Form 740001WD
4-96

Iowa Department of Transportation

INSTRUCTIONAL MEMORANDUMS
To County Engineers

To	Date
County Engineers	October 2001
From	**IM No.**
Office of Local Systems	3.216
Subject	
Economic Analysis (Benefit-to-Cost-Ratio)	

The purpose of this I.M. is to provide a mechanism to help determine the feasibility of an improvement or analyze various alternatives or countermeasures. Various methods (Cost-Effectiveness, Benefit/Cost Ratio, Rate-of-Return, Time of Return and Net Annual Benefit) are available to determine the economic feasibility of an improvement. This I.M. will present only one method, Benefit-to-Cost Ratio, for your consideration.

The Benefit/Cost Ratio is the ratio of the expected benefits, (accrued from a crash/severity reduction based on an improvement), to the costs of the improvement (construction, right of way, engineering, etc.). Included are two forms, which may be utilized to determine the Benefit/Cost Ratio for a particular improvement that is being considered. One form will obtain the Benefit-to-Cost Ratio as it relates to the project length (Rural Roadway Section). The other form is for spot locations, such as intersections, bridges, or curves within the project limits. The only difference in the forms is that the roadway section is based on 100 million vehicle miles (HMVM) of travel whereas the spot location is based on million entering vehicles (MEV).

The information required to fill out the forms is as follows:

1. CRASH DATA: This information can be obtained through Access ALAS Computer Software that is available through Iowa Department of Transportation (Iowa DOT) Office of Traffic and Safety. For most county roads, with no major improvements within the time frame, the data should go back five years. ALAS data should be requested for whole years (no partial years) only. The crash data on the Access ALAS printout should be transferred to the appropriate blanks on the form, keeping in mind that the number of fatalities or injuries may not be the same number of these types of crashes (two injury crashes could involve five injuries). The actual property damage of all crashes should be totaled and entered in the appropriate blank. Use the value of $2,500 per crash, if no damage is recorded. All crashes within the project termini or at the spot location should be included, regardless of type. The crash severity reduction percentage is based on all crashes.

2. IMPROVEMENT BEING CONSIDERED: The improvement described and the cost estimate should only be for the work for which the Benefit/Cost Ratio is being determined.

Example: If, as part of a resurfacing project, the county is considering widening the shoulders and flattening the foreslopes, the description should be similar to: Widen shoulders from 2' to 6' and flatten slopes from 2:1 to 3:1. The cost estimate might include:

Class 10 Excavation, including borrow
Culvert Extensions
Surfacing or Finishing the Shoulders
Seeding and Fertilizing
Right of Way (if necessary),including any damages to fences, buildings, etc.
Additional Engineering or Surveying
Driveway Culverts (remove and relay or replace)

3. SERVICE LIFE AND CRASH/SEVERITY REDUCTION FACTORS: Tables are included listing estimated values for these items for both roadway sections and spot locations. Crash/Severity reduction factors are usually provided for a single countermeasure. However, where multiple countermeasures are being proposed, the crash/severity reduction factor will be a combination of the individual crash/severity reduction factors. Since it is not feasible to reduce crashes by more than 100 percent, the following formula is used to develop an overall crash/severity reduction factor for multiple improvements at a location or along a route.

$AR_M = AR_1 + (1-AR_1)\ AR_2 + (1-AR_1)(1-AR_2)\ AR3 + \ldots + (1-AR_1)(1-AR_{i-1})\ AR_i$ where:

AR_M = overall crash/severity reduction factor for multiple improvements.

AR_i = crash/severity reduction factor for specific improvement or countermeasure.

i = number of improvements.

<u>Example</u>

An example of the use of the multiple improvement formula is shown for three improvements at a single location with individual crash/severity reduction factors of:

$AR_1 = 0.45$
$AR_2 = 0.30$
$AR_3 = 0.15$

The overall crash/severity reduction factor is:
$AR_M = AR_1 + (1-AR_1)\ AR_2 + (1-AR_1)\ (1-AR_2)\ AR_3$

$= 0.450 + (1-0.45)(0.30) + (1-0.45)(1-0.30)(0.15)$
$= 0.450 + 0.165 + 0.058$
$= 0.673 = 0.67$

Most studies indicate that an improvement with a Benefit/Cost Ratio over 1.0 is considered beneficial and under 1.0 is not. However, when considering that estimated values are being utilized, a more in-depth review is in order for ratios from 0.80 to 1.20, inclusive. This review might include items listed on the Review Sheet (Page #4), in this I.M., as:

1. The crash rate determined in the forms should be reviewed against the statewide average for all secondary roads. The five year average rate per 100 million vehicle miles in 1995 - 1999 was 237.

