CHAPTER 5

BENEFIT/COST ANALYSIS

The benefit/cost (B/C) analysis is an economic tool for assessing and comparing possible countermeasures. For each countermeasure considered, it compares expected benefits to expected costs. "Benefits" here consist of the reduced frequency and severity of crashes. "Costs" include elements for selecting, designing, implementing, operating and maintaining a countermeasure. Both benefits and costs are expressed in dollars to facilitate the use of their ratio as a key economic performance indicator. B/C ratios indicate economic viability when they are greater than or equal to 1.0, and they reflect relative economic desirability by the degree to which they exceed 1.0.

This chapter briefly discusses the issue of crash costing, describes B/C methodology in detail with the aid of a worksheet and then illustrates the application of the methodology with a continuation of the intersection example used in Chapters 3 and 4. Also discussed is the use of benefit and cost data in project selection.

HIGHWAY CRASH COSTS

The costs of highway crashes are used for many purposes, including allocating highway safety resources to maximize safety benefits, evaluating proposed safety regulations and convincing policy makers and employers that safety programs are beneficial. Crash costs are one of the most important measures available for determining the effectiveness of highway safety improvement projects. These costs are sensitive, however, to time and the methodology used to compute them. Thus, it is essential that crash costs are current and that the underlying methodology is theoretically sound.

Many individuals and agencies are reluctant to assign a dollar value to a human life. This is an emotional issue that has been and will continue to be the subject of many debates. Nonetheless, once the costs of a proposed safety project have been estimated, a decision must be made whether to fund the project. A common method used to make (or at least influence) this decision is a B/C analysis. Such an analysis requires the quantification of expected project benefit. This quantification requires, in turn, estimates of the numbers of crashes, deaths and injuries which may be avoided by the implementation of the project. It also requires the adoption and use of average dollar values for each life saved and injury avoided.

Over the years, two methods of computing the economic value of human life have prevailed: the Human Capital Method and the Willingness-to-Pay Method (Miller, 1991). The latter method incorporates quality-of-life considerations as well as the direct and indirect costs of resources lost in a crash; hence, it is the method recommended for generating the "comprehensive crash benefits" used in the B/C analysis of proposed highway safety projects (Jacks, 1987). Table 5-1 gives rounded values of comprehensive costs predicted with this method for 1993, on both a per-crash and per-person basis (Streff and Molnar, 1994). (See Chapter 3 for more detailed crash severity level definitions.)

B/C ANALYSIS METHODOLOGY

The Federal Highway Administration publication entitled *Highway Safety Evaluation Procedural Guide* (FHWA, 1981c) describes a nine-step methodology for the B/C analysis of highway safety improvement projects (i.e., crash countermeasures or countermeasure combinations). These steps determine the following countermeasure properties and economic parameters:

Table 5-1.
Comprehensive Crash Costs, 1993

Severity	Cost Per Crash	Cost Per Person
F — Fatal	$3,961,000	$3,057,000
A — Incapacitating Injury	$278,000	$202,000
B — Non-Incapacitating Injury	$66,000	$46,000
C — Possible Injury	$38,000	$22,000
PDO — Property-Damage-Only	$2,700	$2,800

1. annual average safety benefit,
2. implementation cost,
3. net annual operating and maintenance (O&M) costs,
4. service life,
5. salvage value,
6. interest rate,
7. capital-recovery, sinking-fund and present-worth factors,
8. B/C ratio using Equivalent Uniform Annual Benefit and Cost Method, and
9. B/C ratio using Present Worth of Benefits and Costs Method.

Alternative Methods

The analyst is free to apply either or both of the methods listed in the last two steps for computing a B/C ratio. The methods produce the same result; hence, applying both provides a computational cross-check.

The Equivalent Uniform Annual Benefit and Cost Method sums costs and spreads them out over the life of a countermeasure in equal annual installments for comparison to annual benefit. Such installments are similar to car payments where the amount paid is constant throughout the loan period. B/C ratios computed by this method for alternative countermeasures can be directly compared even when the service lives of the countermeasures are not equal. This is because the method assumes that shorter-lived countermeasures will continue to be replaced throughout the service life of the longest-lived countermeasure.

