### Table 6.4: Crashes Prevented Over Life of Countermeasure Project

<table>
<thead>
<tr>
<th>Year k</th>
<th>CPIk</th>
<th>Fatal Benefit</th>
<th>PI Benefit</th>
<th>PDO Benefit</th>
<th>Tot. Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.97</td>
<td>$41,636</td>
<td>$298,664</td>
<td>$3,761</td>
<td>$315,660</td>
</tr>
<tr>
<td>2</td>
<td>2.97</td>
<td>$42,468</td>
<td>$274,937</td>
<td>$3,428</td>
<td>$365,833</td>
</tr>
<tr>
<td>3</td>
<td>3.02</td>
<td>$43,318</td>
<td>$279,158</td>
<td>$3,196</td>
<td>$371,620</td>
</tr>
<tr>
<td>4</td>
<td>3.06</td>
<td>$44,184</td>
<td>$285,934</td>
<td>$2,967</td>
<td>$374,185</td>
</tr>
<tr>
<td>5</td>
<td>3.12</td>
<td>$45,068</td>
<td>$291,311</td>
<td>$2,736</td>
<td>$383,316</td>
</tr>
<tr>
<td>6</td>
<td>3.18</td>
<td>$46,060</td>
<td>$296,622</td>
<td>$2,515</td>
<td>$385,606</td>
</tr>
<tr>
<td>7</td>
<td>3.25</td>
<td>$48,050</td>
<td>$302,529</td>
<td>$2,302</td>
<td>$390,269</td>
</tr>
<tr>
<td>8</td>
<td>3.31</td>
<td>$47,826</td>
<td>$308,651</td>
<td>$2,095</td>
<td>$399,490</td>
</tr>
<tr>
<td>9</td>
<td>3.37</td>
<td>$48,785</td>
<td>$314,783</td>
<td>$1,903</td>
<td>$407,670</td>
</tr>
<tr>
<td>10</td>
<td>3.43</td>
<td>$49,759</td>
<td>$321,095</td>
<td>$1,710</td>
<td>$414,405</td>
</tr>
<tr>
<td>11</td>
<td>3.49</td>
<td>$50,754</td>
<td>$327,500</td>
<td>$1,527</td>
<td>$422,330</td>
</tr>
<tr>
<td>12</td>
<td>3.56</td>
<td>$51,769</td>
<td>$334,050</td>
<td>$1,353</td>
<td>$430,330</td>
</tr>
<tr>
<td>13</td>
<td>3.62</td>
<td>$52,804</td>
<td>$340,731</td>
<td>$1,187</td>
<td>$439,307</td>
</tr>
<tr>
<td>14</td>
<td>3.69</td>
<td>$53,860</td>
<td>$347,546</td>
<td>$1,027</td>
<td>$447,554</td>
</tr>
<tr>
<td>15</td>
<td>3.75</td>
<td>$54,937</td>
<td>$354,497</td>
<td>$873</td>
<td>$456,504</td>
</tr>
<tr>
<td>Total</td>
<td>50.48</td>
<td>$720,024</td>
<td>$4,640,120</td>
<td>$58,117</td>
<td>$5,424,260</td>
</tr>
</tbody>
</table>

A similar calculation is done for the proportion of crashes that are expected to be personal injury (PI) and property damage only (PDO) by year for all 15 years. The estimate of total benefits from the proposed countermeasure over the next 15 years is $5,424,260.

**THINK ABOUT IT**

Do the relative values of the total benefits in Table 4.6 for each crash type seem reasonable to you?

Now that the benefits side of the analysis has been completed, the cost estimation for the countermeasure must be made. If it costs $85 to install each of four stop signs and an average of $15 per year to maintain or replace each sign, the present worth (i = 3.0 percent) of the cost to implement the stop sign countermeasure for 15 years is:

\[
PWC = P_0 + A \frac{(1 + i)^n - 1}{(1 + i)^n} = (4 \times 85) + 4 \times 15 \frac{(1 + 0.03)^{15} - 1}{0.03(1 + 0.03)^{15}}
\]

\[
PWC = 340.00 + 60.00 [11.938] = 1056.28.
\]

In this case, the benefits of the proposed countermeasure far exceed the costs. Often, the analysis is not so clear-cut. Some analyses are very sensitive to the choice of the value of human life, the CRF, and so on. An analyst must be clear in stating his/her assumptions and may find sensitivity analyses helpful. Even when such crucial values can be agreed on, there are usually more projects proposed than can be funded in a given budget cycle. For that reason, a system for ranking competing projects must be adopted. Chapter 5 covered ways to rank alternatives.

