

Calculating Benefit-to-Cost Ratio

The benefit-to-cost ratio is calculated using the following steps:

STEP 1: Gather Crash Data

Determine the quantity of property damage only (PDO) crashes, injury crashes (INJ), number of injuries, fatal crashes (FAT), and number of fatalities.

For predicted crashes, the following methods may be used:

- ✓ Federal Highway Safety Manual guidelines,
- ✓ Estimated by comparison to similar locations¹, and/or
- ✓ Other FHWA approved methods.

STEP 2: Determine Factors

Based on the countermeasure implemented, use www.cmfclearinghouse.org or other CDOT and/or FHWA approved methods to determine the following factors:

- ✓ Crash Reduction Factor (CRF),
- ✓ Service Life,
- ✓ Interest Rate (typically 5%), and
- ✓ Annual Daily Traffic (ADT) Growth Rate (typically 2%).

STEP 3: Calculate Year Factor

Year Factor may be calculated using one of the following methods:

1. **Excel Equations:** =YEARFRAC(Start Date, End Date, 1)
2. **Equation 3.1:** $Year\ Factor\ (N) = \frac{n}{m}$
 Where: n = Total number of days in crash history search
 m = Average number of days per year in crash history search

NOTE: The number of years of crash history could be used as a close approximation of the Year Factor. However, the benefit-to-cost ratio may be slightly off.

STEP 4: Calculate Capital Recovery Factor

$$Capital\ Recovery\ Factor\ (\beta) = \frac{i(1+i)^L}{(1+i)^L - 1}$$

Where: i = Interest Rate
 L = Service Life

STEP 5: Calculate Reduced Annual Crashes

Calculate reduced annual crashes accounting for ADT growth rate for each crash severity type.

$$PDO\ Reduced\ Annual\ Crashes\ (P) = \frac{(PDO)(1+a)^{L/2}}{N}$$

Where: PDO = Number of property damage only crashes observed
 L = Service Life
 N = Year Factor
 a = ADT Growth Rate

¹ Similar Locations – locations that have similar average annual daily traffic and geometry.

$$\text{Injury Reduced Annual Crashes (I)} = \frac{(\text{INJ})(1 + a)^{L/2}}{N}$$

Where: **INJ** = Number of injury crashes or persons injured observed
L = Service Life
N = Year Factor
a = ADT Growth Rate

$$\text{Fatal Reduced Annual Crashes (F)} = \frac{(\text{FAT})(1 + a)^{L/2}}{N}$$

Where: **FAT** = Number of fatal crashes or persons killed observed
L = Service Life
N = Year Factor
a = ADT Growth Rate

STEP 6: Calculate Benefit-to-Cost Ratio (B/C)

$$\text{Benefit to Cost Ratio} = \frac{(\$PDO)(P)(PDO\ CRF) + (\$INJ)(I)(INJ\ CRF) + (\$FAT)(F)(FAT\ CRF)}{(COST)(\beta)}$$

Where: **PDO CRF** = PDO Crash Reduction Factor
INJ CRF = Injury Crash Reduction Factor
FAT CRF = Fatal Crash Reduction Factor
P = PDO Reduced Annual Crashes
I = Injury Reduced Annual Crashes
F = Fatal Reduced Annual Crashes
COST = Total cost of project or safety improvements
β = Capital Recovery Factor
\$PDO = Cost per PDO Crash
\$INJ = Cost per Injury Crash or per number of injuries
\$FAT = Cost per Fatal Crash or per number of fatalities

Note: The Colorado Department of Transportation uses the National Safety Council (NSC) numbers for cost per crash. Per NSC, “the calculable costs of motor vehicles are wage and productivity losses, medical expenses, administrative expenses, more vehicle damage, and employers’ uninsured costs. The cost of all these items for each death, injury, and property damage” could be found on the National Safety Council’s website.

Example: Federal Blvd and 74th Ave Intersection Traffic Signal Upgrade Improvements

STEP 1: Gather Crash Data

Using CDOT crash analysis software, the crash history for Federal Blvd and 74th Ave (SH287C MP 288.97 – 289.04) from January 1, 2014 through December 31, 2018 is as follows:

- PDO = 69
- INJ = 23 (34 injured)
- FAT = 1 (1 killed)

STEP 2: Determine Factors

CDOT crash reduction factors for traffic signal upgrades are as follows:

- PDO CRF: 15%
- INJ CRF: 15%
- FAT CRF: 15%
- Service Life: 15 years
- Interest Rate: 5%
- ADT Growth Rate: 2%

STEP 3: Calculate Year Factor

1. Using Excel: $N = \text{YEARFRAC}(1/1/14, 12/31/18, 1) = 4.99726177$
 $N = 4.99726177$

STEP 4: Calculate Capital Recovery Factor

$$\beta = \frac{i(1+i)^L}{(1+i)^L - 1} = \frac{0.05(1+0.05)^{15}}{(1+0.05)^{15} - 1} = 0.09634229$$

STEP 5: Calculate Reduced Annual Crashes

$$P = \frac{(PDO)(1+a)^{L/2}}{N} = \frac{69(1+0.02)^{\frac{15}{2}}}{4.99726177} = 16.0183685$$

$$I = \frac{(INJ)(1+a)^{L/2}}{N} = \frac{32(1+0.02)^{\frac{15}{2}}}{4.99726177} = 7.89310909$$

$$F = \frac{(FAT)(1+a)^{L/2}}{N} = \frac{1(1+0.02)^{\frac{15}{2}}}{4.99726177} = 0.23215027$$

STEP 6: Calculate Benefit-to-Cost Ratio (B/C)

Project Cost: \$1,000,000

2018 CDOT crash cost values:

- o Per each property damage crash: \$10,700
- o Per each injury: \$98,900
- o Per each death: \$1,766,400

$$B/C = \frac{(\$PDO)(P)(PDO\ CRF) + (\$INJ)(I)(INJ\ CRF) + (\$FAT)(F)(FAT\ CRF)}{(COST)(\beta)}$$

$$B/C = \frac{(10,700)(16.0183685)(0.15) + (98,900)(7.89310909)(0.15) + (1,766,400)(0.23215027)(0.15)}{(1,000,000)(0.09634229)}$$

$$B/C = 2.12$$