Chapter 14

Economic Analysis in the Public and Regulated Sectors (Benefit Cost Analysis)

The Nature of Public Projects

Projects should provide benefits for the greater good of the public that *exceed* the costs of providing those benefits.

- The most frequently used method in evaluating government (local, state, or federal) projects is *benefit-cost analysis*.
- Next most frequent is *cost effectiveness analysis*.

Build-Operate-Transfer

Build-Operate-Transfer expands the private sector role, allowing public agencies to tap into private sector technical, management and financial resources.

This achieves

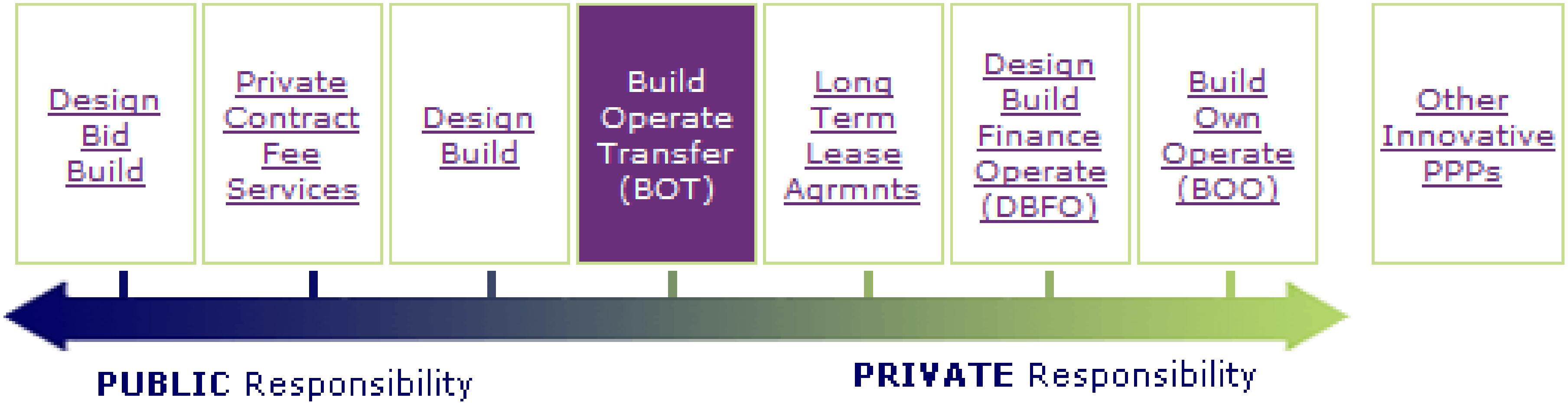
(1) greater cost and schedule certainty,

(2) supplements to in-house staff,

(3) innovative technology applications,

(4) specialized expertise, and

(5) access to private capital.



BOT characteristics include:

1. Responsibility
2. Life-cycle costing
3. Procurement process (competitive bid)
4. Standard specifications

Objectives in Public Project Evaluation

- Flood Control Act on June 22,1936: "*... the Federal Government should improve or participate ... if the benefits to whomsoever they may accrue are in excess of the estimated costs ....*"
- River and Harbor Act of 1902: "*required a board of engineers to report on ... the amount of commerce benefited and the cost.*"
- Prest and Turvey on benefit-cost analysis: " *… a practical way of assessing the desirability of projects where it is important to take a long view and a wide view; it implies enumeration and evaluation of all relevant costs and benefits.*"

Benefit-cost analysis take a “long view” (over time) and a “wide view” (individuals, groups and things) and evaluate monetized benefits, disbenefits, and costs.

Guidelines in Public Sector Evaluation

(from Arrow, et al)

1. B/C analysis is useful to compare favorable and unfavorable effects of a policy
2. B/C analysis is useful in achieving a desired goal at the lowest possible cost
3. Agencies should use B/C analysis to set regulatory priorities
4. B/C analysis should be required for major decisions
5. When costs far exceed benefits in an accepted decision, the *"other" factors should be stated*
6. B/C analysis should be done on major health, safety, and environmental regulations to inform legislators

Example 14.1

Costs and benefits for a public sector investment program are shown on the next slide. The planning horizon is 10 years and TVOM is $i = 7\%$.

