Chapter 16 Economic Analysis in the Service Sector

Cost-Effectiveness Analysis

16.1 Cost effectiveness of the alternatives

Type of Treatment	Cost Effectiveness
Antibiotic A	12,000/75 =160
Antibiotic B	168.75
Antibiotic C	180.49

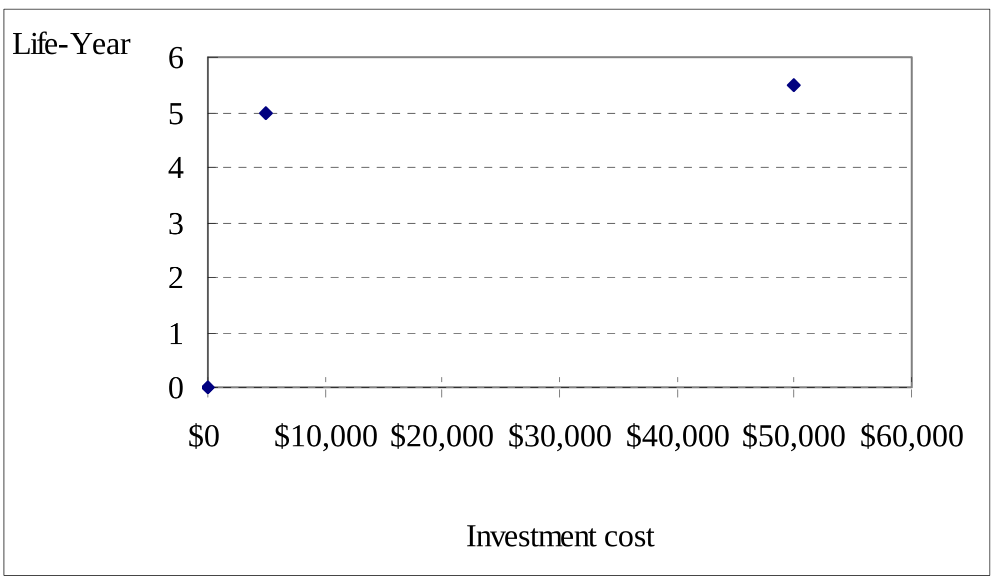
∴ The best treatment option is Antibiotic A.

16.2

- The summary of three mutually exclusive alternatives CER:

Strategy	Cost	Effectiveness	Cost Effectiveness	Incremental CER
Nothing	$0	0 years	0	0
Simple	$5,000	5 years	1,000	1,000
Complex	$50,000	5.5 years	9,091	90,000

- Since there is no clear dominance we can draw a cost-effective diagram.



Budget Available ($)	Treatment Option To Be Implemented
Less than $5,000	As much of Simple treatment as budget allows
$5,000	100% of Simple treatment
$5,000 - $50,000	Simple treatment and as much of Complex treatment as budget allows
$50,000 or larger	100% of Complex treatment

Valuation of Benefits and Costs

16.3

(a) • User's benefits:

- Prevention (or retardation) of highway corrosion: resulting in lower highway maintenance cost. This lower maintenance cost implies lower users' taxes on gasoline, and so forth.
- Prevention of rust on vehicles: resulting in lower repair and maintenance costs and higher resale value of vehicles.
- Prevention of corrosion to utility lines and damages to water supplies: resulting in lower utility rates.
- Prevention of damages to vegetation and soil surrounding areas: increasing land values and agriculture yields.

• Users' costs:

- Paying higher taxes.
- Unknown environmental damages due to using CMA

(b) The state of Michigan may declare certain sections of highway for experimental purpose. CMA may be used exclusively for a designated area and road salts for another area for an extended period time. Then, it investigates the impact of CMA on vegetation yields, which can be compared with those of areas from road salt use. The difference in vegetation yields may be quantified in terms of market value, and so forth.

