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CHAPTER FIFTY

ECONOMIC ANALYSIS

50-1.0 GENERAL

The material provided in this Chapter is intended to provide a methodology to evaluate the cost effectiveness of various safety improvement measures at a specific location.

The designer is responsible for ensuring that the design of the project reflects a cost-effective expenditure of the available construction funds. This applies to the design of individual elements (e.g., roadway width, intersection, traffic signal, bridge width, or culverts). The cost-effective evaluation will be based on the judgment and subjective analysis of the designer. A design may sometimes warrant an analytical cost-effective evaluation. This may include, for example, a safety improvement project which will be extremely expensive, or a 3R project which is not in accordance with the criteria shown in Chapter Fifty-five. Section 50-2.0 discusses the Department's cost-effectiveness procedures.

Value engineering is an important, creative management tool used by the Department to optimize expenditures for highways and transportation facilities. The Department's value-engineering approach is to use a team of individuals from various disciplines who review a project to ensure that it meets the desired objectives. Section 50-3.0 discusses INDOT's value-engineering program.

50-2.0 COST-EFFECTIVE ANALYSES

50-2.01 General

The criteria in this *Manual* reflect general cost-effective considerations and are applicable to a wide range of conditions. However, because of the need to develop design criteria for widespread application, they must inherently assume typical benefits and typical costs that would normally be encountered in the selection and design of a project. What is actually encountered for a specific project or site may vary widely in terms of expected benefits and expected costs. It is therefore appropriate to consider the cost-effectiveness of applying the normal design criteria to an individual project or site.

The cost-effective analysis will be conducted by the application of engineering judgment. A rough estimate of construction and right-of-way costs is usually available. The designer has likely evaluated the projected traffic volumes, accident history, and the project impacts on right of way, the environment, and utility relocation. Once the designer evaluates the likely benefits and costs of the proposed improvement, it is often obvious whether or not a design element under consideration is cost effective. This approach is the most practical in the interest of time. Therefore, engineering judgment will most often be used to conduct the cost-effective analysis.

An analytical cost-effect evaluation may be warranted. The following discusses the basic types of cost-effective methodologies used by INDOT. For additional information on cost-effective methodologies, the user should review NCHRP Synthesis 142 *Methods of Cost-Effectiveness Analysis for Highway Projects*.

The users of any cost-effective methodology should recognize its limitations. These include the following.

1. The research data to establish critical relationships (e.g., an accident-reduction factor for flattening a vertical curve) may have questionable validity. The research may have made assumptions which are not universally applicable, or several research studies may have yielded conflicting results. There may be no data available to establish a critical relationship.

2. A cost-effective methodology may require significant amounts of data, and it may require considerable effort to perform.

3. A cost-effect study can only consider those impacts which are quantifiable and which can be assigned a realistic monetary value. It cannot realistically incorporate the impacts of such factors as general design consistency, aesthetics, land values and uses, access, driver convenience and comfort, social ramifications, or environmental consequences.

Therefore, the results of a cost-effective analysis should only serve as a tool to the decision maker. Despite its analytical approach, there is nonetheless a great deal of subjectivity in the analysis. The final decision must place the results in proper perspective when considering the limitations of the cost-effective methodology.

50-2.02 User Benefit-Cost Analysis

This approach estimates the total user benefits and costs for a project as a whole or for an individual design element within a project. The methodology considers user benefits such as savings in vehicular operation costs, reduced driving time, and reduced accidents. It considers direct project costs such as preliminary engineering, construction, right of way, and maintenance. The objective is to compare overall benefits to overall costs to determine the economic feasibility of the proposed project or improvement to a specific design element. The comparison may be made by means of economic techniques including present worth, benefit-cost ratio, rate of return, or payback period.

Many cost-effective methodologies have been developed and many references exist which address user benefit-cost analyses. The standard reference is the AASHTO publication *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*. The publication's basic approach can be summarized as follows:

1. Select Cost Factors. The *Manual* provides highway user cost data for a base year of 1975. The user of the methodology must select multipliers to convert such data to the year under study.

2. Select Economic Study Model. A method to measure the cash outward and inward flows in equivalent dollars by use of a compound interest must be selected. INDOT has selected a discount rate of 4% to calculate present value. An analysis period (e.g., twenty years for new construction) must also be selected (see Section 50-2.03).

3. Estimate Project Costs. These include construction, right-of-way, and maintenance costs.

4. Calculate Unit User Costs. The user costs, as a function of traffic characteristics and highway geometry, should be estimated for the alternative designs including the do-nothing alternative. User costs include vehicular operating cost, travel time, accident costs, and fares.

5. Calculate User Benefits. The benefits for savings in vehicular operating costs, travel time, accident costs, and fares should be estimated.

6. Convert to Annual User Benefits. It is necessary to convert all benefits to an annual amount.

7. Estimate Residual (Salvage) Value. At the end of a facility's or design element's service life, some value will likely remain. This value should be estimated and its worth included in the methodology to offset project costs.

8. Determine Present Value. The stream of user benefits and user costs over the design service life must be converted to a present value for comparison between the two.

50-2.03 Safety Benefits Based on Accident History

Accident history is usually the best indicator of future accident experience. Therefore, if the data is available and if valid, it is possible to calculate with some precision the cost-effectiveness of a proposed highway safety countermeasure. This approach is applicable to any assessment of the safety cost-effectiveness of a design element intended to reduce the frequency and severity of accidents, assuming that the pertinent information is available. Because accident history can only be obtained for an existing facility, the procedures described below are only used for a safety-improvement project or a 3R safety enhancement. Section 55-8.0 provides a discussion on how to analyze the accident data.

The controlling factor in this analysis is the benefit to cost ratio (B/C). If the B/C ratio is less than 1, the proposed improvement is not economically prudent. If the B/C ratio is 1 or greater, the improvement is economically prudent. If the B/C ratio is less than but very close to 1, the secondary benefits resulting from the proposed improvement should be analyzed before abandoning the proposed improvement.

