

# Replacement Decisions

Topic objectives:

- Understand the concept of the sunk cost in replacement decisions.
- Compare defender and challenger applying cash flow and opportunity approaches.
- Determine the economic service life of a machine.
- Find the optimal time to replace a machine.

- Profit-maintaining projects are projects whose primary purpose is not to increase sales, but rather simply to maintain ongoing operations.
- Profit-maintaining projects involve the options whether to buy new and more efficient equipment or to continue to use existing equipment.
- This class of decision problems is known as the replacement problem.

# Replacement-Analysis Fundamentals

- We examine three aspects of the replacement problem:
  1. Approaches for comparing defender and challenger
  2. Determination of economic service life
  3. Replacement analysis when the required service period is long.

## Basic Concepts and Terminology

- In replacement analysis, the defender is the existing machine and the challenger is the best available replacement equipment.
- An existing equipment will be removed at some future time.
- The question is when it will be removed.

## Current Market Value

- The most common problem encountered in considering the replacement of existing equipment is the determination of what financial information is actually relevant to the analysis.
- In replacement analysis, the only relevant cost is the current market value of the equipment.

# Sunk Cost

- A sunk cost is any past cost that is unaffected by any future investment decision.
- In engineering economic analysis, only future costs should be considered, sunk costs should be ignored.

# Operating Costs

- It is important to focus only on operating costs that differ for the defender and challenger.

# Approaches for Comparing Defender and Challenger

- We consider two approaches to analyzing replacement problems:
  - Cash flow
  - Opportunity-cost

## Cash Flow Approach

- This approach is used as long as the analysis period is the same for all replacement alternatives.
- With this approach, the replacement alternatives are compared based on either PW or AE values.
- In the analysis, the market value of the defender is credited against the purchase price of the challenger.

## Example

- A company is considering upgrading its production line that will be utilized for 3 more years.
- The current machine has a market value of 170,000 riyals, it has a salvage value of 70,000 riyals after 3 years; the annual operating cost is 9 million riyals.
- The upgrade will require an investment of 530,000 riyals; the upgrade will reduce the annual operating cost to 8.85 million riyals; the salvage value of the equipments is 180,000 riyals.

- The cash flows are

Year	Defender	Challenger
0	0	170-530
1	-9,000	-8,850
2	-9,000	-8,850
3	-9,000+70	-8,850+180

# Opportunity-Cost Approach

- In analyzing the problem, the market value can be treated as an opportunity cost of keeping the defender.
- This approach is used when the project lives are different.

## Example

- Under this opportunity cost approach, the cash flows for the defender and challenger from the previous example are

Year	Defender	Challenger
0	-170	-530
1	-9,000	-8,850
2	-9,000	-8,850
3	-9,000+70	-8,850+180

## Economic Service Life

- We need to consider how long an asset should be held, once it is placed in service.
- The costs of owning and operating an asset can be divided into two categories: capital costs and operating costs.
- Capital costs have two components: investment and salvage value.
- For the defender, the current market value is treated as an opportunity cost and as its investment.
- Let  $N$  be the length of time in years that the asset will be kept,  $I$  be the investment, and  $S_N$  be the salvage value at the end of  $N$  years.

- The capital-recovery cost over N years is given by

$$\begin{aligned} CR(i) &= I(A/P, i, N) - S_N(A/F, i, N) \\ &= (I - S_N)(A/P, i, N) + iS_N \end{aligned}$$

