In the name of Allah

Industrial Engineering Department

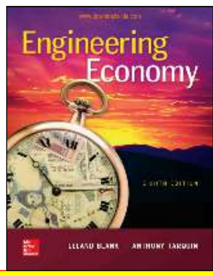
Course Title:
Engineering Economics

8. Rate of Return Analysis: Multiple Alternatives

By: Akbar Esfahanipour

Learning Stage 2: Basic Analysis Tools

- Chapter 5
  - Present Worth Analysis
- Chapter 6
  - Annual Worth Analysis
- Chapter 7
  - Rate of Return Analysis: One Project
- Chapter 8
  - Rate of Return Analysis: Multiple Alternatives
- Chapter 9
  - Benefit/Cost Analysis and Public Sector Economics



Chapter 8 of EE (BT) book 8th edition

LEARNING OUTCOMES

- Purpose:
  - Select the best alternative on the basis of incremental rate of return analysis.

1. Why incremental analysis is required in ROR
2. Incremental cash flow (CF) calculation
3. Interpretation of ROR on incremental CF
4. Select alternative by ROR based on PW relation
5. Select alternative by ROR based on AW relation
6. Select best from several alternatives using ROR method

Why Incremental Analysis is Necessary (1)

- Selecting the alternative with highest ROR may not
  - yield highest return on available capital
- Must consider weighted average of total capital available
  - Capital not invested in a project is assumed to earn at MARR
- Example: Assume $90,000 is available for investment and MARR = 16% per year.
  - If alternative A would earn 35% per year on investment of $50,000, and B would earn 29% per year on investment of $85,000, the weighted averages are:

    Overall $\mathbf{ROR_A} = [\mathbf{50,000(0.35) + 40,000(0.16)}]/\mathbf{90,000} = \mathbf{26.6}\%$

    Overall $\mathbf{ROR_B} = [\mathbf{85,000(0.29) + 5,000(0.16)}]/\mathbf{90,000} = \mathbf{28.3}\%$
  - Which investment is better, economically?

Why Incremental Analysis is Necessary (2)

- Example cont'd
  - If selection basis is higher ROR:
    - Select alternative A (wrong answer)
  - If selection basis is higher overall ROR:
    - Select alternative B
  - Conclusion:
    - Must use an incremental ROR analysis to make a consistently correct selection
- Unlike PW, AW, and FW values, if not analyzed correctly,
  - ROR values can lead to an incorrect alternative selection.
    - This is called the ranking inconsistency problem (to be discussed later)

Calculation of Incremental CF

- Incremental cash flow = cash flow$_B$ − cash flow$_A$
  - where larger initial investment is Alternative B
- Example: Either of the cost alternatives shown below can be used in a grinding process.
  - Tabulate the incremental cash flows.

	A	B	B – A
First cost, $	−40,000	− 60,000	− 20,000
Annual cost, $/year	− 25,000	− 19,000	+6000
Salvage value, $	8,000	10,000	+ 2000

The incremental CF is shown in the (B − A) column

- The ROR on the extra $20,000 investment in B determines which alternative to select (as discussed later)

Interpretation of ROR on Extra Investment

- Based on concept that any avoidable investment
  - that does not yield at least the MARR should not be made.
- Once a lower-cost alternative has been economically justified,
  - the ROR on the extra investment must also yield a ROR ≥ MARR
    - because the extra investment is avoidable by selecting the economically-justified lower-cost alternative.
- This incremental ROR is identified as Δi^*

For independent projects, select all that have ROR ≥ MARR
i.e., no incremental analysis is necessary

ROR Evaluation for Two ME Alternatives

(1) Order alternatives by increasing initial investment cost

(2) Develop incremental CF series using LCM of years

(3) Draw incremental cash flow diagram, if needed

(4) Count sign changes to see if multiple Δi^* values exist

(5) Set up PW, AW, or FW = 0 relation and find $\Delta i^*_{B\text{-}A}$
Note: Incremental ROR analysis requires equal-service comparison.
The LCM of lives must be used in the relation

(6) If $\Delta i^*_{B\text{-}A}$ < MARR, select A; otherwise, select B

If multiple Δi^* values exist, find EROR using either MIRR or ROIC approach.