The Present Worth of Benefits and Costs Method sums all benefits and costs, both present and future, and determines how much these lump sums would be in today's dollars. B/C ratios computed by this method can be directly compared only if they are based on the same length of analysis period. Special "adjustments" therefore have to be made when the countermeasures to be compared have unequal service lives. Perhaps the simplest way of making such adjustments is to assume an analysis period equal to the least common multiple of the lives of the countermeasures being compared. During this period, it is assumed that countermeasures with service lives shorter than the analysis period are renewed or replaced according to their respective service lives.

The Nine Steps

A three-page worksheet (Figure 5-1) has been developed to assist in computing the B/C ratio for a crash countermeasure or countermeasure combination. A reproducible copy of this figure can be found in Appendix F. First fill in the title block of the worksheet using the countermeasure name(s) and code(s) provided in Chapter 4. Then complete the steps described in detail below.

Figure 5-1.
B/C Analysis Worksheet

Location____

Countermeasure Name(s) & Code(s)____

____

Analyst __________________________________ Date__________________________

==

1. Annual Average Safety Benefit

   a. *Annual Average Number of Crashes by Severity (pre-treatment)*

      Determined for ___ years: 19 ___ to 19 ___ (min. is 3 yrs)
      Fatal, F ___ + Non-F Injury, A+B+C _____ + PDO _____ = Total ______

   b. *Crash-Reduction Factor (CRF) by Severity (*may set = CRF_T)*

      CRF_F* _____ CRF_{ABC}* _____ CRF_{PDO}* _____ Total Crashes, CRF_T _____

      Source: Tables 4-11 to 4-13 ___ Other (attach) ___

   c. *Average Cost Per Crash by Severity (C_i)*

      Source: Table 5-1 ___ Other (attach) ___ C_F $ ______________

      Weighted Average for Non-F Injury:

      $C_{ABC} = (C_A x A + C_B x B + C_C x C) / (A+B+C) =$

      ($ ___________ x _____ +

      $ ___________ x _____ +

      $ ___________ x _____) / _____ = C_{ABC} $ ______________

      C_{PDO} $ ______________

   d. *Annual Benefit =*

      (F x CRF_F x C_F) +

      ((A+B+C) x CRF_{ABC} x C_{ABC}) +

      (PDO x CRF_{PDO} x C_{PDO}) =
      (_____ x ______ x $ _____________) +

      (_____ x ______ x $ _____________) +

      (_____ x ______ x $ _____________) = $ _____________

Figure 5-1.
B/C Analysis Worksheet (cont'd)

2. Implementation Cost

Source: Tables 4-11 to 4-13 ___ Other (attach) ___ $ ______________

3. Net Annual Operating and Maintenance (O&M) Costs

Source: Tables 4-11 to 4-13 ___ Other (attach) ___ $ ______________

4. Service Life

Source: Tables 4-11 to 4-13 ___ Other (attach) ___ ____ yrs

5. Salvage Value (if not set equal to 0, explain basis below:)

____ $ ______________

6. Interest Rate _____ %

7. Other Economic Factors
See Appendix E tables for service life & interest rate above:

Capital-Recovery Factor ______________

Sinking-Fund Factor ______________

Present-Worth Factor ______________

Present-Worth Factor for a Series of Payments ______________

8. B/C Ratio Using Equivalent Uniform Annual Benefit and Cost Method

a. *Annual Cost* =

(Implementation Cost x Capital-Recovery Factor) +
(Net Annual Operating and Maintenance Costs) -
(Salvage Value x Sinking-Fund Factor) =

($ ______________ x ______________) +

($ ______________) -

($ ______________ x ______________) = $ ______________

b. *B/C* = (Annual Benefit / Annual Cost) =

($ ______________ / $ ______________) = ____:

Figure 5-1.
B/C Analysis Worksheet (cont'd)

9. B/C Ratio Using Present Worth of Benefits and Costs Method

a. *Present Benefit* =

(Annual Benefit x Present Worth Factor for a Series of Payments) =

($ ______________ x ______________) = $ ______________

b. *Present Cost* =

(Implementation Cost) +
(Net Annual Operating and Maintenance Costs x Present Worth Factor for a Series of Payments) - (Salvage Value x Present Worth Factor) =

($ ______________) +

($ ______________ x ______________) -

($ ______________ x ______________) = $ ______________

c. *B/C* = (Present Benefit/Present Cost) =

($ ______________ / $ ______________) = ____:

1. Compute the annual average safety benefit. There are four sub-steps involved:

   a. Determine the annual average number of crashes occurring at each severity level prior to countermeasure implementation ("pre-treatment"). Refer to the EPDO Method in Chapter 3 for a discussion of severity levels and the number of years of crash data required. (As indicated earlier, from three to as many as seven years of data may be needed, depending on traffic volume and overall crash frequency). Enter the specific years used in the blanks provided. Enter the annual average number of fatal (F) crashes, A-level, B-level and C-level injury (A, B, C) crashes, and property damage only (PDO) crashes in the appropriate blanks. Enter the sum of the injury (A+B+C) crashes in the appropriate blanks. Values for annual average numbers of crashes should be expressed to two decimal places.

   b. Enter crash-reduction factors (CRFs). First enter the CRF for total crashes and indicate whether this value is from a Chapter 4 Table (4-11, 4-12 or 4-13 for the Signs, Signals and Markings categories, respectively) or some other source (reference or attach relevant excerpts of other sources). Again, Appendix D contains tables of CRF values for the remaining countermeasure categories (Channelization, Pavement, Roadway, Pedestrian, Driveways, and Miscellaneous) although no costing data for these countermeasures have been included in this edition of the manual. If CRF values are also available for fatal, non-fatal injury (ABC) and PDO crashes, enter such values in the appropriate blanks and attach documentation; otherwise, assume that the value for total crashes applies across all severity levels. If entered values are for a combination of countermeasures, indicate this fact in the worksheet's title block and on a separate sheet showing the computation of the combined CRF in the manner described in Chapter 4.

   c. Determine the average cost per crash by severity. Enter the comprehensive crash costs from the middle column of Table 5-1 or other agency guidelines (to be cited and/or attached). Values for fatal and PDO crashes are entered directly in the appropriate blanks at the right margin of the worksheet; however, values for the three levels of non-fatal injury crashes are input in an equation that computes an average cost for all non-fatal injury crashes weighted by the respective numbers of A-, B- and C-level crashes. Solve the equation for CABC after double-checking to see that all the proper values have first been input.

   d. Compute the annual benefit anticipated for the countermeasure(s) being evaluated. Use the three-term equation provided in the worksheet. The terms of this equation represent the economic value of reduced fatal crashes, non-fatal injury crashes and PDO crashes, respectively. In each term of the equation, enter for the corresponding severity level(s) the pre-treatment annual average number of crashes (from Sub-Step 1a) in the first blank, CRF (from Sub-Step 1b) in the second blank and average cost per crash (from Sub-Step 1c) in the third blank. Then solve the equation for the annual benefit in dollars.

2. Determine countermeasure implementation cost. The cost of implementing a crash countermeasure will depend on many project-specific variables which are difficult to quantify at the planning stage, not the least of which is the appropriate scale of application. Tables 4-11 to 4-13 provide unit cost data for various countermeasures and, under stated assumptions regarding project size, the resulting total implementation cost. Carefully review the data and assumptions given in these tables for the countermeasure being evaluated; if you are willing to accept them, take the corresponding total project implementation cost and enter it in the B/C analysis worksheet. If, however, you choose to use a different total cost, attach supporting documentation indicating your assumptions regarding unit cost and project size. Also note or show your computation of implementation cost for any counter-measure combination being evaluated. Normally the costs of the countermeasures in the combination

are simply summed; however, some components of implementation cost (such as that for construction zone traffic control) may be shared and any assumptions in this regard should be documented. You may also wish to include those countermeasures listed in Appendix D which are applicable to the analysis and for which you have costing data available. As this manual will continue to be updated and revised, SEMCOG would appreciate receiving any additional costing data, particularly for those countermeasures for which no costing data is currently included.

3. Determine the net annual O&M costs. Enter the difference between the annual average O&M costs for the location before project implementation and those costs after implementation. If the project is expected to reduce overall annual O&M costs, the net cost entered here would be negative. As with implementation costs, agency experience may suggest values different than those provided in Tables 4-11 through 4-13; attach documentation for any alternate values used in completing the worksheet.