The following provides INDOT's procedure for evaluating the safety benefits of a project improvement based on accident history.

50-2.03(01) Definitions

1. Equivalent Uniform Annual Benefit (EUAB). The projected annual dollar savings amortized over the service life of the improvement. This savings is based on accident reduction and other related cost savings.

2. Equivalent Uniform Annual Cost (EUAC). The projected annual cost amortized over the service life of the improvement. This cost is based on the initial cost, annual maintenance cost, and the terminal (salvage) value of the improvement.

3. Net Annual Benefit (NAB). The difference between the equivalent uniform annual benefit and the equivalent uniform annual cost.

4. Capital Recovery Factor (CRF). The factor used to determine the annual cost with interest to recover the capital investment during the expected service life of the improvement for an equal payment series.

5. Present-Worth Factor (PWF). The factor used to determine the present-day value of the projected economic benefits during the expected service life of the improvement. The present-worth factor for single payment (PWF_{SP}) is used when determining the present-day worth of the terminal value of the improvement. The present-worth factor for equal payment series (PWF_{EPS}) is used when determining the present-day value of the annual maintenance costs.

6. Service Life. The time period that the improvement can reasonably be expected to impact accident experience. The expected service life should reflect this time period and is not necessarily the physical life of the improvement.

7. Accident Reduction Factor (ARF). The expected percent reduction in accidents based on the type of improvement.

8. Accident Projection Factor (APF). The factor used to project the number of accidents in a given year. It is assumed to be equal to the factor used to project the increase in AADT. Accidents are assumed to increase at the same rate as the AADT.

50-2.03(02) Criteria and Constants

The following criteria and constants should be used in computing the B/C ratio. Any deviation from these criteria or constants should be documented in the project files and, where necessary, an informational copy should be furnished to FHWA. The designer should consider the following:

1. Accident Costs. To evaluate a project on the same basis, benefits should be computed with the accident-cost values shown in Figure 50-2A, Accident Cost Per Accident ($).

2. Service Life. Figure 50-2B shows service lives of various improvements. Costs and benefits should be based on these time periods.

3. Interest Rate. An interest rate of 4% should be used. Figure 50-2C, 4% Interest Factors for Annual Compounding Interest, provides the present-worth and capital-recovery factors for a 4% interest rate.

4. AADT and Accident Projection. The designer should assume a 2% increase in AADT and accidents per year over the previous year, unless better data or method of projection is available.

5. Accident Reduction Benefits. INDOT is currently using ARFs developed by the State of Missouri. These factors are shown in Section 50-2.03(05); see Figure 50-2G, Missouri Accident Reduction Factors). The ARF should be applied to the total number of accidents, regardless of the number of people or vehicles involved, when calculating accident reduction benefits. Examples are as follows.

    a. For a two-car property-damage-only accident, use the ARF from Figure 50-2G times $3,000, the accident cost from Figure 50-2A, Accident Cost Per Accident ($).

    b. For a two-car accident where one car is property-damaged only and two personal injuries occur in the other car, use the ARF from Figure 50-2G times $37,000, the accident cost from Figure 50-2A.

For an improvement that involves multiple alternates, Equation 50-2.1 should be used to calculate the total percent accident reduction for each type of accident.

$$ARP_t = ARP_l + \frac{ARP_2(100 - ARP_1)}{100} + ARP_3\left(\frac{100 - ARP_1}{100}\right)\left(\frac{100 - ARP_2}{100}\right) \quad \text{(Equation 50-2.1)}$$

Where:

ARP_t = total percent accident reduction for multiple improvements

ARP_1 = the largest percentage reduction in accidents of one of the improvements

ARP_2 = the second largest percent reduction in accidents of one of the improvements

ARP_3 = the third largest percentage reduction in accidents of one of the improvements

For more information on how to determine accident reduction factors, the user should review the Institute of Transportation Engineers publication, *Selecting and Making Highway Safety Improvements, a Self Instructional Text TTC-440.*

6. Secondary Benefits. Secondary benefits, such as improved capacity or other economic benefits, will not be included in the final computed B/C ratio of the selected alternate solution. Secondary benefits may be used in the B/C computational ratios of the alternate improvements studied in determining the selection of the preferred alternate but should not be used for the final B/C ratio.

7. Equivalent Uniform Annual Benefit (EUAB) and Equivalent Uniform Annual Cost (EUAC). A summary of the calculations required to determine EUAB, EUAC, and the B/C ratio are shown in Section 50-2.03(03). Example calculations for determining B/C ratios are shown in Section 50-2.03(04).

50-2.03(03) Summary of Steps to Determine the Benefit-Cost Ratio and Net Annual Benefit

The following provides a step-by-step procedure which can be used to compute the B/C ratio and the NAB:

1. Collect accident data and identify accident pattern (see Section 55-8.0).

2. Identify the proposed safety improvement (e.g., flatten horizontal or vertical curve, widen roadway or bridge width, add exclusive left-turn lane, provide traffic signal).

3. Determine the expected service life of the proposed improvement from Figure 50-2B, Service Life.

4. Estimate the construction costs and expected annual maintenance costs.

5. Assuming that the accident data will parallel the AADT, estimate accident reduction for each severity class and for each year of the service life of the improvement as follows:

$$AR = (N_a)(ARF)(APF_2) \quad \text{(Equation 50-2.2)}$$

Where:

AR = Accident reduction by year of service life
N_a = Number of accidents (from accident data)
ARF = Accident reduction factor (from existing records, judgment, or Figure 50-2G)
APF_2 = Accident projection factor

6. Assign values to accident reductions using data from ARF in Figure 50-2G, Missouri Accident Reduction Factors. Compute the accident reduction benefits as follows:

$$ARB = (AR)(AC_3) \quad \text{(Equation 50-2.3)}$$

The result of this step is the gross dollar figure for the total annual benefits for each year of the service life of each improvement.

7. Estimate secondary benefits, wherever possible, and include them in the gross benefit figure but do not include them in the final B/C computation of the selected alternate.

