled out for head-on & sideswipe/same-direction crashes at this location: Restricted Sight Distance, Inadequate Roadway Shoulders and Severe Curves. The remaining higher-priority possible causes are shown in boldface type. Comments in the figure also describe location features expected to be important in the selection of countermeasures.

Figure 4-6.
Crash Pattern Identification and Prioritization at Sem-Cog Intersection

Average Daily Traffic (ADT) Range 20,001 - 30,000

Evaluation Criteria		Possible Crash Pattern: Head-On & SS/OD	Head-Left Rear-Left	Angle	Rear-End Rear-Right & SS/SD
Location's Crashes	No. by Type / Total No.	21/141	18/141	39/141	36 / 141
	Location's %	14.9	12.8	27.7	25.5
Regional Crash % (table or computation)	4-1. Area Type: Urban	**5.3**	**11.3**	**26.2**	42.6
	4-2. Functional Class: Arterial	**5.3**	**11.4**	**26**	42.7
	4-3. No. of Lanes: 2	**5.4**	**10**	28.2	40.5
	4-4. Sig. X Unsig. ___	**5.3**	**11.6**	**26**	42.7
	Computed (attach details)				
Significant Pattern?	Enter YES if Location's % Exceeds At Least One of the Above Regional %s	YES	YES	YES	NO
Pattern Priority[1]	Average Regional % [2]	5.3	11.1	26.1	---
	Over-Representation Ratio (ORR) = Location's % / Average Regional %	2.8	1.2	1.1	---
	Severity Weighting (SW)	1	2	2	---
	Pattern Priority Index (PPI) = 10 / (ORR x SW)	3.6	4.2	4.5	---

[1] Complete this block only for significant patterns.
[2] Circle or highlight, and then average, only those Regional Percentages which are less than the location's %. This is necessary to guarantee an ORR greater than 1.0.

Figure 4-7.
Possible Causes for Multiple-Vehicle Crash Patterns at Sem-Cog Intersection

Possible Cause	**Crash Pattern**					
	Head-On & SS/OD	**Left-Turn**	**Angle**		**Rear-End & SS/SD**	
			Sig	**Unsig**	**Sig**	**Unsig**
Pattern Priority Index (PPI)	**3.6**	**4.2**	**4.5**	-	-	-
Excessive Speed	●	●	●	o	o	o
Restricted Sight Distance	●	●	●	o		o
Slippery Surface			●	o	o	o
Narrow Lanes	●				o	o
Inadequate Signal Change Interval		●	●			
Turning Vehicles Slowing or Stopping in					o	o
Unexpected Slowing and Lane Changing					o	o
Poor Visibility of Traffic Signal			●		o	
Unexpected/Unnecessary Stops Due to			●		o	
Unsafe Right-Turns-on-Red			●		o	
Crossing Pedestrians					o	o
Poor Visibility of STOP/YIELD Signs				o		o
Proper Stopping Position Unclear			●	o		
Inadequate Pavement Markings	●					
Inadequate Roadway Shoulders	●					
Inadequate Maintenance	●					
Severe Curves	●					
Inadequate Gaps in Oncoming Traffic		●				
Inadequate Signalization for Left-		●				
Inadequate Gaps for Turning and						o
Unexpected Cross Traffic				o		

Figure 4-8.
Higher-Priority Possible Causes for Crash Patterns at __Sem-Cog Intersection__

Crash Pattern	Possible Cause	Applicable? (Step 7) Yes	No	Comments
Causes Associated with Highest Priority Pattern (Step 3)				
Head-On & SS/OD	**Excessive Speed**	X		A speed survey should be conducted if recent speed data are not available.
	Restricted Sight Distance		X	This pattern/cause combination deals with passing-related crashes on two-lane roads. See other patterns below for intersections.
	Narrow Lanes	X		Marked lanes (including left-turn lane) average only 10-1/2 ft wide due to on-street parking.
	Inadequate Pavement Markings	X		Both streets have conventional striping repainted annually. The intersection is lighted.
	Inadequate Roadway Shoulders		X	Both Sem Rd. and Cog Ave. are curbed urban streets without shoulders.
	Inadequate Maintenance	X		Drivers attempting to avoid frequent potholes may cause sideswipe crashes.
	Severe Curves		X	Both streets run straight through the intersection without any directional changes.
Causes Associated with Multiple Patterns (Step 4)				
Left-Turn & Angle	**Excessive Speed**	X		Recent speed survey?
	Restricted Sight Distance	X		Drivers of left-turning vehicles frequently have their view of through traffic blocked by vehicles waiting to make left-turns from the opposite direction. With respect to possible off-street causes and countermeasures, note that buildings abutting the sidewalks on all four corners preclude meaningful sight triangles. There are no driveways near any of the corners which would allow vehicles waiting to enter the street to block cross-corner viewing.
	Inadequate Signal Change Interval	X		Currently, there is a nominal yellow interval and no all-red interval.