Example: Incremental ROR Evaluation

- Example: Either of the cost alternatives shown below can be used in a chemical refining process.
  - If the company's MARR is 15% per year, determine which should be selected on the basis of ROR analysis?

	A	B
First cost ,$	−40,000	−60,000
Annual cost, $/year	−25,000	−19,000
Salvage value, $	8,000	10,000
Life, years	5	5

- Initial observations: ME, cost alternatives with equal life estimates and no multiple ROR values indicated

Example: ROR Evaluation of Two Alternatives

- Solution, using the procedure:

	A	B	B – A
First cost, $	−40,000	−60,000	−20,000
Annual cost, $/year	−25,000	−19,000	+6000
Salvage value, $	8,000	10,000	+2000
Life, years	5	5	

Order by first cost and find incremental cash flow B − A

Write ROR equation (in terms of PW, AW, or FW) on incremental CF

$$0 = -20{,}000 + 6000(P/A, \Delta i^*, 5) + 2000(P/F, \Delta i^*, 5)$$

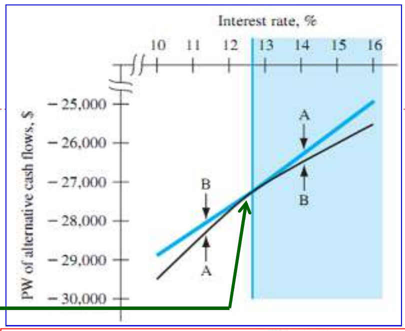
Solve for Δi^* and compare to MARR

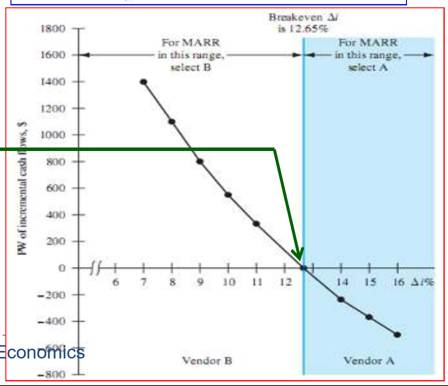
$\Delta i^*_{B\text{-}A} = 17.2\% > \text{MARR of } 15\%$

ROR on $20,000 extra investment is acceptable: Select B

Breakeven ROR Value

- A ROR at which the PW, AW or FW values:
  - Of cash flows for two alternatives are exactly equal.
    - This is the i* value
  - Of incremental cash flows between two alternatives are exactly equal.
    - This is the Δi* value





If MARR > breakeven ROR, select lower-investment alternative

ROR Analysis – Multiple Alternatives

- Six-Step Procedure for Mutually Exclusive Alternatives
  - 1) Order alternatives from smallest to largest initial investment
  - 2) For revenue alts, calculate i* (vs. DN) and eliminate all with i* < MARR; remaining alternative with lowest cost is defender.
    - For cost alternatives, go to step 3
  - 3) Determine incremental CF between defender and next lowest-cost alternative (known as the challenger). Set up ROR relation
  - 4) Calculate Δi* on incremental CF between two alternatives from step 3
  - 5) If Δi* ≥ MARR, eliminate defender and challenger becomes new defender against next alternative on list
  - 6) Repeat steps 3 – 5 until only one alternative remains then Select it.
- For Independent Projects
  - Compare each alternative vs. DN and select all with ROR ≥ MARR

Example: ROR for Multiple Alternatives

- Five mutually exclusive alternatives are under consideration for improving visitor safety and access to additional areas of a national park.
  - If all alternatives are considered to last indefinitely, determine which should be selected on the basis of a ROR analysis using an interest rate of 10%.