2. Type of crashes should be reviewed against the type of improvement. If the majority of the crashes within the project termini occurred at intersections, then flattening foreslopes may not have much of an effect.

3. The severity of the crashes should be reviewed with respect to location. If most of the crashes along the route were Property Damage Only (PDO's) and one location had a number of injury or fatality crashes then a review of that particular "spot" location may be in order.

4. The cost of the improvement being considered should be compared with the project cost without the improvement. If a proposed resurfacing project is estimated to cost $200,000 and the estimated cost to widen shoulders or flatten foreslopes is $500,000, it may be desirable to program the improvement at some future time. If the project is estimated at $750,000 and the improvement at $50,000, it may be wise to include the improvement.

5. The environmental or social effects of the improvement should always be considered. These might include: farmland being taken out of production; relocation of families; adverse effect on wetlands or parks; and disturbance of historical or archaeological areas. The Context-Sensitive Design process may be appropriate.

6. In some cases, other alternatives are available that may result in a similar benefit, or lower cost partial improvements may be used to mitigate the existing condition, if a total improvement is not cost effective or feasible. If the reconstruction of a horizontal curve requires taking a farmstead or relocating a bridge, and is not economically feasible, installing chevrons and advisory speed plates may be used to mitigate the situation.

These forms can be utilized as a tool in deciding whether an improvement is economically feasible. The completed Benefit/Cost Ratio sheet(s) should be attached, with copies of the ALAS printout, to the justification letter outlining the reasons for the county's request for any design exceptions. The Benefit/Cost Ratio should not be your only basis; other reasons that were considered in the decision-making process should be detailed in the county's justification letter. See I.M. 3.218.

BENEFIT/COST RATIO REVIEW SHEET

1. **B/C Ratio under 0.80:** Improvement probably not cost-effective at this time.

2. **B/C Ratio = 0.80 to 1.20:** Improvement may be cost effective, should also consider:

    1. Crash rate compared to statewide average.
    2. Type of crashes vs. type of improvement.
    3. Severity of Crashes.
    4. Cost of improvement vs. project cost without improvement.
    5. Environment and social effects of improvement.
    6. Other alternatives to the improvement (i.e. signing, pavement markings, etc.).

3. **B/C Ratio over 1.20:** Improvement is probably cost effective and should be accomplished as part of project or the work programmed in the near future.

BENEFIT/COST DETERMINATION
(Rural Roadway Section)

COUNTY _____

Project No. _____ Date _____

Location _____ Prepared by _____

Length (miles) _____ Current ADT _____

CRASH DATA: From _____ to _____, Total # _____Years
(date) (date)

# Fatal Crashes	_____	# Fatalities	_____	x $1,000,000	= $_____
# Injury Crashes	_____	# Major Injuries	_____	x $150,000	= $_____
		# Minor Injuries	_____	x $10,000	= $_____
		# Possible Injuries	_____	x $2,500	= $_____
#PDO Crashes	_____			Actual Prop. Dam. (Total)	= $_____

(Use $2,500/Crash if no actual $ property loss is shown)

(1) Total # Crash _____ **(2)** Total Loss = $_____

(3) Cost/Crash = (2)/(1) =Total Loss/Total # Crash = $_____/crash

(4) Crash Rate $= \frac{\text{Total \# Crash x 100,000,000}}{\text{ADT x Length x years x 365}}$ = _____ Crash/HMVM

DESIGN EXCEPTION BEING CONSIDERED:
Description of Improvement:
(not project description)
(5) Estimated Cost Imp. $ _____ (Thousand)
(5A) Estimated Service Life (E.S.L.) _____ years
(5B) Estimated Overall Crash/Severity Reduction Factor _____ percent
(See #3, Page 2)

B/C ANALYSIS:

(6) Estimated Traffic Volume =
ADT x $\frac{1 + (1.02)^{(5A)}}{2}$ x 5A x Length x 0.00000365 = _____HMVM

(7) Total Crash Loss = (3) x (4) x (6)
Cost/ Crash x Crash Rate x Est. Traf. Vol. = _____ (Thousand)