**Implementation Component: Schedule and Implement Safety Improvement Projects**. The scheduling of projects is more of a management and budgeting activity, but the proper implementation of the projects depends on good design and construction practices.

**Evaluation Component: Determine the Effect of Highway Safety Improvements**. Notice that a feedback loop exists on the left side of Figure 6.4. The loop begins at the evaluation component of the HSIP. By monitoring the performance of the implemented projects, the agency can ensure that maximum benefits are derived from the projects and the agency can collect information to help make future decisions regarding highway safety improvement projects.

### 6.1.4 Traffic Conflict Analysis

Although there are too many collisions, they are still rare events at any given location. However, some locations have the potential to be dangerous or to be more dangerous than they already are. To assess the potential for actual collisions, a procedure has been developed to collect data on traffic conditions that are conducive to dangerous interactions between vehicles. This procedure is the traffic conflict technique.

As originally defined by Perkins and Harris (1990), a traffic conflict was any evasive action taken by a driver to avoid a collision. Classic cases are (a) sudden application of the brake to avoid "rear-ending" a vehicle in front that has slowed to turn and (b) sudden swerving to avoid a rear-end collision. During the 1970s and 1980s, the definition was expanded and refined to include time-distance and severity elements. "A traffic conflict occurs when two or more road users approach the same point in time and space, and at least one road user takes successful evasive action to avoid a collision within a predefined minimum time to collision" (Hamilton Associates, 1996).

Figure 6.7 provides a structure for traffic conflict analysis. An "Existing Hazard" is any potential interaction between vehicles. Whether it meets the definition of a traffic conflict depends on the subsequent events indicated in the figure. "Normal interaction between road users generally does not result in a traffic conflict. A precautionary measure to avoid a perceived dangerous situation is also not a conflict. A conflict only occurs when evasive action that is not part of normal driving is taken to avoid a real hazard" (Hamilton Associates, 1996, p. 5). Observers conducting a traffic conflict study must be able to say "yes" to each question along the left-hand side of Figure 6.7. In addition, the observer is expected to assess the severity of each observed traffic conflict, according to the criteria list below.

1. **Time to collision (TTC)**. Using estimated (or measured) approach speed and distance to the potential point of collision, an approximate TTC value can be computed. The severity score for each TTC value is given in Table 6.5.
2. Risk of collision (ROC). ROC is “a subjective measure of the collision potential, and is dependent on the perceived control that the road user appears to have over the traffic conflict event. … For example, a high ROC score would be associated with emergency braking or sudden abrupt swerving with limited maneuvering room, whereas light braking or mild lane changes on a wide and open roadway may result in a low ROC score” (Hamilton Associates, 1996, p. 7).

The rear-end collision case mentioned earlier in this section is just one of seven traffic conflict types:

1. Left turn opposing
2. Left turn crossing
3. Crossing
4. Rear-end
5. Right turn
6. Weaving
7. Pedestrian

Just as a collision diagram (Figure 6.6) can be used to look for patterns in crash data for a site, noting the type of traffic conflict can assist in the development of corrective action at a location with too many traffic conflicts. Although traffic conflicts usually occur more frequently than collisions, they are still rare events. Observers use a form that looks much like a collision diagram to record the key elements of the observed conflict. When these sheets are summarized, an intersection conflict index (ICI) is computed. The ICI results from a series of simple calculations:

\[
\text{Average hourly conflicts (AHC)} = \frac{\text{Total number of observed conflicts}}{\text{Number of observation hours}} \tag{6.7}
\]

A typical value for AHC is 2.0-3.0 conflicts per hour.

\[
\text{AHC per thousand entering vehicles, } \text{AHC/TEV} = \frac{\text{AHC} \times 1000}{\text{AHEV}} \tag{6.8}
\]

where AHEV = average hourly entering volume. A typical value for AHC/TEV is about 1.5.

The next intermediate calculation is

Total conflict severity (TCS) = TTC Severity + ROC Severity \tag{6.9}

where the TTC Severity and ROC Severity scores come from Table 6.5. The TCS value applies to each observed conflict. When all conflicts at a site are combined, we get

Overall average conflict severity (OACS) = \frac{\sum \text{TCS of each observed conflict}}{\text{Total number of observed conflicts}} \tag{6.10}

A typical value for OACS is just above 3.0.
2. Risk of collision (ROC). ROC is "a subjective measure of the collision potential, and is dependent on the perceived control that the road user appears to have over the traffic conflict event. For example, a high ROC score would be associated with emergency braking or sudden abrupt swerving with limited maneuvering room, while light braking or mild lane changes on a wide and open roadway may result in a low ROC score" (Hamilton Associates, 1996, p. 7).
As Figure 6.8 shows, the ICT value is much like the level of service rating in highway capacity analysis. A rating of A though E is assigned to an intersection, based on its location in the figure. For example, if an intersection has 2.5 hourly conflicts per thousand entering vehicles and an average conflict severity of 3.4, it falls in the “ICI D” region of Figure 6.8.