8. Convert gross benefits from Step 6 above to the EUAB as follows:

   a. Adjust the benefits to the present-day values by multiplying each year's total benefit, from Step 6 above, by the present-worth factor for that year from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

   b. Add up all of these adjusted benefits.

   c. Multiply the total of the adjusted benefits by the CRF from Figure 50-2C for the last year of the improvement's service life.

   d. The formula for the above steps is as follows:

$$EUAB = (CRF)(\text{Summation of Yearly-Adjusted Benefits}) \quad \text{(Equation 50-2.4)}$$

9. Convert the gross costs to the EUAC as follows:

   a. Multiply the annual maintenance cost by the present-worth factor for equal payment series for the last year of the improvement's service life to determine the cumulative maintenance cost.

   b. Add the initial cost to the total of the cumulative maintenance costs.

   c. Multiply the terminal value by the present-worth factor for single payment for the improvement's last service year and subtract that amount from the result of Step 9.c.

   d. Multiply the result of Step 9.d. by the CRF for the improvement's last service year.

   e. The formula for the above steps is as follows:

$$EUAC = CRF\left[I_c + (M_{ac})(PWF_{EPS}) - T(PWF_{SP})\right] \quad \text{(Equation 50-2.5)}$$

Where:

CRF	=	Capital recovery factor for the last year of the improvement's service life
I_c	=	Initial cost
M_{ac}	=	Annual maintenance cost
PWF	=	Present-worth factor
PWF_{EPS}	=	Present-worth factor (equal-payment series)
PWF_{SP}	=	Present-worth factor (single payment)
T	=	Terminal value

10. Calculate the B/C ratio by dividing the EUAB by the EUAC as follows:

$$B/C = \frac{EUAB}{EUAC_5} \quad \text{(Equation 50-2.6)}$$

11. Calculate the NAB by subtracting the EUAC from the EUAB as follows:

$$NAB = EUAB - EUAC_6 \quad \text{(Equation 50-2.7)}$$

50-2.03(04) Example Calculations for Benefit-Cost Ratio and Net Annual Benefit

The following are two examples for determining the B/C ratio and the NAB.

* * * * * * * * * *

<u>Example 50-2.1</u>

Given: S.R. 62, an Urban Collector
Non-freeway 3R Project
Horizontal curve which meets the criteria described in Section 55-4.03, but has a history of accidents as shown in Figure 50-2D, Accident Summary (Example 50-2.1).

Problem: Determine if realignment of the horizontal curve will be cost effective

Solution: The following steps from Section 50-2.03(03) apply:

Step 1: Collect accident data. The accident data is provided in Figure 50-2D.

Step 2: Identify the proposed safety improvement. The selected improvement is to realign the horizontal curve.

Step 3: Determine the service life of improvement. From Figure 50-2B, Service Life, the expected service life for a horizontal alignment change is 20 years.

Step 4: Estimate initial construction and annual maintenance costs. From similar projects, the construction cost is estimated to be $750,000 with annual maintenance after realignment to be $3,000. After 20 years, the terminal (salvage) value is expected to be $20,000.

Step 5: Estimate the assumed accident reduction for each accident type and for each year of service life. The following will apply.

a. From Figure 50-2G, the ARF is 50%.

b. The ARF is assumed to be 2% per year; see Section 50-2.03(02) Item 4 and Figure 50-2E, Accident Reduction Benefits (Example 50-2.1), column 2.

c. From Figure 50-2D, the average annual PDO accidents is 5.66 and average annual F/I accidents is 2.33.

d. Using Equation 50-2.2, Figure 50-2E, columns 3 and 4 show the expected number of PDO and F/I accidents to be reduced.

Step 6: Compute accident reduction benefits. The following will apply; see Figure 50-2E:

a. Column 5. Determine the benefits of the reduced number of PDO accidents by multiplying the value in column 3 by $3,000, from Figure 50-2A, Accident Cost Per Accident ($), using Equation 50-2.3.

b. Column 6. Determine the benefits of the reduced number of F/I accidents by multiplying the value in column 4 by $37,000, from Figure 50-2A, using Equation 50-2.3.

c. Column 7. Determine total benefit of the reduced number of accidents by adding columns 5 and 6.

d. Column 8. Determine the present-worth factor from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

e. Column 9. Determine the present worth of the benefits from the reduced number of accidents by multiplying column 7 by column 8.

f. Total. Determine the total yearly benefits by summing the values in column 9. The total yearly benefit for this realignment example is $846,958.

Step 7: Estimate the secondary benefits. For this example, there are no secondary benefits.

Step 8: Convert gross benefit from Step 6 to EUAB. The CRF factor from Figure 50-2C for 20 years is 0.0736. Use Equation 50-2.4 to obtain the following:

$$EUAB = 0.0736 \times \$846{,}958 = \$62{,}336$$

Step 9: Convert gross costs to EUAC. Using Equation 50-2.5:

$$EUAC = (0.0736) \times [\$750{,}000 + \$3{,}000(13.5903) - \$20{,}000(0.4564)] = \$57{,}529$$

Where:

CRF = Capital recovery factor for the last year of the improvement's service life = 0.0736 at 20 years (from Figure 50-2C)

I_c = Initial cost = $750,000

PWF_{EPS} = Present-worth factor for equal-payment series = 13.5903 at 20 years (from Figure 50-2C)

PWF_{SP} = Present-worth factor for single-payment series = 0.4564 at 20 years (from Figure 50-2C)

M_{ac} = Annual maintenance cost = $3,000

T = Terminal (salvage) value = $20,000

Step 10: Calculate the B/C ratio. Use Equation 50-2.6 to obtain the following:

$$B/C\ Ratio = \frac{EUAB}{EUAC} = \frac{\$62,336}{\$57,529} = 1.0836$$

Step 11: Calculate the NAB. Use Equation 50-2.7 to obtain the following:

$$NAB = EUAB - EUAC = \$62,336 - \$57,529 = \$4,807$$

Comments:

1. The NAB is a positive value as expected because the B/C ratio is greater than 1. This means that, if the proposed improvement were constructed, the projected annual benefits would be $4,807.

