Engineering Economy
Exam 4 Practice Problems

By
Douglas Rittmann, Ph.D., P.E.

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Rate of Return Evaluation of Multiple Alternatives

When comparing two or more alternatives by the rate of return method, the first step is to classify them as either mutually exclusive or independent, and second as either revenue or service-only alternatives, because their classification determines what they are to be compared against. There are only three types of alternatives based on these classifications as shown in Table 8.1. The way they are to be evaluated is also shown in the Table.

Table 8.1 – Types of Alternatives and Required Comparisons

Types of Alternatives	How Evaluated
Independent	Only against do-nothing
Mutually exclusive revenue	Against do-nothing first, then against each other
Mutually exclusive service-only	Only against each other

All alternatives will be considered mutually exclusive unless indicated otherwise. Independent alternatives are compared only against the do-nothing alternative wherein all alternatives which have a rate of return that exceeds the MARR are selected. For mutually exclusive alternatives, the do-nothing is a viable option when revenue alternatives are involved. This is essentially what was done in the previous chapter when there was only one alternative involved and its rate of return was determined. When there is more than one alternative involved, the alternatives must be compared against each other on an incremental basis as described below. An incremental analysis refers to an economic analysis of the *difference* in cash flow between *two alternatives*. Such an analysis is based on the fact that if the *extra investment* required in the alternative which has the higher initial investment does not earn at least the minimum attractive rate of return, then that increment of investment should not be made because that increment of money could be better invested elsewhere (where it would earn at least the MARR). The procedure for comparing mutually exclusive alternatives can be summarized as follows:

Procedure

(1) Rank the alternatives in terms of increasing initial investment cost. If the alternatives are *revenue* alternatives, then do-nothing is added and is the first alternative.
(2) Identify the first two alternatives as A and B
(3) Tabulate the difference in cash flow between the first two alternatives (i.e. the incremental cash flow) by subtracting the cash flow for alternative A from the cash flow for alternative B (i.e. B-A) over their least common multiple of lives.
(4) Find the rate of return on the incremental cash flow. If i* is $\geq$ MARR, eliminate A, or vice versa.
(5) Compare the survivor with the next-in-line alternative per steps (3) and (4) above.
Continue steps (3) thru (5) until only one alternative remains

From the following comparisons of mutually exclusive alternatives, decide which one should be selected, if any, assuming the company's MARR is 15% per year. The ranking of the alternatives according to increasing initial investment cost is DN, A, B, C, D

(**A**) Select A (**B**) Select B (**C**) Select C (**D**) Select D

Comparison	Rate of Return Result, %
DN vs A	15.1
DN vs B	11.7
DN vs C	19.4
DN vs D	17.5
A vs B	8.1
A vs C	21.4
A vs D	18.3
B vs C	33.1
B vs D	22.9
C vs D	11.7

Compare DN vs A: $i > 15\%$; eliminate DN

Compare A vs B: $i < 15\%$; eliminate B

Compare A vs C: $i > 15\%$; eliminate A

Compare C vs D: $i < 15\%$; eliminate D

Answer is (C)

The cash flows associated with two alternatives are tabulated in the table below. The equation to find the rate of return on the increment of investment between the two alternatives is

Year	Alt A	Alt B	B - A
0	-25,000	-35,000	-10,000
1	10,000	15,000	5,000
2	10,000	15,000	5,000
3	10,000	15,000	5,000

(A) $0 = -10{,}000 + 5000\,(P/A, i, 3)$

(B) $0 = -10{,}000\,(A/P, i, 3) + 5000$

(C) $0 = -10{,}000\,(F/P, i, 3) + 5000\,(F/A, i, 3)$

(D) All of the above

Answer: D

The benefit/cost method of analysis is a procedure wherein the magnitude of the benefits (B) associated with an alternative is compared with the magnitude of is costs (C). In dividing the benefits by the costs, a number equal to or greater than one would obviously mean that benefits exceed costs, indicating economic attractiveness.

A conventional B/C analysis is used almost exclusively for government projects. As such, the following terms apply:

Benefits (B) - Favorable consequences to the public
Disbenefits (D) - Unfavorable consequences to the public
Costs (C) - Consequences to the government (savings to the government are regarded as negative costs)

The sign convention treats benefits and costs as positive values and disbenefits as negatives. Thus, a conventional benefit-to-cost ratio is calculated as
$B/C = (B - D) / C$
In non-government evaluations, some analysts place maintenance and operation (M&O) costs in the numerator as disbenefits, in which case the resulting ratio is known as a modified B/C ratio.