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E10 =PV(0.07,A10,,-C10)

EOY	Cost	Benefit	PW Costs	PW Benefits	
0	$0	$0	$0	$0	
1	$100,000	$0	$93,458	$0	
2	$200,000	$0	$174,688	$0	
3	$300,000	$50,000	$244,889	$40,815	
4	$300,000	$100,000	$228,869	$76,290	
5	$200,000	$300,000	$142,597	$213,896	
6	$100,000	$400,000	$66,634	$266,537	
7	$50,000	$400,000	$31,137	$249,100	
8	$50,000	$400,000	$29,100	$232,804	
9	$50,000	$400,000	$27,197	$217,573	=PV(0.07,A11,,-C11)
10	$50,000	$250,000	$25,417	$127,087	=PV(0.07,A12,,-B12)
	PRESENT WORTH		$1,063,987	$1,424,102	

Note that the PW of benefits is $1,424,102, and the PW of costs is $1,063,987,the net PW of benefits minus costs is $360,115 and the B/C ratio =1.33.

So, the program is desirable when considered alone.

Systematic Economic Analysis Technique

1. Identify the (public-sector) investment alternatives
2. Define the planning horizon (for the benefit-cost study)
3. **Specify the discount rate**
4. **Estimate the (benefit and cost profiles in monetary terms) cash flows**
5. **Compare the alternatives (using a measure of worth related to benefits and costs)**
6. Perform supplementary analyses
7. Select the preferred (alternative) investment

Benefit-Cost and Cost-Effectiveness Calculations

- Benefit-cost analysis typically uses:
  - - ***B/C*** benefit-cost ratio
  - - ***B-C*** benefits minus costs

- Both *B* and *C* are expressed in monetary units as PW or AW (or even FW) where an appropriate discount rate *i* has been used to calculate PW or AW.

B/C Formula

$$B/C(i) = \frac{\sum_{t=1}^{n} B_t (1+i)^{-t}}{\sum_{t=0}^{n} C_t (1+i)^{-t}} \quad (14.1) \quad = PW(B)/PW(C)$$

Where t = end of year,

n = planning horizon,

i = discount rate,

B_t is benefits in t, and

C_t is costs in t,

where both B_t and C_t are expressed in monetary units.

$$B-C(i) = \sum_{t=1}^{n} B_t (1+i)^{-t} - \sum_{t=0}^{n} C_t (1+i)^{-t} \qquad (14.2)$$

$$= PW\ (B) - PW\ (C\ )$$

Where t = end of year,
n = planning horizon,
i = discount rate,
B_t is benefits in t, and
C_t is costs in t,
where both B_t and C_t are expressed in monetary units.

Comparing Two Alternatives

- When two project alternatives are being compared using a *B/C* ratio, the analysis should be done on an ***incremental*** basis.
  - Let the alternative with the lower present worth of costs be Alternative 1 and let the other be Alternative 2.
  - Then , the *incremental benefits* of the second alternative over the first, $\Delta B_{2\text{-}1}(i)$, are divided by the *incremental costs* of the second over the first, $\Delta C_{2\text{-}1}(i)$.

= *Incremental Benefits/Incremental Cost*

Incremental B/C Ratio

$$\Delta B/C_{2-1}(i) = \frac{\Delta B_{2-1}(i)}{\Delta C_{2-1}(i)} = \frac{\sum_{t=1}^{n}(B_{2t} - B_{1t})(1+i)^{-t}}{\sum_{t=0}^{n}(C_{2t} - C_{1t})(1+i)^{-t}} \qquad (14.3)$$

- Incremental *B/C* analysis is like incremental rate of return analysis. Here, you prefer alternative 2 over 1 as long as the Δ *(B/C)*> 1. Then, compare alternative 3 to the winner of 1 and 2, and so on
- Do not just select the alternative with the highest overall *B/C* ratio

Comparing Two Alternatives

- When two project alternatives are being compared using *B-C*, no special incremental procedure is necessary

- Just select the alternative that has the highest value of *B-C*

Cost-Effectiveness Analysis

- Use cost-effectiveness analysis whenever each alternative has the same annual benefits or effects. Simply minimize the PW or AW of costs

$$C_{j,preferred}(i) = \min \forall_j \left(\sum_{t=0}^{n} C_{jt}(i) \right) \qquad (14.5)$$

- Or, use C-E analysis when alternatives have the same costs. Maximize the PW or AW of benefits

$$B_{j,preferred}(i) = \max \forall_j \left(\sum_{t=1}^{n} B_{jt}(i) \right) \qquad (14.6)$$

Example 14.2

- Three highway alternatives, A, B, and C
- **Benefits** are assumed to be **all equal**, so use *Cost-Effectiveness analysis*

- For each alternative,

$$AW_{total} = AW_{first/resurfacing} + AW_{maintenance}$$

- See next slide for data and calculations
- Route A wins **with lowest cost**!