   This variable may also be used to account for the cost of renewing or replacing countermeasures having shorter service lives than others considered for initial implementation at the same time. For example, if a proposed countermeasure combination includes a sign counter-measure with a seven-year service life and a marking countermeasure with a one-year service life, the combination could be said to have a seven-year service life with a net annual O&M cost adequate to cover both sign maintenance and annual restriping.

4. Determine countermeasure service life. Enter the time period over which a countermeasure is expected to reduce crash rates and/or crash severity, not the physical life expectancy of the countermeasure itself. Suggested service lives are listed in Tables 4-11 to 4-13 for typical traffic engineering countermeasures; however, additional and alternative values can be found in other sources (e.g., FHWA, 1981a). Identify the source used and attach relevant excerpts from any outside sources. As indicated in Step 3, combinations of countermeasures having unequal service lives can be handled by assuming an overall service life equal to the least common multiple of the lives of the countermeasures being analyzed (for further discussion of the problem of unequal service lives, see Wohl and Martin, 1967).

5. Determine a salvage value. Figure 5-1 assumes that this value will normally be set equal to zero. Note exceptions in the space provided.

6. Select an interest rate. Enter an agency-approved interest rate to reflect the time value of money. Economic analyses are very sensitive to small variations in interest rates. The same interest rate should therefore be used in evaluating all safety improvements being considered within a given planning or budgeting cycle. The rate used should normally reflect current interest rates for government bonds and securities, as well as both past and current policies of the agency (FHWA, 1981a).

7. Determine other economic factors. First decide which method(s) will be used in completing the computation of a B/C ratio: the Equivalent Uniform Annual Benefit and Cost Method (Step 8), the Present Worth of Benefits and Costs Method (Step 9), or both. The first method requires the Capital-Recovery and Sinking-Fund factors and the second method requires the Present-Worth Factor and the Present-Worth Factor for a Series of Payments. Look up the necessary factors in compound interest tables (Appendix E) and enter the factors in the blanks provided on the worksheet.

8. Compute the B/C ratio using the Equivalent Uniform Annual Benefit and Cost Method. First confirm that this method is desired (noting the discussion of the alternative methods at the beginning of this section). If it is not, skip to Step 9; if it is, complete the following two sub-steps:

a. Enter in the blanks of the Annual Cost equation the corresponding quantities from the top half of the page and solve.

b. Enter in the blanks of the B/C equation the Annual Benefit from the preceding page and the Annual Cost from the preceding sub-step and solve. Circle or highlight the resulting ratio if it is greater than or equal to 1.0.

9. Compute the B/C ratio using the Present Worth of Benefits and Costs Method. First confirm that this method is desired (noting the discussion of alternative methods at the beginning of this section). If it is not, verify that Step 8 has been completed and skip Step 9; if it is, complete the following three sub-steps:

   a. Enter in the blanks of the Present Benefit equation the two indicated quantities and solve.

   b. Enter in the blanks of the Present Cost equation the corresponding quantities from the preceding page and solve.

   c. Enter in the blanks of the B/C equation the Present Benefit from Sub-Step 9a and the Present Cost from Sub-Step 9b and solve. Circle or highlight the resulting ratio if it is greater than or equal to 1.0. If the B/C ratio was also computed in Step 8, verify that Steps 8 and 9 produced the same ratio.

EXAMPLE OF B/C ANALYSIS

This section completes the example started in Chapter 3 and continued in Chapter 4. The sample intersection was shown to be a high-crash location based on 1993 to 1995 data. Significant crash patterns included head-on & sideswipe/opposite-direction crashes, head-left/rear-left crashes and angle crashes. Eleven higher-priority countermeasures for such patterns were identified.

Three of the identified countermeasures, designated "Package A" in Figure 4-11, involve fairly simple traffic engineering and enforcement actions that could be implemented immediately. Another five of the countermeasures, designated "Package B," involve making better use of available pavement on the intersection's approaches. The likely costs and implementation phasing of Package B are not fully known at present but warrant further study.
The use of the B/C Analysis Worksheet is illustrated in Figure 5-2 for the proposed simultaneous implementation of the two traffic engineering countermeasures within Package A: Post/Reduce Speed Limit (SN-19) and Add All-Red Clearance Interval (SG-4). The third countermeasure within the package, Increase Traffic/Speed Enforcement, is not included in the analysis due to the lack of cost data.