16.4 This is an open-end type question. (No solution is given.)

16.5 This is an open-end type question. (No solution is given.)

Benefit-Cost Analysis

16.6

(a) $BC(i)$ analysis:

- Design A:

$$I = \$400,000$$
$$C^{'} = \$50,000(P/A, 8\%, 15) = \$427,974$$
$$B = \$85,000$$

- Design B:

$$I = \$300,000$$
$$C^{'} = \$80,000(P/A, 8\%, 15) = \$684,758$$
$$B = \$85,000$$

- Incremental analysis: Fee collections in the amount of \$85,000 will be the same for both alternatives. Therefore, we will not be able to compute the $BC(i)$ ratio. If this happens, we may select the best alternative based on either the lease cost $(I + C^{'})$ criterion or the incremental $B^{'}C(i)$ criterion. Using the $B^{'}C(i)$ criterion,

$$\Delta B^{'}C(8\%)_{A-B} = \frac{\Delta B - \Delta C^{'}}{\Delta I} = \frac{0-(\$427,974-\$684,758)}{\$100,000} = 2.56 > 1$$

$\therefore$ Select design A.

(b) Incremental analysis (A – C):

$$\Delta B^{'}C(8\%)_{A-C} = \frac{\Delta B - \Delta C^{'}}{\Delta I} = \frac{0-(\$427,974-\$556,366)}{\$50,000} = 2.57 > 1$$

$\therefore$ Select design A**.**

16.7

- Building X:

$$B_X = \$1,960,000(P/A, 10\%, 20) = \$16,686,656$$
$$C_X = \$8,000,000 + \$240,000(P/A, 10\%, 20)$$
$$-\$4,800,000(P/F, 10\%, 20)$$
$$= \$9,329,984$$
$$BC(10\%)_X = \frac{\$16,686,656}{\$9,329,984} = 1.79 > 1$$

• Building Y:

$$\begin{aligned} B_Y &= \$1,320,000(P/A,10\%,20) = \$11,237,952 \\ C_Y &= \$12,000,000 + \$180,000(P/A,10\%,20) \\ &\quad - \$7,200,000(P/F,10\%,20) \\ &= \$12,462,528 \end{aligned}$$

$$BC(10\%)_Y = \frac{\$11,237,904}{\$12,462,528} = 0.90 < 1$$

Since Building Y is not desirable at the outset, we don't need to conduct an incremental analysis. Building X becomes the better choice.

16.8 Incremental $BC(i)$ analysis:

Present Worth	Proposals A1	A2	A3	Incremental A3-A1	A2-A1
I	\$100	\$300	\$200	\$100	\$200
B	\$400	\$700	\$500	\$100	\$300
C	\$100	\$200	\$150	\$50	\$100
$BC(i)$	2	1.4	1.43	0.67	1

$\therefore$ Select either A1 or A2.

16.9 Incremental $BC(i)$ analysis

Present Worth	Design A	B	C	Incremental C-B	A-B
I	\$7,284	\$7,070	\$5,656	-\$1,414	\$754
B	\$2,440	\$880	\$1,600	\$720	\$1,560
C'	\$3,865	\$3,394	\$2,922	-\$472	\$471
$BC(i)$	1.24	1.65	1.25	-5.7	0.37

$\therefore$ Select Design B

16.10

(a) The benefit-cost ratio for each alternative:

- Alternative A:

$$B = (\$1,000,000 + \$250,000 + \$350,000 + \$100,000)(P/A,10\%,50)$$
$$= \$16,855,185$$
$$C = \$8,000,000 + \$200,000(P/A,10\%,50)$$
$$= \$9,982,963$$
$$BC(10\%)_A = \frac{\$16,855,185}{\$9,982,963} = 1.69 > 1$$

- Alternative B:

$$B = (\$1,200,000 + \$350,000 + \$450,000 + \$200,000)(P/A,10\%,50)$$
$$= \$21,812,592$$
$$C = \$10,000,000 + \$250,000(P/A,10\%,50)$$
$$= \$12,478,704$$
$$BC(10\%)_B = \frac{\$21,812,592}{\$12,478,704} = 1.75 > 1$$

- Alternative C:

$$B = (\$1,800,000 + \$500,000 + \$600,000 + \$350,000)(P/A,10\%,50)$$
$$= \$32,223,147$$
$$C = \$15,000,000 + \$350,000(P/A,10\%,50)$$
$$= \$18,470,185$$
$$BC(10\%)_B = \frac{\$32,223,147}{\$18,470,185} = 1.74 > 1$$