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B17 =PMT(B6,B7,PV(B6,10,,B9*B3)+PV(B6,20,,B10*B3))

	A	B	C	D	E
1		Route A	Route B	Route C	
2	General info				
3	Miles	26	22	20.5	
4					
5	Government-related info				
6	Discount rate	8.00%	8.00%	8.00%	
7	Planning horizon in years	30	30	30	
8	First Cost $/mi	$2,000,000	$3,000,000	$4,000,000	
9	Resurfacing cost $/mi @10 yrs	$2,000,000	$2,000,000	$2,000,000	
10	Resurfacing cost $/mi @20 yrs	$2,000,000	$2,000,000	$2,000,000	
11	Maintenance $/mi-yr	$10,000	$12,000	$20,000	
12					
13	Summary of Annual Equivalent Government Costs				
14		Route A	Route B	Route C	
15	Government				
16	First cost of highway $/year	$4,619,027	$5,862,611	$7,283,850	=-PMT(D6,D7,D8*D3)
17	Resurfacing costs $/year	$3,130,507	$2,648,890	$2,468,284	
18	Maintenance costs $/year	$260,000	$264,000	$410,000	=D11*D3
19	Total $/year	$8,009,533	$8,775,501	$10,162,134	=SUM(D16:D18)
20					
21					
22					
23					

=PMT(D6,D7,PV(D6,10,,D9*D3)+PV(D6,20,,D10*D3))

Lowest cost

Figure 14.2 | Figure 14.3 | Figure 14.4 | Figure 14.5 | Figure 14.6 | Figure 14.8 | Figu

Example 14.3

- Same road project as Example 2, except considering different "benefits" for A, B, and C
- Different numbers of vehicle types considered
- Cost of operation is considered for each type
- Cost of time spent driving, by vehicle, is considered
- Cost of accidents on each route is also considered
- Relevant government and public costs are given on the next slide, and the incremental B/C analysis follows two slides from here. Note that **"benefits"** here are expressed as **"cost *savings*"**

	Route A	Route B	Route C
General info			
Miles	26	22	20.5
Hvy truck speed miles/hour	35	40	40
Other veh speed miles/hour	45	50	50
Accidents/year	105	75	50
Cost/accident	$18,000	$18,000	$18,000
Government-related info			
Discount rate	8.00%	8.00%	8.00%
Planning horizon in years	30	30	30
First Cost $/mi	$2,000,000	$3,000,000	$4,000,000
Resurfacing cost $/mi @10 yrs	$2,000,000	$2,000,000	$2,000,000
Resurfacing cost $/mi @20 yrs	$2,000,000	$2,000,000	$2,000,000
Maintenance $/mi-yr	$10,000	$12,000	$20,000
Public-related info	Vehicles/day	Op cost/mile	Time cost/veh hr
Light commercial trucks	350	$0.70	$25
Heavy commercial trucks	250	$1.10	$25
Motorcycles	80	$0.30	$10
Commercial autos	830	$0.60	$25
Noncommercial autos	2490	$0.60	$10
Total vehicles	4000		
Automobiles	3320		
% commercial autos	25.00%		
% noncommercial autos	75.00%		

Relevant government and public costs plus other input data.

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B38 =($B18*$C18+$B19*$C19+$B20*$C20+$B21*$C21+$B22*$C22)*B3*365

	A	B	C	D	E
29	**Summary of Annual Equivalent Government and Public Costs**				
30		**Route A**	**Route B**	**Route C**	
31	**Government**				
32	**First cost of highway $/year**	**$4,619,027**	**$5,862,611**	**$7,283,850**	**=-PMT(D10,D11,D12*D3)**
33	**Resurfacing costs $/year**	**$3,130,507**	**$2,648,890**	**$2,468,284**	
34	**Maintenance costs $/year**	**$260,000**	**$264,000**	**$410,000**	**=D15*D3**
35	**Total $/year**	**$8,009,533**	**$8,775,501**	**$10,162,134**	**=SUM(D32:D34)**
37	**Public**				
38	**Operating costs**	**$24,066,640**	**$20,364,080**	**$18,975,620**	
39	**Time costs**	**$13,335,710**	**$10,119,808**	**$9,429,821**	
40	**Accident costs**	**$1,890,000**	**$1,350,000**	**$900,000**	**=D7*D6**
41	**Total $/year**	**$39,292,350**	**$31,833,888**	**$29,305,441**	**=SUM(D38:D40)**
43	**Benefit B to A**		**$7,458,462**	B (B) – B(A)	
44	**Cost B to A**		**$765,968**		
45	**B/C Ratio B to A**	**Prefer B to A**	**9.74**		
47	**Benefit C to B**			**$2,528,447**	**=C41-D41**
48	**Cost C to B**			**$1,386,633**	**=D35-C35**
49	**B/C Ratio C to B**		**Prefer C to B**	**1.82**	**=D47/D48**
51	**=PMT(D10,D11,PV(D10,10,,D13*D3)+PV(D10,20,,D14*D3))**				
53	**=($B18*$C18+$B19*$C19+$B20*$C20+$B21*$C21+$B22*$C22)*D3*365**				
55	**=($B18*$D18/D5+$B19*$D19/D4+$B20*$D20/D5+$B21*$D21/D5+$B22*$D22/D5)*D3*365**				