The results from applying this worksheet are indicated below under each of the steps described earlier. These steps require the analyst to:

1. Compute the annual average safety benefit. This involves four sub-steps:
   a. Determine the annual average number of crashes occurring at each severity level prior to countermeasure implementation ("pre-treatment"). The example data used to illustrate the EPDO Method in Chapter 3 are in the corresponding blanks of Figure 5-2 (for Sub-Step 1c as well as 1a).

   b. Enter CRFs. The value of CRFT for this specific countermeasure combination is determined in Chapter 4 to be 0.363. Since this value was not taken directly from any of that chapter's tables, the "Other" option is checked for source (computations of the type shown at the end of Chapter 4 would ordinarily be attached to the worksheet). No severity-specific values are available, so the value for total crashes is also entered in the other blanks on the same line of the worksheet.

c. Determine the average cost per crash by severity. The values of CF and CPDO given in Table 5-1 are entered directly into the blanks at the right margin. The values for A-, B- and C-level injury crashes are entered in the first blank on each line of the equation for CABC. Since other values needed in the equation have already been entered in Sub-Step 1a, the equation can now be solved.

d. Compute the annual benefit anticipated for the countermeasure(s) being evaluated. Values determined in Sub-Steps 1a to 1c are entered in the corresponding blanks of the equation for Annual Benefit and the equation is solved. The result, $314,000, is rounded to the nearest 100 dollars.

2. Determine countermeasure implementation cost. As noted on the example worksheet, the implementation costs given in the Chapter 4 tables for SN-19 and SG-4 are simply added (they each cost $900).

3. Determine the net annual O&M costs. According to Tables 4-11 and 4-12, both countermeasures have zero O&M costs.

4. Determine countermeasure service life. Table 4-11 gives a service life for SN-19 (speed limit signs) of seven years. Table 4-12 gives a service life for SG-4 (signal retiming) of one year, but this does not really apply to all-red clearance intervals which — unlike cycling green and red phases — ordinarily do not warrant an annual retiming effort. Hence, the service life being assumed here for the countermeasure Add All-Red Clearance Interval is the same seven years used for the companion signing countermeasure.

5. Determine a salvage value. Neither countermeasure in the combination has a salvage value.

6. Select an interest rate. An unusually large value (10 percent) is used here to reflect future economic uncertainty. This value is sufficiently high that it should produce a conservative or "worst-case" B/C ratio (i.e., a low ratio resulting from a high cost). The analyst may want to repeat the cost and B/C ratio computations with a lower interest rate in order to establish a range of possible B/C ratios.

7. Determine other economic factors. Both methods for completing the B/C computation are being illustrated here, so all four factors are determined using the tables in Appendix E and are entered in the appropriate blanks.

8. Compute the B/C ratio using the Equivalent Uniform Annual Benefit and Cost Method. The necessary input values for the Annual Cost and B/C equations are taken from earlier places within the worksheet and entered in the corresponding blanks. The Annual Cost is then computed to be $370 and the B/C ratio is ($314,000/$370 =) 849:1. It is immediately obvious from this example that operational, non-capital-intensive crash countermeasures can be highly cost-effective.

9. Compute the B/C ratio using the Present Worth of Benefits and Costs Method. The necessary input values for the Present Benefit, Present Cost and B/C equations are taken from earlier places within the worksheet and entered in the corresponding blanks. The Present Benefit is then computed to be $1,528,700 (rounded), the Present Cost is $1,800 and the resulting B/C ratio is — once again — 849:1. The computational cross-check has therefore succeeded.

Figure 5-2.
Example Use of B/C Analysis Worksheet

Location ____ Intersection of Sem Road and Cog Avenue
Countermeasure Name(s) & Code(s) ____ Post/Reduce Speed Limit (SN-3) and
Add All-Red Clearance Interval (SG-14)

Analyst ____ John Smith ____ Date ____ 09/04/97

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1. Annual Average Safety Benefit

a. *Annual Average Number of Crashes by Severity (pre-treatment)*

Determined for 3 years: 1993 to 1995 (min. is 3 yrs)
Fatal, F 0.0 + Non-F Injury, A+B+C 12.00 + PDO 35.00 = Total 47.00

b. *Crash-Reduction Factor (CRF) by Severity (*may set = CRF_T)*

CRF_F* 0.363 CRF_{ABC}* 0.363 CRF_{PDO}* 0.363 Total Crashes, CRF_T 0.363

Source: Tables 4-11 to 4-13 ___ Other (attach) X
Note: See computation of combined CRF_T at end of Chapter 4.