(8) Total Crash Benefit = (7) x (5B) =
Tot. Crash Loss x Est. % Crash Reduction = _____ (Thousand)

Benefit/Cost Ratio = $\frac{(8)}{(5)}$ = $\frac{\text{Tot. Crash Benefit}}{\text{Est. Cost Imp.}}$ = _____

IMPROVEMENTS FOR RURAL ROADWAY SECTIONS

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Add Lane(s)	20	05
Widen Pavement	20	22
Widen Shoulder	20	08
Widen Pavement/Shoulder	20	28
Flatten Foreslopes	20	08
Widen Shoulder/Flatten Foreslopes	20	15
Friction Improvement:		
Overlay	10	27
P. C. Grooving	10	14
Signing	6	05
Edgeline Markings	2	04
Horizontal Realignment	20	25
Vertical Realignment	20	30
Horizontal/Vertical Realignment/ Correct Superelevation	20	45
Roadway Lighting	15	06
Relocate Driveways	20	05
Flatten Entrance Slopes	20	05
Right of Way	100	--

BENEFIT/COST DETERMINATION
(Spot Location)

COUNTY _____

Project No. _____ Date _____

Location _____ Prepared by _____

Length (miles) _____ Current ADT _____

CRASH DATA: From _____ to _____, Total # _____Years
(date) (date)

# Fatal Crashes	_____	# Fatalities	_____	x $1,000,000	= $_____
# Injury Crashes	_____	# Major Injuries	_____	x $150,000	= $_____
		# Minor Injuries	_____	x $10,000	= $_____
		# Possible Injuries	_____	x $2,500	= $_____
#PDO Crashes	_____			Actual Prop. Dam. (Total)	= $_____

(Use $2,500/Crash if no actual $ property loss is shown)

(1) Total # Crash _____ **(2)** Total Loss = $_____

(3) Cost/Crash = (2)/(1) =Total Loss/Total # Crash = $_____/crash

(4) Crash Rate = $\frac{\text{Total \# Crash x 1,000,000}}{\text{ADT x years x 365}}$ = _____Crash/MEV

DESIGN EXCEPTION BEING CONSIDERED:
Description of Improvement:
(not project description)
(5) Estimated Cost Imp. $_____(Thousand)
(5A) Estimated Service Life (E.S.L.) _____ years
(5B) Estimated Overall Crash/Severity Reduction Factor _____ percent
(See #3, page 2)

B/C ANALYSIS:

(6) Estimated Traffic = ADT x $\frac{1+(1.02)^{(5A)}}{2}$ x (5A) x 0.000365 = _____ MEV
Volume

(7) Total Crash Loss = (3) x (4) x (6)
Cost/ Crash x Crash Rate x Est. Traf. Vol. = _____ (Thousand)

(8) Total Crash Benefit = (7) x (5B) =
Tot. Crash Loss x Est. % Crash Reduction = _____ (Thousand)

Benefit/Cost Ratio = $\frac{(8)}{(5)}$ = $\frac{\text{Tot. Crash Benefit}}{\text{Est. Cost Imp.}}$ = _____

IMPROVEMENTS FOR SPOT LOCATIONS

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Intersections:		
Channelize/Add Turning Lanes	15	25
Improve Sight Distance	15	35
Upgrade Signs/Markings	6/2	36
Illuminate (not destination lighting)	15	20
Add Accel/Decel lane	20	25
Rumble Strips (Applies only to crashes involving stop condition)	5 A.C. 10 P.C.	44 44
Reconstruct Approach Angle	20	35
Add Beacons	10	25
Curves:		
Vertical Realignment	20	57
Horizontal Realignment	20	38
Horizontal/Vertical Realignment/ Correct Superelevation	20	73
Pavement Markings/Delineate	2/6	15
Bridges:		
Widen	20	48
Guardrail	15	24
Impact Attenuator	10	35
Replace	50	50
Eliminate	50	75

IMPROVEMENTS FOR
SPOT LOCATIONS
(continued)

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Culverts:		
Lengthen	20	48
Guardrail or Grate	15	24
Remove Headwall & Delineate	20	35
Railroad Crossing:		
Signalize	10	50
Upgrade Warning Devices	10	27
Illuminate	15	62
Replace with Grade Separation	50	39
Eliminate	50	75
High Fills:		
Guardrail	10	16
Delineate	6	10
Flatten Foreslopes	20	25