2. Because the B/C ratio is greater than 1, this project would be cost effective to construct.

Example 50-2.2

Given: S.R. 62, an Urban Collector
Non-freeway 3R Project
Horizontal curve which meets the criteria described in Section 55-4.03, but has a history of accidents as shown in Figure 50-2D, Accident Summary (Example 50-2.1).

Problem: Determine if improving the superelevation at the horizontal curve will be cost-effective.

Solution: The following steps from Section 50-2.03(03) apply.

Step 1: Collect accident data. The accident data is provided in Figure 50-2D.

Step 2: Identify the proposed safety improvement. The selected improvement is to improve the superelevation on the horizontal curve.

Step 3: Determine the service life of improvement. From Figure 50-2B, Service Life, the expected service life for horizontal-alignment change is 20 years.

Step 4: Estimate initial construction and annual maintenance costs. From similar projects, the construction cost is estimated to be $750,000 with annual maintenance after realignment to be $3,000. After 20 years, the terminal (salvage) value is expected to be $20,000.

Step 5: Estimate the assumed accident reduction for each accident type and for each year of service life. The following will apply.

a. From Figure 50-2G, Missouri Accident Reduction Factors, the ARF is 50%. However, because the selected improvement would still have restricted horizontal geometry, an ARF of 30% is assumed for these computations.

b. The APF is assumed to be 2% per year; see Section 50-2.03(02) Item 4, and Figure 50-2F column 2.

c. From Figure 50-2D, the average annual PDO accidents is 5.66 and average annual F/I accidents is 2.33.

d. Using Equation 50-2.2, and Figure 50-2F columns 3 and 4, Accident Reduction Benefits (Example 50-2.2), show the expected number of PDO and F/I accidents to be reduced.

Step 6: Compute accident reduction benefits. The following will apply; see Figure 50-2F.

a. Column 5. Determine the benefits of the reduced number of PDO accidents by multiplying the value in column 3 by $3,000 (from Figure 50-2A) using Equation 50-2.3.

b. Column 6. Determine the benefits of the reduced number of F/I accidents by multiplying the value in column 4 by $37,000 (from Figure 50-2A) using Equation 50-2.3.

c. Column 7. Determine total benefit of the reduced number of accidents by adding columns 5 and 6.

d. Column 8. Determine the present worth factor from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

e. Column 9. Determine the present worth of the benefits from the reduced number of accidents by multiplying column 7 by column 8.

f. Total. Determine the total yearly benefits by summing the values in column 9. The total yearly benefit for this example is $508,175.

Step 7: Estimate the secondary benefits. For this example, there are no secondary benefits.

Step 8: Convert gross benefit from Step 6 to EUAB. The CRF factor from Figure 50-2C for 20 years is 0.0736. Using Equation 50-2.4, the EUAB is as follows:

$$EUAB = 0.0736 \text{ x } \$508{,}175 = \$37{,}402$$

Step 9: Convert gross costs to EUAC. Using Equation 50-2.5, the EUAB is as follows:

$$EUAC = (0.0736) \text{ x } [\$750{,}000 + \$3{,}000\,(13.5903) - \$20{,}000\,(0.4564)] = \$57{,}529$$

Where:

CRF = Capital-recovery factor for the last year of the improvement's service life = 0.0736 at 20 years (from Figure 50-2C)

I_c = Initial cost = $750,000

PWF_{EPS} = Present-worth factor for equal payment series = 13.5903 at 20 years (from Figure 50-2C)

PWF_{SP} = Present-worth factor for single payment series = 0.4564 at 20 years (from Figure 50-2C)

M_{ac} = Annual maintenance cost = $3,000

T = Terminal (salvage) value = $20,000

Step 10: Calculate the B/C ratio using Equation 50-2.6 as follows:

$$B/C\ Ratio = \frac{EUAB}{EUAC} = \frac{\$37{,}402}{\$57{,}529} = 0.6501$$

Step 11: Calculate the NAB using Equation 50-2.7 as follows:

$$NAB = EUAB - EUAC = \$37{,}402 - \$57{,}529 = -\$20{,}127$$

Comments:

1. The NAB is a negative value as expected because the B/C ratio is less than 1. This means that, if the proposed improvement were constructed, the projected annual cost would be $20,127.

2. Because the B/C ratio is considerably less than one, it will not be economically prudent to construct the proposed pavement.

* * * * * * * * * *

50-2.03(05) Accident Reduction Factors

The Department is presently using the accident reduction factors developed by the State of Missouri. These factors are provided in Figure 50-2G.

50-2.04 Safety Benefits Based on Accident Potential (Run-off-the-Road Accident)

It is unusual for a roadside site to have a sufficiently high-accident experience to estimate safety benefits based on accident history. They usually occur at random locations along the highway roadside. However, run-off-the-road accidents in total represent a high proportion of highway accidents. Therefore, roadside hazard improvements may be warranted even if a particular site has never experienced a hazard.

The AASHTO *Roadside Design Guide* Appendix A provides a methodology to evaluate the cost-effectiveness of a roadside-safety improvement. This methodology will assess the potential for a given hazard to be struck based on pertinent traffic, highway, and hazard characteristics and will allow for the calculation of the cost effectiveness of the alternative countermeasures. It can be used to evaluate individual sites or to evaluate roadside safety for a highway segment (e.g., 1 to 2 miles in length). There is an inherent realization in this approach that a certain number of hazardous locations where a treatment is deemed to be cost effective will never experience an accident, and a certain number of hazardous locations where a treatment is deemed to be not cost effective will, in fact, experience an accident.

The AASHTO methodology establishes the following possible countermeasures in order of desirability.

1. Remove the roadside hazard.

2. Laterally relocate the hazard to a location where the potential for being struck is acceptable.

3. Reduce the severity of the hazard by making it breakaway or by making it traversable.

4. Shield the hazard with guardrail or crash cushion.

5. Do nothing; i.e., leave the hazard unshielded.

The above procedure permits the determination of which countermeasure is the most cost effective.