c. *Average Cost Per Crash by Severity (C_i)*

Source: Table 5-1 X Other (attach) ___ C_F \$ 3,961,000

Weighted Average for Non-F Injury:

$C_{ABC} = (C_A xA + C_B xB + C_C xC) / (A+B+C) =$

(\$ 278,000 x 1.00 +

\$ 66,000 x 2.67 +

\$ 38,000 x 8.33) / 12.00 = C_{ABC} \$ 64,230

C_{PDO} \$ 2,700

d. *Annual Benefit =*

(F x CRF_F x C_F) +

((A+B+C) x CRF_{ABC} x C_{ABC}) +

(PDO x CRF_{PDO} x C_{PDO}) =

(0.0 x 0.363 x \$ 3,961,000) +
(12.00 x 0.363 x \$ 64,230) +
(35.00 x 0.363 x \$ 2,700) = \$ 314,000

Figure 5-2.
B/C Analysis Worksheet (cont'd)

2. Implementation Cost

Source: Tables 4-11 to 4-13 _X_ Other (attach) ___ $ 1,800
Note: Costs from these tables for SN-3 and SG-14 are added.

3. Net Annual Operating and Maintenance (O&M) Costs

Source: Tables 4-11 to 4-13 _X_ Other (attach) ___ $ 0

4. Service Life

Source: Tables 4-11 to 4-13 _X_ Other (attach) ___ 7 yrs
Note: All-red interval does not need annual retiming.

5. Salvage Value (if not set equal to 0, explain basis below:)

____ $ 0

6. Interest Rate 10 %

7. Other Economic Factors
See Appendix E tables for service life & interest rate above:

Capital-Recovery Factor 0.2054

Sinking-Fund Factor 0.1054

Present-Worth Factor 0.5132

Present-Worth Factor for a Series of Payments 4.8684

8. B/C Ratio Using Equivalent Uniform Annual Benefit and Cost Method

a. *Annual Cost* =

(Implementation Cost x Capital-Recovery Factor) +
(Net Annual Operating and Maintenance Costs) -
(Salvage Value x Sinking-Fund Factor) =

($ 1,800 x 0.2054) +

($ 0) -

($ 0 x 0.1054) = $ 370

b. *B/C* = (Annual Benefit / Annual Cost) =
($ 314,000 / $ 370) = 849:1

Figure 5-2.
B/C Analysis Worksheet (cont'd)

9. B/C Ratio Using Present Worth of Benefits and Costs Method

   a. *Present Benefit* =

      (Annual Benefit x Present Worth Factor for a Series of Payments) =

      ($ 314,000 x 4.8684) = $ 1,528,700

   b. *Present Cost* =

      (Implementation Cost) +
      (Net Annual Operating and Maintenance Costs x Present Worth Factor for a Series of Payments) - (Salvage Value x Present Worth Factor) =

      ($ 1,800) +

      ($ 0 x 4.8684) -

      ($ 0 x 0.5132) = $ 1,800

   c. *B/C* = (Present Benefit/Present Cost) =

      ($ 1,528,700 / $ 1,800) = 849:1

PROJECT SELECTION

Unfortunately, most local agencies do not have sufficient funds to complete all the safety improvements they would like to make. Therefore, countermeasures and the locations to be treated should be selected so as to maximize the amount of safety benefit per dollar spent, subject to various engineering, financial and institutional constraints.

This section briefly describes three of the simpler methods of using benefit and cost data to prioritize safety improvement projects (countermeasures or countermeasure combinations). Additional discussion and methods can be found in the Highway Safety Improvement Program User's Manual (FHWA, 1981a) and the Local Highway Safety Improvement Program Users' Guide (FHWA, 1986a).

All three methods discussed here — the Net Benefit Method, B/C Ratio Method and Incremental B/C Method — are useful in ranking alternative projects at a single location. However, only the latter two methods aid in the selection of projects tending to optimize safety benefits on a system-wide basis.