(b) Select the best alternative based on $BC(i)$:

$$BC(10\%)_{B-A} = \frac{\$21,812,592 - \$16,855,185}{\$12,478,704 - \$9,982,963}$$
$$= 1.99 > 1 \ (Select\ \ B)$$

$$BC(10\%)_{C-B} = \frac{\$32,223,147 - \$21,812,592}{\$18,470,185 - \$12,478,704}$$
$$= 1.74 > 1 \ (Select\ \ C)$$

Comments: You could select the best alternative based on $B'C(i)$:

	Alternative		
	A	B	C
I	\$8,000,000	\$10,000,000	\$15,000,000
C'	\$1,982,963	\$2,478,704	\$3,470,185
$B'C(i)$	1.86	1.93	1.92

$$B'C(10\%)_{B-A} = \frac{(\$21,812,592 - \$16,855,185) - (\$2,478,704 - \$1,982,963)}{\$10,000,000 - \$8,000,000}$$
$$= 2.23 > 1 \ (Select\ B)$$

$$B'C(10\%)_{C-B} = \frac{(\$32,223,147 - \$21,812,592) - (\$3,470,185 - \$2,478,704)}{\$15,000,000 - \$10,000,000}$$
$$= 1.88 > 1 \ (Select\ C)$$

16.11

- Option 1 – The "long" route:

$$\begin{aligned}\text{user's annual cost} &= 22 \text{ miles} \times \$0.25 \text{ per mile} \times 400{,}000 \text{ cars} \\ &= \$2,200,000 \\ \text{sponsor's annual cost} &= \$21,000,000(A/P, 10\%, 40) + \$140,000 \\ &= \$2,287,448\end{aligned}$$

- Option 2 – Shortcut:

$$\begin{aligned}\text{user's annual cost} &= 10 \text{ miles} \times \$0.25 \text{ per mile} \times 400{,}000 \text{ cars} \\ &= \$1,000,000 \\ \text{sponsor's annual cost} &= \$45,000,000(A/P, 10\%, 40) + \$165,000 \\ &= \$4,766,674\end{aligned}$$

- Incremental analysis (Option 2 - Option 1):

$$\begin{aligned}\text{Incremental user's benefit} &= \$2,200,000 - \$1,000,000 \\ &= \$1,200,000\end{aligned}$$

$$BC(10\%)_{2-1} = \frac{\$1,200,000}{\$4,766,674 - \$2,287,448}$$
$$= 0.48 < 1$$

$\therefore$ Assuming that there is no do-nothing alternative, select option 1.

16.12

- Multiple alternatives:

Projects	PW of Benefits	PW of Costs	Net PW	B/C ratio
A1	$40	$85	-$45	0.47
A2	$150	$110	$40	1.36
A3	$70	$25	$45	2.80
A4	$120	$73	$47	1.64

Since the BC ratio for project A1 is less than 1, we delete it from our comparison.

- Incremental analysis

A3 vs. A4:

$$BC(10\%)_{A4-A3} = \frac{\$120-\$70}{\$73-\$25}$$
$$=1.04>1$$

Select A4

A2 vs. A4:

$$BC(10\%)_{A2-A4} = \frac{\$150-\$120}{\$110-\$73}$$
$$=0.81<1$$

Select A4

Short Case Studies

ST 16.1 Capital allocation decision, assuming that the government will be able to raise the required funds at 10% interest:

District	Project	PW(10%)	Investment
I	1. 27th Street	$1,606,431	$980,000
	2. Holden Avenue	$3,438,531	$3,500,000
	3. Forest City Road	$2,682,758	$2,800,000
	4. Fairbanks Avenue	$2,652,473	$1,400,000
II	5. Oak Ridge Road	$1,672,473	$2,380,000
	6. University Blvd.	$5,258,050	$5,040,000
	7. Hiawassee Road	$4,130,824	$2,520,000
	8. Lake Avenue	$2,958,052	$4,900,000
III	9. Apopka-Ocoee Road	$552,475	$1,365,000
	10. Kaley Avenue	$4,459,032	$2,100,000

	11.Apopka-Vineland Road	\$1,166,557	\$1,170,000
	12. Washington Street	\$1,788,245	\$1,120,000
IV	13. Mercy Drive	\$5,066,566	\$2,800,000
	14. Apopka Road	\$2,338,635	\$1,690,000
	15. Old Dixie Highway	\$1,213,846	\$975,000
	16. Old Apopka Road	\$1,899,946	\$1,462,500

(a) \$6 million to each district:

District	Projects	NPW
I	1,2,4	\$7,697,488
II	5,7	\$5,803,297
III	9,10,11,12	\$5,966,309
IV	13,14,16	\$9,305,147

(b) \$15 million to districts I & II and \$9 million to districts III & IV:

District	Projects	NPW	Investment
I & II	2,4,5,6,7	\$17,152,400	\$14,840,000
III & IV	10,12,13,14,15	\$12,866,320	\$8,685,000

(c) If \$24 million were allocated based on project merit alone, the optimal solution would be:

Total investment = \$23,587,500
Total net present value = \$31,852,543
Projects selected = 1, 2, 4, 6, 7, 10, 12, 13, 14, 15, 16

ST 16.2 Given $i = 8\%$, $g = 10\%$, garbage amount/day = 300 tons

(a) The operating cost of the current system in terms of \$/ton of solid waste:

- Annual garbage collection required (assuming 365 days):

$$\text{Total amount of garbage} = 300 \text{ tons} \times 365 \text{ days} = 109{,}500 \text{ tons}$$

- Equivalent annual operating and maintenance cost:

$$\begin{aligned} PW(8\%) &= \$905{,}400(P/A_1, 10\%, 8\%, 20) \\ &= \$20{,}071{,}500 \\ AEC(8\%) &= \$20{,}071{,}500(A/P, 8\%, 20) \\ &= \$2{,}044{,}300 \end{aligned}$$

- Operating cost per ton:

$$\text{cost per ton} = \frac{\$2{,}044{,}300}{109{,}500} = \$18.67/\text{ton}$$

(b) The economics of each solid-waste disposal alternative in terms of $/ton:

- Site 1:

$$\begin{aligned} AEC(8\%)_1 &= \$4{,}053{,}000(A/P,8\%,20) + \$342{,}000 - (\$13{,}200 + \$87{,}600) \\ &= \$653{,}000 \end{aligned}$$

$$\text{cost per ton} = \frac{\$653{,}000}{109{,}500} = \$5.96/\text{ton}$$

- Site 2:

$$\begin{aligned} AEC(8\%)_2 &= \$4{,}384{,}000(A/P,8\%,20) + \$480{,}000 - (\$14{,}700 + \$99{,}300) \\ &= \$812{,}520 \end{aligned}$$

$$\text{cost per ton} = \frac{\$812{,}520}{109{,}500} = \$7.42/\text{ton}$$

- Site 3:

$$\begin{aligned} AEC(8\%)_3 &= \$4{,}764{,}000(A/P,8\%,20) + \$414{,}000 - (\$15{,}300 + \$103{,}500) \\ &= \$780{,}424 \end{aligned}$$

$$\text{cost per ton} = \frac{\$780{,}424}{109{,}500} = \$7.13/\text{ton}$$

- Site 4:

$$\begin{aligned} AEC(8\%)_2 &= \$5{,}454{,}000(A/P,8\%,20) + \$408{,}000 - (\$17{,}100 + \$119{,}400) \\ &= \$827{,}000 \end{aligned}$$

$$\text{cost per ton} = \frac{\$827{,}000}{109{,}500} = \$7.55/\text{ton}$$

$\therefore$ Site 1 is the most economical choice.

ST 16.3

(a) Let's define the following variables to compute the equivalent annual cost.

$$
\begin{aligned}
A_{la} &= \text{initial land cost} \\
A_{eq} &= \text{initial equipment cost} \\
A_{st} &= \text{initial structure cost} \\
A_{pu} &= \text{initial pumping equipment cost} \\
A_{en} &= \text{initial annual energy cost in today's dollars} \\
A_{lb} &= \text{initial annual labor cost in today's dollars} \\
A_{en} &= \text{initial annual repair cost in today's dollars}
\end{aligned}
$$

- Land:

$$
\begin{aligned}
PW(10\%)_{land} &= A_{la} - A_{la}(1.03/1.1)^{120} \\
&= \$0.99963A_{la}
\end{aligned}
$$

- Equipment: Let's define the following additional variables.