Chapter Forty-nine provides the Department's warrants for guardrail and other safety appurtenances. AASHTO *Roadside Design Guide* Appendix A in conjunction with the Department input data (e.g., accident costs) should be used to determine the appropriate warrant application. Section 49-10.0 provides a step-by-step guide on how to use ROADSIDE (i.e., the ROADSIDE Computer Software Program for Appendix A).

50-3.0 VALUE ENGINEERING

50-3.01 General

Value Engineering (VE) can be defined as a systematic application of recognized techniques, applied by a multi-disciplinary team which identifies the function of a product or service; establishes a worth for that function; and provides alternative ways to accomplish the necessary function reliably, at the lowest overall cost, through the use of creative techniques. VE is not merely a method of cost cutting but a methodology to review alternatives and to suggest choices that still provide a reasonable product without reducing its quality. Value engineering is a proven effective tool for both product improvement and design enhancement. VE can substantially improve design and cost-effectiveness of projects, facilities, operations, procedures and other areas of the transportation program.

VE uses the team approach to review all aspects of the project: design, procurement, construction, operation, and maintenance. A VE team is made up of 5 to 7 individuals with a variety of expertise to study the major problem areas anticipated within the project (e.g., traffic, right of way, structures, soils, materials, construction, design, maintenance). Due to cost and time constraints, the VE team will normally only review 20% of the project elements which account for approximately 80% of a project's total cost. For the greatest benefit, VE should be implemented as early as practical in a project's development. Figure 50-3A, VE Potential During Life of a Project (Conceptual), illustrates the benefit of how implementing VE early in the project development can provide the greatest savings.

50-3.02 INDOT Application

Not every project warrants the review of a value-engineering team. The Department most often relies on the designer to implement the VE approach in his or her design. A large project or a project with special design concerns is a prime candidate for review by a value-engineering team. Project selection for VE review is determined during the project's preliminary-engineering-study stage.

50-3.03 References

For more detailed information on value-engineering techniques and procedures, the user is referred to the publications as follows:

1. *Value Engineering for Highways*, FHWA, Revised October 1983.

2. *AASHTO Guidelines for Value Engineering*, 1987, AASHTO.

3. *Value Engineering in Preconstruction and Construction*, NCHRP Synthesis 78, TRB, September 1981.

Route Type	Fatal / Injury *	Property Damage Only
Interstate Route, Rural	75,000	6,500
Interstate Route, Urban	52,000	6,500
U.S. or State Route, Rural	78,000	6,500
U.S. or State Route, Urban	48,000	6,500
Other Route, Rural	56,500	6,500
Other Route, Urban	42,500	6,500

* This cost includes property-damage cost.

ACCIDENT COST PER ACCIDENT
In 2001 Dollars

Figure 50-2A

Code	Project Description	Service Life
Intersection Improvement		
10	Channelization, left-turn bay	10
11	Traffic Signalization	10
12	Combination of 10 and 11	10
13	Sight distance improvement	10
19	Other intersection improvement except structures	10
1A	Combination of 10 and 19	10
1B	Combination of 11, 13, 19 and/or 65	10
Cross Section		
20	Pavement widening, no lanes added	20
21	Lanes added without new median	20
22	Highway divided, new median added	20
23	Shoulder widening or improvement	20
24	Combination of 20 and 23	20
25	Skid treatment, grooving	10
26	Skid treatment, resurfacing	10
27	Flattening or clearing side slopes	20
29	Other cross section or combination of 20-27	20
2A	Combination of 20 and 26	15
Structure		
30	Widening bridge or major structure	20
31	Replacing bridge or major structure	30
32	New bridge or major structure, except 34 & 51	30
33	Minor structure	20
34	Pedestrian over- or under-crossing	30
39	Other structure	20
Alignment		
40	Horizontal alignment change, except 52	20
41	Vertical alignment change	20
42	Combination of 40 and 41	20
49	Other alignment change	20
Railroad Grade Crossing		
50	Add flashing lights	10
51	Eliminate with new or reconstructed grade separation	30
52	Elimination by relocating highway or railroad	30
53	Illumination	10
54	Flashing lights replacing active devices	10
55	Automatic gates replacing signs	10
56	Automatic gates replacing active devices	10
57	Signing and marking	10
58	Crossing-surface treatment	10
59	Other railroad grade crossing	10
5A	Combination of 50, 54, 55, 56, 57, or 58	10

SERVICE LIFE (years)

Figure 50-2B

Code	Project Description	Service Life
Roadside Appurtenances		
60	Traffic signs	6
61	Breakaway signs or luminaire supports	10
62	Road-edge guardrail	10
63	Median barrier	15
64	Markings or delineators	2
65	Lighting	15
66	Improve drainage structures	20
67	Fencing	10
68	Impact attenuators	10
69	Other roadside appurtenances	10
6A	Combination of 60-64	10
6B	Combination of 63-64	10
6C	Combination of 60 and 62	8
6D	Combination of 60 and 64	4
6E	Combination of 62 and 69	10
6F	Combination of 62, 66, and 69	10
6G	Combination of 60 and 63	10
Other Safety Improvement		
90	Safety provisions for roadside features and appurtenances	20
99	Project not otherwise classified	20
9A	Combination of 11, 26, and 69	10
9B	Combination of 26 and 66	15
9C	Combination of 27, 30, 62, and 99	20
9D	Combination of 11 and 60	8
9E	Combination of 11 and 64	6
9F	Combination of 23, 26, and 62	15
9G	Combination of 27, 61, 62, and 64	10
9H	Combination of 22, 39, and 65	20
9I	Combination of 23, 61, 62, 64, 65, and 66	15

SERVICE LIFE (years)

Figure 50-2B (continued)