Net Benefit Method

This method is used to identify the project offering the greatest safety benefit at a given location. "Net benefit" is the difference between the equivalent uniform annual benefit and the equivalent uniform annual cost, two quantities computed above in the B/C analysis worksheet. Alternative projects having a net benefit greater than zero (or B/C ratio greater than 1.0) are ranked in descending order by value of net benefit. The project having the largest net benefit is considered by this method to be the best alternative.

The Net Benefit Method tends to identify high-cost, capital-intensive projects. Implementing only this type of project would dedicate large portions of the total safety improvement budget to a rather limited number of locations, usually to the disadvantage of other locations in the network for which low-cost countermeasures might be well-suited. As discussed below, this method should probably be used only in conjunction with other project selection methods.

B/C Ratio Method

This method ranks candidate projects based on the amount of safety benefit they offer for every dollar spent. The method can be applied at either a single location or system-wide.

In applying the method at a single location, alternative projects having B/C ratios exceeding 1.0 are first ranked in descending order by B/C ratio. The project having the largest B/C ratio is considered by this method to be the best alternative.

In applying the method system-wide, candidate projects having B/C ratios exceeding 1.0 are first ranked in descending order by B/C ratio. Project selection then begins at the top of the list and proceeds down the list until available funds are depleted. A project on the list is skipped if it would treat the same location as a project higher on the list or if the addition of its cost to cumulative program cost would result in a budget overrun. Separate project lists may be developed on the basis of such factors as district, roadway functional class and average daily traffic volume.

The B/C Ratio Method tends to favor low-cost operational safety improvements. While such improvements might offer very high benefits per dollar spent, they do not always provide reliably long-lasting reductions in both crash frequency and crash severity. Many of the most hazardous known

locations should be corrected, even if the B/C ratios for the countermeasures identified for those locations are not as high as elsewhere.
There are several possible ways of offsetting the above-noted disadvantages of the Net Benefit and B/C Ratio Methods of project selection.

One way is to compile a project list by each method and then select an arbitrary number of unique projects from the top of each list. Another way is to subdivide all possible projects into low-, medium- and high-cost classes and then select a project from each list until available funds are depleted. Yet another way is to apply the Incremental B/C Method.

Incremental B/C Method

This method can be used to select projects based on whether extra increments of expenditure are justified for a particular location. It can also be used to simultaneously determine the optimal level of expenditure at multiple locations, each having more than one possible treatment alternative (FHWA, 1981a).

The Incremental B/C method assumes that the relative merit of a project is measured by its increased benefit (compared to the next-lower-cost project) divided by its increase in cost (compared to the next-lower-cost project). The increased benefit divided by the increase in cost is known as the incremental B/C ratio. To apply the Incremental B/C Method, complete the following steps for each location being studied:

1. Determine the benefit, cost and B/C ratio of each candidate project.

2. List the projects having a B/C ratio greater than 1.0 in order of increasing cost.

3. Calculate the incremental B/C ratio of the second-lowest-cost project compared to the lowest-cost project.

4. Continue, in order of increasing cost, to calculate the incremental B/C ratio for each project compared to the next-lower-cost project.

5. Stop when the incremental B/C ratio first falls below 1.0.

According to this method, the last incremental B/C ratio on the list which exceeds 1.0 identifies the most economically attractive (or best) project. This project — the higher-cost alternative of the two being compared by the ratio — is the most expensive project on the list having additional benefits in excess of additional costs.

To apply the Incremental B/C Method in system-wide project selection:

1. Use the method to identify the best project at each location studied.

2. List the resulting best projects in order of increasing cost.

3. Complete Steps 3, 4 and 5 of the Incremental B/C Method (above) for the list of best projects.

4. Identify the best system-wide project (according to the method's criterion).

5. Select projects by starting with the best system-wide project and proceeding UP the list (i.e., in the direction of decreasing cost) until available funds are depleted. Skip a project if the addition of its cost to cumulative program cost would result in a budget overrun.

If the list of projects generated by the last step fails to utilize all available safety improvement funds, the agency may want to consider adding projects suggested by the application of other methods. Alternatively, spare funds might be held in a contingency account (if law and policy allow), in order to finance future cost overruns or other projects whose need becomes more apparent later in the fiscal year.

This method reduces the impact of very-low-cost projects. It also enhances the consideration of additional projects based on their expected additional benefits. An example of the method's application at a single location can be found in the Local Highway Safety Improvement Program User's Guide (FHWA, 1986a).