Figure 14.2 | Figure 14.3 | Figure 14.4 | **Figure 14.5** | Figure 14.6 | Figure 14.8

Example 14.3, concluded

- Note that *government costs* are given as:

  A: $8,009,533; B: $8,775,501; C: $10,162,134

  - So, incremental costs B to A = $765,968
  - and incremental costs C to B = $1,386,633

- Note that *costs to public* are:

  A: $39,292,350; B: $31,833,888; C: $29,305,441

  - So, incremental "Benefit" B to A = $7,458,462
  - and incremental "Benefit" C to B = $2,528,447

- $\Delta B/C_{\text{B to A}}$ = $7,458,462/$765,968 = 9.74 B wins
- $\Delta B/C_{\text{C to B}}$ = $2, 528, 447/$1,386,633 = 1.82 C wins

Example 14.4

- The difference in incremental benefits and costs may be used for Example 14.3
- $\Delta(B\text{-}C)_{B\text{-}A} = \Delta B_{B\text{-}A} - \Delta C_{B\text{-}A}$

  = $7,458,462 - $765,968

  = $6,692,494/year

  So, B is preferred to A
- $\Delta(B\text{-}C)_{C\text{-}B} = \Delta B_{C\text{-}B} - \Delta C_{C\text{-}B} =$

  = $2,528,447 – 1,386,633

  = $1,141,814/year

  And, C is preferred to B
- C wins overall – same as in Example 14.3

Notes on Ex. 14.2, 14.3, and 14.4

- Example 14.2 used Cost Effectiveness Analysis, comparing government costs only, since benefits were assumed equal for each of routes A, B, and C
- Examples 14.3 and 14.4 used Benefit-Cost analysis since benefits were assumed different for each of routes A, B, and C
- The incremental B/C ratio was used in Example 14.3, and incremental B-C analysis was used in Example 14.4
- Incremental benefits and incremental costs were evaluated using annual worth. Of course, the present worth of all costs would have been perfectly fine to use.

- B/C analysis is useful for evaluating one project.

- Incremental ΔB/ΔC analysis is required when comparing more than one alternative.

- B-C analysis is useful for one or many alternatives.

- More often than not, the benefit-cost ratio *B/C* (or incremental *B/C* ratio) is used. This is unfortunate because, just as in rate of return analyses in the private sector, the benefit-cost ratio *B/C* is easy to misuse and misinterpret

- Also, the *B/C* ratio is very sensitive to the classification of problem elements as "benefits" or "costs." *B-C* is not.

A city is considering building a new Public Library to serve its citizens. Three alternatives have been identified with the following data:

Government (COST)	Alternative A	Alternative B	Alternative C
Initial Cost (SR)	6,000,000	4,000,000	9,000,000
Annual Maintenance Cost (SR/year)	180,000	210,000	260,000

Public (BENFIT)	Alternative A	Alternative B	Alternative C
Benefits (SR/year)	1,000,000	900,000	1,500,000
Dis-benefits(Cost) (SR/year)	150,000	400,000	500,000

Using 8% interest rate, 15-year study period, a salvage value of 50% of the initial cost, and **B/C ratio**, determine which alternative should be selected.

A_W analysis

<u>Costs to the city</u>:

Cost (A) = 6,000,000 (A/P 8, 15) + 180,000 - 6,000,000 X 0.5 (A/F 8, 15)
= SR 770,490/year

Cost (B) = 4,000,000 (A/P 8, 15) + 210,000 - 4,000,000 X 0.5 (A/F 8, 15)
= SR 603,660/year

Cost (C) = 9,000,000 (A/P 8, 15) + 260,000 - 9,000,000 X 0.5 (A/F 8, 15)
= SR 1,145,735/year

<u>Benefit to the users:</u>

Benefit (A) = 1,000,000 - 150,000 = SR 850,000/year

Benefit (B) = 900,000 - 400,000 = SR 500,000/year

Benefit (C) = 1,500,000 - 500,000 = SR 1,000,000/year

Initial cost

Ordering the alternatives from lowest to higher initial investment: B →A →C

A-B: $\frac{B}{C})_{A-B} = \frac{B_A - B_B}{C_A - C_B} = \frac{(850{,}000 - 500{,}000)}{(770{,}490 - 603{,}660)} = 2.098$ *Select Alt. A*