	A	B	C	D	E
First cost, \$ millions	−20	−40	−35	−90	−70
Annual M&O cost, \$ millions	−2	−1.5	−1.9	−1.1	−1.3

Solution: Rank on the basis of initial cost: A, C, B, E, D; calculate CC values

C vs. A: $0 = -15 + 0.1/0.1$ $\Delta i^* = 6.7\%$ eliminate C

B vs. A: $0 = -20 + 0.5/0.1$ $\Delta i^* = 25\%$ eliminate A

E vs. B: $0 = -30 + 0.2/0.1$ $\Delta i^* = 6.7\%$ eliminate E

D vs. B: $0 = -50 + 0.4/0.1$ $\Delta i^* = 8\%$ eliminate D So, Select alternative B

Multiple Alternatives with unknown MARR

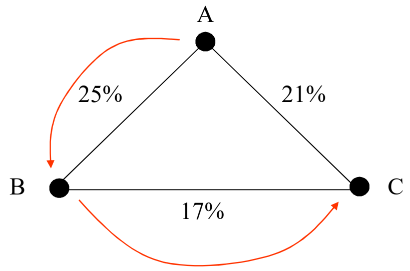
- Using Network
  - Compare ME alternatives with/without DN
- How to draw Network
  - Nodes: alternatives
  - Edges: ΔROR of pairs of origin/destination Alternatives
- Objective
  - Find conditions for selecting of the alternatives
  - Start from the least Initial Cost & go to the most Initial Cost Alt.
    - In case of having more than one route, select one with the largest ΔROR
- Evaluation:
  - If MARR ≥ an edge ΔROR then the origin alt. is justified
  - If MARR < an edge ΔROR then the destination alt. is justified

Multiple Alternatives with unknown MARR

- Example:
  - Consider the following infinite alternatives with unknown MARR. Derive the conditions for selection of the Alts with/without DN.

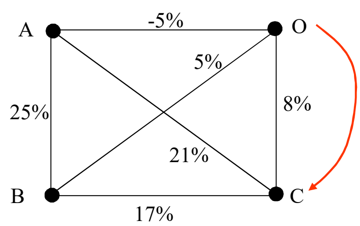
	A	B	C
Initial cost	2000	3000	4000
Annual revenue	-100	150	320

- Solution: without DN
  - $\Delta ROR_{B\text{-}A} = 1000/250 = 25\%$
  - $\Delta ROR_{C\text{-}A} = 2000/420 = 21\%$
  - $\Delta ROR_{C\text{-}B} = 1000/170$ 17%



Multiple Alternatives with unknown MARR

- Solution: without DN
  - If MARR > 25% , then Select A
  - If 25% ≥ MARR > 17%, then select B
  - If 17% ≥ MARR , then Select C
- Solution: with DN
  - $NPW_A = 0 \rightarrow 2000 = -100/i \rightarrow i = -0.05$
  - $NPW_B = 0 \rightarrow 3000 = 150/i \rightarrow i = 0.05$
  - $NPW_C = 0 \rightarrow 4000 = 320/i \rightarrow i = 0.08$



- Now write the conditions
  - If MARR > 8%, then Select DN
  - If MARR ≤ 8%, then Select C

Summary of Important Points

- Must consider incremental cash flows for mutually exclusive alternatives
  - Incremental cash flow = cash flow_B − cash flow_A
    - where alternative with larger initial investment is Alternative B
  - Eliminate B if incremental ROR $\Delta i^* < MARR$; otherwise, eliminate A
- Breakeven ROR is i* between project cash flows of two alternatives, or Δi^* between incremental cash flows of two alternatives
- For multiple mutually exclusive alternatives,
  - compare two at a time and eliminate alternatives until only one remains
- For independent alternatives,
  - compare each against DN and select all that have ROR ≥ MARR