A B/C ratio can be conducted in terms of PW, AW, or FW values, as long as all values are expressed in the same units. The next example illustrates the calculations involved.

The U.S. Parks and Wildlife Service is considering providing public access to a previously inaccessible portion of Carlsbad Caverns. The cost of the project is expected to be $1.8 million, with maintenance expected to cost $60,000 per year. However, increased tourism is expected to generate additional income of $250,000 per year to local businesses. Calculate the B/C ratio for the permanent project using an interest rate of 8% per year.

Solution: Using an AW analysis,

$$B = 250{,}000$$
$$C = 1{,}800{,}000\ (0.08) + 60{,}000 = 204{,}000$$

$$B/C = 250{,}000 / 204{,}000 = 1.22$$

Therefore, the project should be undertaken.

Economic Service Life

Until now, the life of an asset was always provided as part of the economic data (i.e. first cost, annual operating cost, salvage value, etc). In this section, we show how the life of an asset is determined.

It should be obvious that an asset should be kept for a period of time that would minimize its cost to the company. The time that would do that is known as its economic service life (also called its minimum cost life) and it is found by calculating the asset's annual worth over various time periods and selecting the time that corresponds with the lowest AW value. The next example illustrates the procedure.

An asset which has a first cost of $40,000 is expected to have an annual operating cost of $15,000 per year. It will provide the needed service for a maximum of 6 years. If the salvage value changes as shown below, determine the economic life of the asset at 20% per year.

Year	End of Year Salvage value, $
1	$32,000
2	30,000
3	24,000
4	20,000
5	11,000
6	0

AW1 = -40,000 (A/P, 20%, 1) - 15,000 + 32,000
= -$31,000

For two years of retention, the AW is:

AW2 = -40,000 (A/P, 20%, 2) - 15,000 + 30,000 (A/F, 20%, 2)
= -$27,545

Similarly, for years 3, 4, 5, and 6, the AW values are: $27,396, -$26,726, -$26,897, and -$27,028. The lowest AW is -$26,726 at n = 4. Therefore, the economic life is 4 years.

The overall rate of return results (i.e. each alternative vs DN) shown below are for independent alternatives. If the company's MARR is 15% per year, the ones which should be selected are

(A) Only Y
(B) Only W
(C) W, Y, and Z
(D) Cannot tell without incremental analysis

	W	X	Y	Z
First cost, $	-30,000	-65,000	-75,000	-92,000
Rate of return, %	16	10	22	17

Answer: C

For the alternatives shown below, the first comparison that should be made is

(a) DN vs H (b) DN vs E (c) E vs F
(d) H vs F

Alternatives

	E	F	G	H
First cost, $	**-85,000**	**-68,000**	**-95,000**	**-40,000**
Annual cost, $	**-50,000**	**-57,000**	**-46,000**	**-60,000**
Life, years	**10**	**10**	**10**	**10**

The alternatives are service alternatives. Therefore, cannot compare against DN. Ranking according to initial investment cost is H, F, E, G. Therefore, first comparison is H vs F. Answer is (D).

The costs associated with two routes for a new road are shown below. Using an interest rate of 8% per year, determine which route should be selected according to a B/C analysis over a 25 year study period.

	Long Route	Short Route
First cost, $	10,000,000	15,000,000
Road user costs, $/yr	800,000	500,000
Life, yrs	30	30

Solution:

The consequences to the public are the road user costs. The benefits are the lower road-user costs associated with the shorter route (the higher cost alternative). Thus,

B = 800,000 - 500,000
= $300,000 per year

C = (15,000,000 - 10,000,000) (A/P, 8%, 25)
= 5,000,000 (0.09368)
= $468,400

B/C = 300,000 / 468,400
= 0.64 Therefore, build the long route.

A veterans organization is considering a permanent memorial for soldiers who died while serving in the armed forces during non-wartime periods. The cost of the memorial (including land and all structures) is expected to be $8,000,000. Maintenance of the site will cost $300,000 per year. Benefits and disbenefits have been identified which amount to $900,000 and $40,000 per year, respectively. At an interest rate of 6% per year, the B/C ratio is closest to:

(A) Less than 1.0
(B) 1.1
(C) 1.5
(D) Over 1.7

Solution:

$$B = 900{,}000$$

$$D = 40{,}000$$

$$C = 8{,}000{,}000\ (0.06) + 300{,}000$$

$$= 780{,}000$$

$$B/C = \frac{900{,}000 - 40{,}000}{780{,}000}$$

$$= 1.1$$