Year	Single Payment		Equal-Payments Series			
	Compound Amount	Present Worth	Compound Amount	Sinking Fund	Present Worth	Capital Recovery
1	1.0400	0.9615	1.0000	1.0000	0.9615	1.0400
2	1.0816	0.9246	2.0400	0.4902	1.8861	0.5302
3	1.1249	0.8890	3.1216	0.3203	2.7751	0.3603
4	1.1699	0.8548	4.2465	0.2355	3.6299	0.2755
5	1.2167	0.8219	5.4163	0.1846	4.4518	0.2246
6	1.2653	0.7903	6.6330	0.1508	5.2421	0.1908
7	1.3159	0.7599	7.8983	0.1266	6.0021	0.1666
8	1.3686	0.7307	9.2142	0.1085	6.7327	0.1485
9	1.4233	0.7026	10.5828	0.0945	7.4353	0.1345
10	1.4802	0.6756	12.0061	0.0833	8.1109	0.1233
11	1.5395	0.6496	13.4864	0.0741	8.7605	0.1141
12	1.6010	0.6246	15.0258	0.0666	9.3851	0.1066
13	1.6651	0.6006	16.6268	0.0601	9.9856	0.1001
14	1.7317	0.5775	18.2919	0.0547	10.5631	0.0947
15	1.8009	0.5553	20.0236	0.0499	11.1184	0.0899
16	1.8730	0.5339	21.8245	0.0458	11.6523	0.0858
17	1.9479	0.5134	23.6975	0.0422	12.1657	0.0822
18	2.0258	0.4936	25.6454	0.0390	12.6593	0.0790
19	2.1068	0.4746	27.6712	0.0361	13.1339	0.0761
20	2.1911	0.4564	29.7781	0.0336	13.5903	0.0736
21	2.2788	0.4388	31.9692	0.0313	14.0292	0.0713
22	2.3699	0.4220	34.2480	0.0292	14.4511	0.0692
23	2.4647	0.4057	36.6179	0.0273	14.8568	0.0673
24	2.5633	0.3901	39.0826	0.0256	15.2470	0.0656
25	2.6658	0.3751	41.6459	0.0240	15.6221	0.0640
26	2.7725	0.3607	44.3117	0.0226	15.9828	0.0626
27	2.8834	0.3468	47.0842	0.0212	16.3296	0.0612
28	2.9987	0.3335	49.9676	0.0200	16.6631	0.0600
29	3.1187	0.3207	52.9663	0.0189	16.9837	0.0589
30	3.2434	0.3083	56.0849	0.0178	17.2920	0.0578
31	3.3731	0.2965	59.3283	0.0169	17.5885	0.0569
32	3.5081	0.2851	62.7015	0.0159	17.8736	0.0559
33	3.6484	0.2741	66.2095	0.0151	18.1476	0.0551
34	3.7943	0.2636	69.8579	0.0143	18.4112	0.0543
35	3.9461	0.2534	73.6522	0.0136	18.6646	0.0536
36	4.1039	0.2437	77.5983	0.0129	18.9083	0.0529
37	4.2681	0.2343	81.7022	0.0122	19.1426	0.0522
38	4.4388	0.2253	85.9703	0.0116	19.3679	0.0516
39	4.6164	0.2166	90.4091	0.0111	19.5845	0.0511
40	4.8010	0.2083	95.0255	0.0105	19.7928	0.0505
41	4.9931	0.2003	99.8265	0.0100	19.9931	0.0500
42	5.1928	0.1926	104.8196	0.0095	20.1856	0.0495
43	5.4005	0.1852	110.0124	0.0091	20.3708	0.0491
44	5.6165	0.1780	115.4129	0.0087	20.5488	0.0487
45	5.8412	0.1712	121.0294	0.0083	20.7200	0.0483
46	6.0748	0.1646	126.8706	0.0079	20.8847	0.0479
47	6.3178	0.1583	132.9454	0.0075	21.0429	0.0475
48	6.5705	0.1522	139.2632	0.0072	21.1951	0.0472
49	6.8333	0.1463	145.8337	0.0069	21.3415	0.0469
50	7.1067	0.1407	152.6671	0.0066	21.4822	0.0466

4% INTEREST FACTORS FOR ANNUAL COMPOUNDING INTEREST

Figure 50-2C

Accident Summary		Year	Accident Types															
			H.O.		R.E.		R.A.		S.S.		T.M.		Ped.		L.C.		Other	
PD	F/I		PD	F/I	PD	F/I	PD	F/I	PD	F/I	PD	F/I	PD	F/I	PD	F/I	PD	F/I
6	2	1988	0	0	1	0	0	0	4	2	0	0	0	0	1	0	0	0
5	3	1989	2	1	0	0	0	0	2	1	0	0	0	0	1	1	0	0
6	2	1990	0	0	0	0	0	0	5	2	0	0	0	0	1	0	0	0
Accident Totals			2	1	1	0	0	0	11	5	0	0	0	0	3	1	0	0
Average / Year			0.6	0.3	0.3	0	0	0	3.7	1.7	0	0	0	0	1	0.3	0	0
Sum of Average PD per Year = 5.6 Sum of Average F/I per Year = 2.3																		

Where:

PD = Property Damage Only
F/I = Fatal/Injury
H.O. = Head On
R.E. = Rear End
R.A. = Right Angle
S.S. = Sideswipe
T.M. = Turning Movement
Ped. = Pedestrian
L.C. = Lost Control

ACCIDENT SUMMARY
(Example 50-2.1)