The boundaries in Figure 6.8 are based on a compilation of data gathered at numerous intersections. (Note the points plotted in Figure 6.8.) Cumulative plots of AHC and OACS values were studied, and the stratification shown in Table 6.6 was derived from Equation 6.7: AHC = (94 observed conflicts/40 hours observed) = 2.35 conflicts per hour; Using Equation 6.8; AHC/TEV = (2.35 × 1000)/1205 = 1.905 conflicts per thousand entering vehicles. From Equation 6.9, TCS = Total TTC + Total ROC = 190 + 201 = 391. The average observed conflict severity comes from Equation 6.10: OACS = (2 × TCS of each observed conflict)/Total number of observed conflicts = 391/94 = 4.16. When the values AHC/TEV = 1.905 and OACS = 4.16 are plotted in Figure 6.8, the resulting point lies in the region labeled “ICI D.”

**TABLE 6.6 Intersection Conflict Index Summary**

<table>
<thead>
<tr>
<th>Intersection Conflict Index</th>
<th>Conflict Risk (Frequency and Severity Combined)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Minor</td>
</tr>
<tr>
<td>B</td>
<td>Low</td>
</tr>
<tr>
<td>C</td>
<td>Moderate</td>
</tr>
<tr>
<td>D</td>
<td>High</td>
</tr>
<tr>
<td>E</td>
<td>Extreme</td>
</tr>
</tbody>
</table>


**Example 6.5**

The intersection of Wykliiffe Boulevard and Kolfax Avenue may not have qualified as a hazardous intersection in Example 6.3, but many drivers perceive it as unsafe. A team of observers spent 40 hours at the intersection and collected the following information:

- 94 total conflicts, with 54 being of the rear-end conflict type
- Average hourly approach volume = 1205 vehicles
- Total TTC severity = 190 for the 94 conflicts, using the TTC scores in Table 6.5
- Total ROC severity = 201 for the 94 conflicts, using the ROC scores in Table 6.5

What intersection conflict index (ICI) value applies to this intersection?

**Solution to Example 6.5**

According to Equation 6.7, AHC = (94 observed conflicts/40 hours observed) = 2.35 conflicts per hour. Using Equation 6.8, AHC/TEV = (2.35 × 1000)/1205 = 1.905 conflicts per thousand entering vehicles. From Equation 6.9, TCS = Total TTC + Total ROC = 190 + 201 = 391. The average observed conflict severity comes from Equation 6.10: OACS = (2 × TCS of each observed conflict)/Total number of observed conflicts = 391/94 = 4.16. When the values AHC/TEV = 1.905 and OACS = 4.16 are plotted in Figure 6.8, the resulting point lies in the region labeled “ICI D.”

**THINK ABOUT IT**

Given the results of Example 6.5, what measures would you recommend be considered?

### 6.2 Human Factors and Transportation Engineering

#### 6.2.1 Human Factors Concepts for Design

Human factors, also called ergonomics or engineering psychology (Wickens, 1999), is the study of how human beings function in their natural or constructed surroundings.
As Figure 6.8 shows, the ICI value is much like the level of service rating in highway capacity analysis. A rating of A though E is assigned to an intersection, based on its location in the figure. For example, if an intersection has 2.5 hourly conflicts per thousand entering vehicles and an average conflict severity of 3.4, it falls in the "ICI D" region of Figure 6.8.

The boundaries in Figure 6.8 are based on a compilation of data gathered at numerous intersections. (Note the points plotted in Figure 6.8.) Cumulative plots of AHC and OACS values were studied, and the stratification shown in Table 6.6 was used.

6.2 Human Factors and Transportation Engineering

A pavement resurfacing project on I-25 causes the two northbound (NB) lanes to be closed. NB traffic must cross the median and use one of the two SB lanes until the 3-month project is completed. The contractor follows the procedures for workzone signs and marking given in the Manual of Uniform Traffic Control Devices, but a fatal crash and several other collisions occur on the SB approach to the median crossover in the first few weeks of the project. The county highway engineer takes his video camera to an overpass with a clear view of the NB approach during the Sunday afternoon peak period (Figure 6.9). In the first 10 minutes, he records several dangerous maneuvers on videotape. What can be done to make the workzone safe?

6.2.1 Human Factors Concepts for Design

Human factors, also called ergonomics or engineering psychology (Wickens, 1999), is the study of how human beings function in their natural or constructed surroundings.