C-A: $\frac{B}{C})_{C-A} = \frac{B_C - B_A}{C_C - C_A} = \frac{(1{,}000{,}000 - 850{,}000)}{(1{,}145{,}735 - 770{,}490)} = 0.400$ *Select Alt. A*

P_W analysis

Costs to the city:

Cost (A) = 6,000,000 + 180,000 (P/A 8, 15) - 6,000,000 X 0.5 (P/F 8, 15)
= SR 6,594,986.4

Cost (B) = 4,000,000 + 210,000 (P/A 8, 15) - 4,000,000 X 0.5 (P/F 8, 15)
= SR 5,167,010.8

Cost (C) = 9,000,000 + 260,000 (P/A 8, 15) - 9,000,000 X 0.5 (P/F 8, 15)
= SR 9,806,884.8

Benefit to the users:

Benefit (A) = (1,000,000 - 150,000) (P/A 8, 15) = SR 7,275,550

Benefit (B) = (900,000 - 400,000) (P/A 8, 15) = SR 4,279,740

Benefit (C) = (1,500,000 - 500,000) (P/A 8, 15) = SR 8,559,480

Ordering the alternatives from lowest to higher initial investment: B →A →C

A - B: $\frac{B}{C})_{A-B} = \frac{B_A - B_B}{C_A - C_B} = \frac{(7,275,550 - 4,279,740)}{(6,594,986.4 - 5,167,010.8)} = 2.09$ *Select Alt. A*

C - A: $\frac{B}{C})_{C-A} = \frac{B_C - B_A}{C_C - C_A} = \frac{(8,559,480 - 7,275,550)}{(9,806,884.8 - 6,594,986.4)} = 0.40$ *Select Alt. A*

Pit Stop #14 – Same Thing; Different Look

1. True or False: Benefit-cost analysis is primarily used by regulated utilities.
2. True or False: Build-Operate-Transfer (BOT) makes use of a public-private partnership.
3. True or False: Benefits and disbenefits must be converted to monetary values to use benefit-cost analysis.
4. True or False: OMB's Circular No. A-94, Revised is the definitive document for benefit-cost analysis.
5. True or False: The seven step SEAT is only applicable to public sector evaluation after *extensive* modification.
6. True or False: The B/C ratio is directly applicable to evaluation of one or many alternatives.
7. True or False: The B-C evaluation is directly applicable to evaluation of one or many alternatives.
8. True or False: Some in the public sector recommend using an interest rate of 0% on any money from outside sources.
9. True or False: The Revenue Requirements method is not economically equivalent to the industrial ATCF approach.
10. True or False: The Revenue Requirements method determines the income that exactly "pays" for costs, depreciation, interest on borrowed money, taxes, and a desirable return to owners.

Pit Stop #14 – Same Thing; Different Look

1. True or False: Benefit-cost analysis is primarily used by regulated utilities. False. It is used in the public sector. Revenue Requirements analysis is used by regulated utilities.
2. True or False: Build-Operate-Transfer (BOT) makes use of a public-private partnership. True, in order to utilize the strengths of both public and private sectors.
3. True or False: Benefits and disbenefits must be converted to monetary values to use benefit-cost analysis. True. Then, the PW or AW values are used in the benefit-cost analyses.
4. True or False: OMB's Circular No. A-94, Revised is the definitive document for benefit-cost analysis. True in the United States of America.
5. True or False: The seven step SEAT is only applicable to public sector evaluation after *extensive* modification. False. SEAT is applicable as-is, and explanation is facilitated by only minor modification to some wording.
6. True or False: The B/C ratio is directly applicable to evaluation of one or many alternatives. False. The B/C ratio is applicable to evaluation of one alternative, but multiple alternatives require incremental B/C analysis.
7. True or False: The B-C evaluation is directly applicable to evaluation of one or many alternatives. True. B-C analysis is very robust. Unfortunately, the B/C ratio is more often used.
8. True or False: Some in the public sector recommend using an interest rate of 0% on any money from outside sources. True, unfortunately. This can lead to acceptance of projects that should never see the light of day.
9. True or False: The Revenue Requirements method is not economically equivalent to the industrial ATCF approach. False. While it follows a different analysis format, both methods are completely equivalent .
10. True or False: The Revenue Requirements method determines the income that exactly "pays" for costs, depreciation, interest on borrowed money, taxes, and a desirable return to owners. True. This is known as the *minimum revenue requirement*.