Figure 50-2D

Service Year (1)	Accident Reduction			Adjusted Benefits ($)				
	APF (2)	PDO (3)	F/I (4)	PDO *x* $3,000 (5)	F/I *x* $37,000 (6)	Total Benefit (7)	PWF (8)	Adjusted Benefits (9)
1	1.02	2.89	1.19	8,660	43,967	52,627	0.9615	50,603
2	1.04	2.94	1.21	8,830	44,829	53,659	0.9246	49,611
3	1.06	3.00	1.23	8,999	45,691	54,691	0.8890	48,620
4	1.08	3.06	1.26	9,169	46,553	55,723	0.8548	47,632
5	1.10	3.11	1.28	9,339	47,416	56,755	0.8219	46,648
6	1.13	3.20	1.32	9,594	48,709	58,302	0.7903	46,077
7	1.15	3.25	1.34	9,764	49,571	59,334	0.7599	45,089
8	1.17	3.31	1.36	9,933	50,433	60,366	0.7307	44,109
9	1.20	3.40	1.40	10,188	51,726	61,914	0.7026	43,500
10	1.22	3.45	1.42	10,358	52,588	62,946	0.6756	42,524
11	1.24	3.51	1.44	10,528	53,450	63,978	0.6496	41,559
12	1.27	3.59	1.48	10,782	54,743	65,526	0.6246	40,927
13	1.29	3.65	1.50	10,952	55,605	66,558	0.6006	39,973
14	1.32	3.74	1.54	11,207	56,899	68,105	0.5775	39,329
15	1.35	3.82	1.57	11,462	58,192	69,653	0.5553	38,676
16	1.37	3.88	1.60	11,631	59,054	70,685	0.5339	37,739
17	1.40	3.96	1.63	11,886	60,347	72,233	0.5134	37,082
18	1.43	4.05	1.67	12,141	61,640	73,781	0.4936	36,420
19	1.46	4.13	1.70	12,395	62,933	75,329	0.4746	35,754
20	1.49	4.22	1.74	12,650	64,226	76,877	0.4564	35,085
Sum of Average/Yr: PDO = 5.66; F/I = 2.33; APF = 1.02 Summation of Adjusted Total Yearly Benefits = $846,958								

ACCIDENT REDUCTION BENEFITS
(Example 50-2.1)

Figure 50-2E

Service Year (1)	Accident Reduction			Adjusted Benefits ($)				
	APF (2)	PDO (3)	F/I (4)	PDO *x* $3,000 (5)	F/I *x* $37,000 (6)	Total Benefit (7)	PWF (8)	Adjusted Benefits (9)
1	1.02	1.73	0.71	5,196	26,380	31,576	0.9615	30,362
2	1.04	1.77	0.73	5,298	26,898	32,195	0.9246	29,766
3	1.06	1.80	0.74	5,400	27,415	32,814	0.8890	29,172
4	1.08	1.83	0.75	5,502	27,932	33,434	0.8548	28,579
5	1.10	1.87	0.77	5,603	28,449	34,053	0.8219	27,989
6	1.13	1.92	0.79	5,756	29,225	34,981	0.7903	27,646
7	1.15	1.95	0.80	5,858	29,742	35,601	0.7599	27,053
8	1.17	1.99	0.82	5,960	30,260	36,220	0.7307	26,465
9	1.20	2.04	0.84	6,113	31,036	37,148	0.7026	26,100
10	1.22	2.07	0.85	6,215	31,553	37,768	0.6756	25,514
11	1.24	2.11	0.87	6,317	32,070	38,387	0.6496	24,935
12	1.27	2.16	0.89	6,469	32,846	39,315	0.6246	24,556
13	1.29	2.19	0.90	6,571	33,363	39,935	0.6006	23,984
14	1.32	2.24	0.92	6,724	34,139	40,863	0.5775	23,598
15	1.35	2.29	0.94	6,877	34,915	41,792	0.5553	23,206
16	1.37	2.33	0.96	6,979	35,432	42,411	0.5339	22,644
17	1.40	2.38	0.98	7,132	36,208	43,340	0.5134	22,249
18	1.43	2.43	1.00	7,284	36,984	44,269	0.4936	21,852
19	1.46	2.48	1.02	7,437	37,760	45,197	0.4746	21,453
20	1.49	2.53	1.04	7,590	38,536	46,126	0.4564	21,051
Sum of Average/Yr: PDO = 5.66; F/I = 2.33; APF = 1.02 Summation of Adjusted Total Yearly Benefits = $508,175								

ACCIDENT REDUCTION BENEFITS
(Example 50-2.2)

Figure 50-2F

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Pavement Markings														
General Pavement Markings						10	20	10			10	10		
Double Yellow Center Lines	5													
Right Edge Lines	2												25	
Reflectorized Raised Pavement Markers	5													
No Passing Lines	65													
Pavement Treatments														
Deslicking[a]	20	15												50
Resurfacing[c]	42	46												

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Signs														
Upgrade Signs				20	10						10	10		
Overhead Lane Signs					10		10							
Overhead Warning Signs					20	20		20	20					
Four-Way Stop Signs[c]	70	≥67												
Special Curve Warning Signs	75													
Minor Leg Stop Control	48^b; $\geq 38^a$	71^b; $\geq 18^a$												
Yield Signs	$\geq 59^b$; $\geq 46^a$	80^b												
Directional or Warning Signs at Intersection	29^b; 41^a	$\geq 59^b$; $\geq 47^a$	$\geq 26^a$											

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be <8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Signs (Continued)														
Warning Signs and Delineators at Intersections														
Warning Signs on Sections	14[b]; ≥20[a]	≥14[b]; ≥26[a]												
Regulations														
Eliminate Parking	32[a]	3[a]												
Change Two-Way Operation to One-Way	25													
Prohibit Turns	40[a]	39[a]												
Channelization														
Install Median Barriers		≥61[a]												
Add Painted/ Raised Median	12[a]													

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Channelization (Continued)														
Add Left-Turn Lane Without Signals	≥19; 6[a]	≥80; ≥54[a]												
Turn Bay New Left Channelization at Signalized Intersection w/ or w/o Left-Turn Phase	w/o 15; w/ 36[a]				20									
New Left-Turn Channelization at Unsignalized Intersection With Curbs - Painted	Curb 70; Paint 15													
Install Two-Way Left-Turn Lanes	35													

[a] On two or more lanes; [b] Two lanes

[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Access Control														
Close Median Openings				100	50	100	50	100						
Relocate Drive				20	20	10	10	10	10					
Signalization														
Install Warning Signals		≥73[a]												
Flashing Beacons (Red-Yellow)	50													
Flashing Beacons (All Red)	75													
Flashing Beacons at RR Crossing	80													
Advance Warning Flashers	30													