$$
\begin{aligned}
I_{15n} &= \text{replacement cost in year 15n} \\
S_{15n} &= \text{salvage value in year 15n} \\
C_{15n} &= \text{net replacement cost in year 15n}
\end{aligned}
$$

where $n = 1, 2, 3, 4, 5, 6, \textit{and } 7$

The total replacement cost over the analysis period is calculated as follows:

$$
\begin{aligned}
I_{15} &= A_{eq}(1.05)^{15} = 2.07893A_{eq} \\
S_{15} &= 0.5A_{eq} \\
C_{15} &= (2.07893 - 0.5)A_{eq} = 1.57893A_{eq} \\
C_{15n} &= (1.57893A_{eq})(1.05)^{15(n-1)} \\
S_{15n} &= 0.5A_{eq}(1.05)^{15n}
\end{aligned}
$$

$$
\begin{aligned}
PW(10\%)_{equipment} &= A_{eq} + \sum_{n=1}^{7} C_{15n} - S_{120} \\
&= A_{eq} + \sum_{n=1}^{7} \frac{(1.57893A_{eq})(1.05)^{15(n-1)}}{(1.1)^{15n}} - \frac{0.5A_{eq}(1.05)^{120}}{(1.1)^{120}} \\
&= 1.745A_{eq}
\end{aligned}
$$

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- Structure:

$$PW(10\%)_{structure} = A_{st} + (0.40)A_{st}\left[\frac{1}{(1.1)^{40}} + \frac{1}{(1.1)^{80}}\right] - \frac{0.6A_{st}}{(1.1)^{120}}$$
$$= 1.00902A_{st}$$

- Pumping:

$$PW(10\%)_{pumping} = 1.745A_{pu}$$

- Energy:

$$PW(10\%)_{energy} = \sum_{j=1}^{120} A_{en}(1.05/1.1)^{j} = 20.92302A_{en}$$

- Labor:

$$PW(10\%)_{labor} = \sum_{j=1}^{120} A_{lb}(1.04/1.1)^{j} = 17.3113A_{lb}$$

- Repair:

$$PW(10\%)_{repair} = \sum_{j=1}^{120} A_{re}(1.02/1.1)^{j} = 12.748A_{re}$$

- Present worth of the life-cycle cost:

$$PW(10\%) = 0.99963A_{la} + 1.745A_{eq} + 1.00902A_{st} + 1.745A_{pu}$$
$$+ 20.92302A_{en} + 17.3113A_{lb} + 12.748A_{re}$$

Parameters	Option 2	3	4	5
A_{la}	\$2,400,000	\$49,000	\$49,000	\$400,000
A_{eq}	\$500,000	\$500,000	\$400,000	\$175,000
A_{st}	\$700,000	\$2,100,000	\$2,463,000	\$1,750,000
A_{pu}	\$100,000	0	0	\$100,000
A_{en}	\$200,000	\$125,000	\$100,000	\$50,000
A_{lb}	\$95,000	\$65,000	\$53,000	\$37,000
A_{re}	\$30,000	\$20,000	\$15,000	\$5,000
PW(10%)	\$10,364,300	\$7,036,290	\$6,433,460	\$4,395,790
AEC(10%)	\$1,036,440	\$703,637	\$643,353	\$439,584

$\therefore$ Option 5 is the least cost alternative.

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(b)

$$\text{Cost / gallon} = \$439{,}584 / 2{,}000{,}000(365)$$
$$= \$0.0006 \text{ per gallon}$$

$$\text{Monthly charge} = (0.0006)(400)(30)$$
$$= \$7.23 \text{ per month}$$

ST 16.4

(a) Users benefits and disbenefits:

- Users' benefits
  (1) Reduced travel time.
  (2) Reduced fuel consumption.
  (3) Reduced air pollution.
  (4) Reduced number of accidents.

- Users' disbenefits: Increased automobile purchase and maintenance costs.

(b) Sponsor's cost:

- Development costs associated with computerized dashboard navigational systems, roadside sensors, and automated steering and speed controls.
- Implementation and maintenance costs.
- Public promotional and educational costs.

(c) On a national level, the sponsor's costs are estimated to be as follows:

- R&D costs = $2.5 billion
- Implementation costs = $18 billion
- Maintenance costs = $4 billion per year

Comments: However, the users' benefits are sketchy, except the level of reduction possible in the area of travel time, fuel consumption, and air pollution. Ask the students to quantify these in dollar terms by consulting various government publications on public transportation. Once these figures are estimated, the benefit-cost ratio can be easily derived.