Figure 4-9.
Other Possible Causes for Crash Patterns at <u>Sem-Cog Intersection</u>

Crash Pattern	Possible Cause	Applicable? (Step 7)		Comments
		Yes	No	
Angle	Slippery Surface			
	Poor Visibility of Traffic Signal			
	Unexpected/ Unnecessary Stops Due to Signal			
	Unsafe Right-Turns-on-Red			
	Proper Stopping Position Unclear			
Left-Turn	Inadequate Gaps in Oncoming Traffic			
	Inadequate Signalization for Left-Turn Volume			

Possible Countermeasures

Applying the above method results in the identification of possible countermeasures for the sample intersection as indicated below under each of the method's steps. These steps apply to the Figure 4-4 worksheet (repeated for the example as Figure 4-10) and require the analyst to:

1. Identify possible countermeasures. The pattern/cause/countermeasure combinations relevant to this example are found in Tables 4-5, 4-6 and 4-7. These tables are reviewed for the six higher-priority possible causes remaining after the Figure 4-8 review: Excessive Speed, Narrow Lanes, Inadequate Pavement Markings, Inadequate Maintenance, Restricted Sight Distance and Inadequate Signal Change Interval.

2. Compile a separate list of the possible countermeasures identified in Step 1. A total of 30 countermeasure "line items" are listed in Figure 4-10. This number includes some duplicate and clearly infeasible countermeasures.

3. Review the list compiled in Step 2 and rule out inapplicable countermeasures. Using the three criteria presented earlier, the 30 line items are reduced to the 11 higher-priority possible countermeasures shown in boldface type in Figure 4-10. Reasons for excluding the other 19 line items are stated briefly in the "Comments" column of the figure.

Countermeasure Packages

Figure 4-5 (repeated for the example as Figure 4-11) is used to sort the eleven higher-priority possible countermeasures for the sample intersection into two logical implementation packages and a group of so-called "set asides." Package A includes three quickly implementable, operational-type countermeasures. Package B consists of five related countermeasures of various types that may be implemented over a somewhat longer period of time. The remaining three countermeasures are duplicative or less desirable and have been set aside.

The Xs in the figure indicating data availability are limited to the information presented in this edition of the *SEMCOG Traffic Safety Manual*. Users are encouraged to develop their own data for the missing values and provide copies of such new information to the SEMCOG Transportation Department.

CRFs for countermeasure combinations must be computed using Eq. (4-2) and the related steps described earlier. This equation mathematically combines the CRFs given for individual countermeasures in Tables 4-11 to 4-13. Those countermeasures for which costing data is not available have not been included in the continuation of this analysis. Therefore, the result of the combined CRF calculation will be on the low, or conservative, side.

Package A

In order of decreasing size, the two known individual CRFs are $CRF_{SN\text{-}19}$ = 0.25 (for Post/Reduce Speed Limit) and $CRF_{SG\text{-}4}$ = 0.10 (for Add All-Red Clearance Interval); hence,

$$CRF_A = 1 - [(1 - CRF_{SN\text{-}19}) \times (1 - CRF_{SG\text{-}4})]$$

$$= 1 - [(1 - 0.25) \times (1 - 0.15)] = 0.363$$

Package B

The two known individual CRFs are $CRF_{SN-14} = 0.30$ (for Eliminate Parking near Intersections) and $CRF_{MK-1} = 0.15$ (for Upgrade Markings — Halve Maintenance Cycle); hence,

$$CRF_B = 1 - [(1 - CRF_{SN-14}) \times (1 - CRF_{MK-1})]$$

$$= 1 - [(1 - 0.30) \times (1 - 0.15)] = 0.405$$

Packages A and B Combined

The combined CRF for all four countermeasures implemented simultaneously would be:
$CRF_{A\&B} = 1-[(1-0.25) \times (1-0.15) \times (1-0.30) \times (1-0.15)] = 0.621$.