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Signalization (Continued)														
Improve Signals	31 2[a]	≥35												
Add Pedestrian Signals	13 3[a]	56 42												
Add Left-Turn Lanes and Signals	27[a]	1[a]												
Add Left-Turn w/o Turning Lane	39[a]	57[a]												
Add Turn-Lane, Signal and Illumination	46[a]	76[a]												
Improve Timing					10	10		10	10		10			
305-mm Lens					10									
Improve Signals to Correspond to *MUTCD*					20	20	10	20	20			20		

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Signalization (Continued)														
Add Left-Turn Lane without Signal Turn Phase	≥19 6[a]	≥80 ≥54[a]	≥18[a]											
Modify Signals	27													
Actuate					10	10	20	10	20					
Optically-Programmed Signals				20	10	10		10						
Pedestrian Phase											60			
Remove Signal					90									
Add Signal					90 minus 1% for every 2000 vpd	80								

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Lighting														
Add Lighting												50		
At Intersection: New / Upgrading												75 / 50		
At Railroad Crossing												60		
At Bridge Approach												50		
At Underpass												10		
Miscellaneous														
Relocate Fixed Object										60				
Curtail Turning Movement	40[b]	39[b]												
Realignment	50													
Superelevation	50													

[a] On two or more lanes; [b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

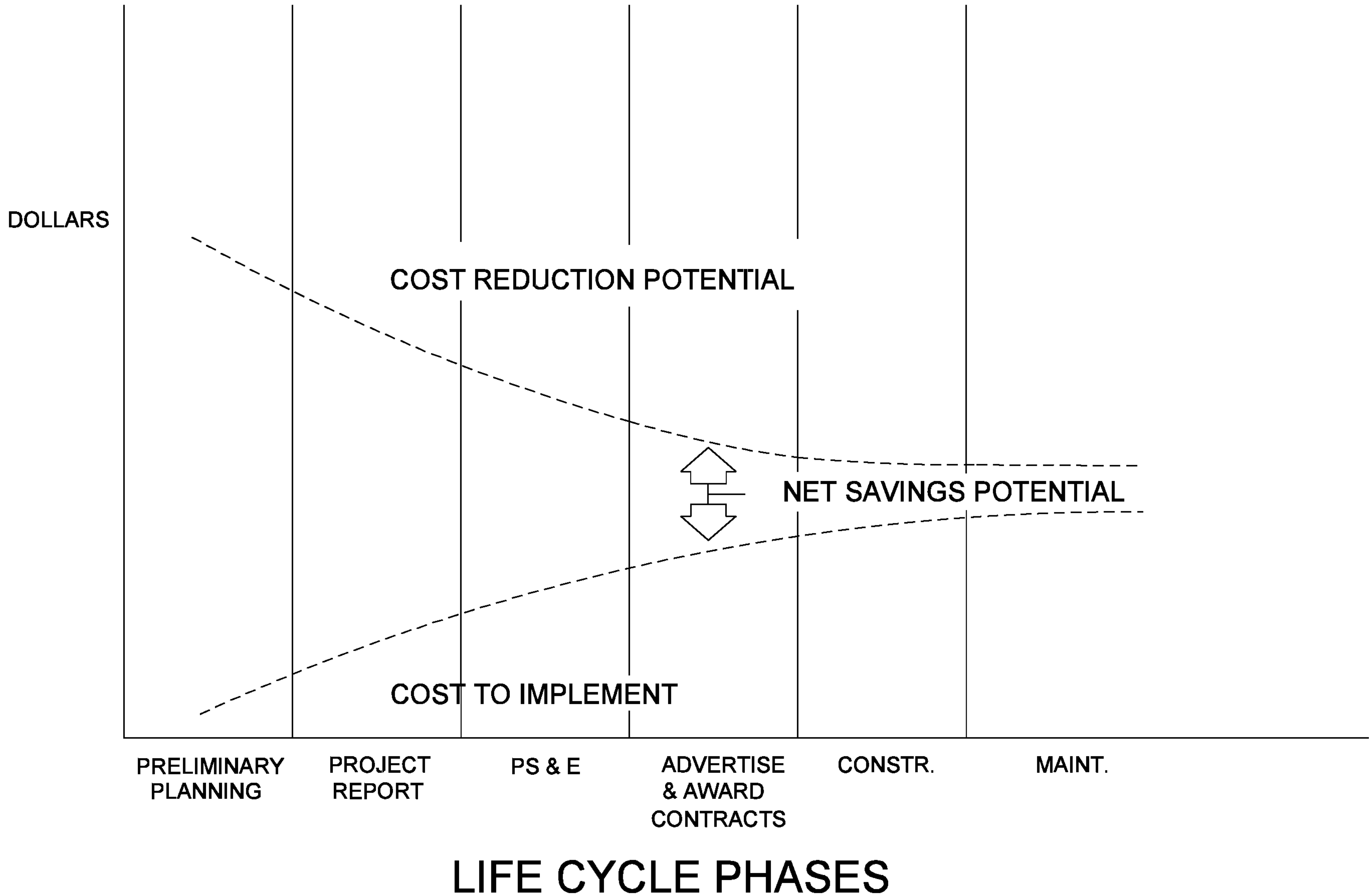
Figure 50-2G (Continued)

Improvement	Accident Reduction Factors (Percent)													
	All	Fatal Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedestrian	Night	Ran Off Road	Wet Pavement
Miscellaneous (Continued)														
Reconstruction	25													
≥ Rough Estimate														
Reconstruction of Horiz. And Vert. Curves	50													

[a] On two or more lanes
[b] Two lanes
[c] Minor street must be 35% or more of total intersection volumes; total intersection volume must be < 8,000 AADT

MISSOURI ACCIDENT REDUCTION FACTORS

Figure 50-2G (Continued)



VE POTENTIAL DURING LIFE OF A PROJECT
(Conceptual)

Figure 50-3A