Figure 4-10.
Possible Countermeasures for Crash Patterns at __Sem-Cog Intersection__

Crash Pattern	Possible Cause	Possible Countermeasure (Step 1) Specific Name[1]	Generic Code	Applicable? (Step 3) Yes	No	Comments[1]
Head-On & SS/OD (Table 4-5)	Excessive Speed	**Post/Reduce Speed Limit**	SN-3	X		
		Increase Traffic/ Speed Enforcement	MS	X		
	Narrow Lanes	Eliminate Parking	SN-1		X	See Eliminate Parking Near Inter- section (below).
		Widen Lanes	RD	X		
	Inadequate Pavement Markings	Supplement Center-line with RPMs	MK-2		X	Unwarranted given existing I/S lighting.
		Upgrade Markings (Halve Maint. Cycle)	MK-6	X		
		Add Ctr + Lanelines to Unstriped Street	MK-8		X	Inapplicable given existing centerline.
		Add Ctr + Edgelines to Unstriped Road	MK-10		X	Inapplicable given existing centerline.
		Add Centerline to Unstriped Pavement	MK-15		X	Inapplicable given existing centerline.
		Install Flush Median	CH	X		
		Install Raised Median	CH	X		
	Inadequate Maintenance	**Repair/Replace Roadway Surface**	PV	X		
		Repair/Replace Shoulder Surface	PV		X	No shoulder to maintain.
Left-Turn (Table 4-6)	Excessive Speed	Post/Reduce Speed Limit	SN-3		X	Duplicate.
		Increase Traffic/ Speed Enforcement	MS		X	Duplicate.
	Restricted Sight Distance	Reduce Obstructions in Median	MS		X	No median or obstructions.
		Favorably Offset Opposing LT Lanes	CH	X		

Figure 4-10.
Possible Countermeasures for Crash Patterns at Sem-Cog Intersection (cont'd)

Crash Pattern	Possible Cause	Possible Countermeasure (Step 1)		Applicable? (Step 3)		Comments[1]
		Specific Name[1]	Generic Code	Yes	No	
Left-Turn (cont'd)	Restricted Sight Distance	Move I/S Away from Curves/Crests	RD		X	Both streets are straight and level.
		Reduce Obstructions on Insides of Curves	MS		X	Both streets are straight and level.
		Flatten Curves	RD		X	Both streets are straight and level.
		Lower Roadbed on Hill Crests	RD		X	Both streets are straight and level.
	Inadequate Signal Change Interval	**Increase Yellow Change Interval**	SG-14	X		
		Add All-Red Clearance Interval	SG-14	X		
Angle (Table 4-7)	Excessive Speed	Post/Reduce Speed Limit	SN-3		X	Duplicate.
		Increase Traffic/ Speed Enforcement	MS		X	Duplicate.
	Restricted Sight Distance	**Eliminate Parking Near Intersection**	SN-1	X		Better than simply Remove Parking.
		Remove Obstructions from Sight Triangle	MS		X	Infeasible to remove buildings.
		Close/Relocate Driveways Near Intersection	DY		X	No driveways nearby.
	Inadequate Signal Change Interval	Increase Yellow Change Interval	SG-14		X	Duplicate.
		Add All-Red Clearance Interval	SG-14		X	Duplicate.

[1] RPMs = Reflective Pavement Markers, I/S = Intersection, Ctr = Centerline and LT = Left-Turn.

Figure 4-11.
Countermeasure Packaging at __Sem-Cog Intersection__

Countermeasure		Check Data Available				Comments
Package	**Specific Name and [Generic Code]**	**Service Life**	**Unit Costs**	**Units/ Project**	**CRF**	
A	Post/Reduce Speed Limit [SN-19]	X	X	X	X	Speed study may be required.
	Increase Traffic/ Speed Enforcement [MS-9]					May want to try before changing speed limit.
	Add All-Red Clearance Interval [SG-4]	X	X	X	X	Preferred over longer yellow.
B	Eliminate Parking Near Intersection [SN-14]	X	X		X	Sign quantity depends on parking details.
	Repair/Replace Roadway Surface [PV-4]					Resurfacing facilitates new striping pattern.
	Favorably Offset Opposing LT Lanes [CH-5]					Parking removal allows both this treatment and lane widening.
	Widen Lanes [RD-2]					Remove parking.
	Upgrade Markings (Halve Maint. Cycle) [MK-1]	X	X		X	Striping required depends on inter-section size.
Set-Asides (Explain to right)	Install Flush Median [CH-2]	There is already a median left-turn-only lane. Its narrowness may be causing SS/OD crashes.				
	Install Raised Median [CH-1]	Favorably Offset Opposing LT Lanes is a specific form of this countermeasure.				
	Increase Yellow Change Interval [SG-3]	Prevailing traffic engineering sentiment favors all-red intervals over longer yellow intervals.				