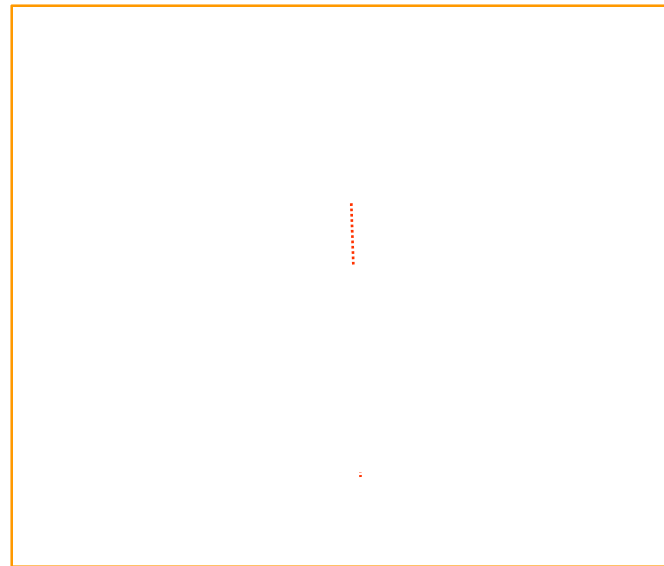
- Operating and maintenance (O&M) costs tend to increase as a function of the age of the asset.
- Let  $OC_n$  be the total operating costs in year n and  $OC(i)$  be the annual equivalent of the operating costs of N years, then

$$OC(i) = \left( \sum_{n=1}^N OC_n(P/F, i, n) \right) (A/P, i, N)$$

- The total annual equivalent cost is given by

$$AE = CR(i) + OC(i)$$

- The economic service life of an asset is the period of useful life that minimizes the annual equivalent costs, in real terms.



## Example

- A company is considering purchasing a new machine.
- The capital cost is 20,000<sup>SR</sup>, has operating cost of 6,000<sup>SR</sup> in the first year, and has salvage value of 14,000<sup>SR</sup> at the end of the first year.
- The annual operating cost increases by 25%.
- The salvage value declines by 30%.
- The machine has a maximum life of 8 years.
- The interest rate is 12%.
- What is the economic service life of the machine?

- The solution procedure requires the extension the replacement cycle year by year and computation of the annual equivalent cost.

- For  $N = 1$ ,

$$\begin{aligned} \text{AEC}(12\%) &= (20 - 14) (A/P, 12\%, 1) + 0.12(14) + 6 \\ &= 14,400. \end{aligned}$$

- For  $N = 2$ ,

$$\begin{aligned} \text{AEC}(12\%) &= (20 - 9.8) (A/P, 12\%, 2) + 0.12(9.8) \\ &\quad + 6 (P/A1, 25\%, 12\%, 2)(A/P, 12\%, 2) \\ &= 13,919. \end{aligned}$$

- For  $N = 3$ ,

$$\begin{aligned} \text{AEC}(12\%) &= (20 - 6.86) (A/P, 12\%, 3) + 0.12(6.86) \\ &\quad + 6 (P/A1, 25\%, 12\%, 3) (A/P, 12\%, 3) \\ &= 13,792. \end{aligned}$$

- For  $N = 4$ ,

$$\text{AEC}(12\%) = 13,961$$

- AEC begins to increase, hence we stop.
- The economic service life of the machine is 3 years.

# Replacement Strategies under the Infinite Planning Horizon

- We assume the process for which the machine is needed is expected to continue for an infinite period.
- A more effective machine is on the market which will provide the same service.
- The question is: when, if at all, should the defender be replaced with the challenger?

- The following procedure is followed in replacement analysis:
  1. Compute the economic lives of the defender ( $N_D^*$ ) and challenger ( $N_C^*$ ). Let the annual equivalent cost for the defender for its perspective life is  $AE_D^*$  and for the challenger it is  $AE_C^*$ .
  2. Compare  $AE_D^*$  and  $AE_C^*$ . If  $AE_D^* > AE_C^*$ , the defender should be replaced by the challenger now. If  $AE_D^* < AE_C^*$ , the defender should not be replaced now and should be used for the duration of its economic life.

3. When the economic life the defender is over, we calculate the cost of using the defender for one more year. If this cost  $> AE_C^*$ , the defender should be replaced at the end of its economic life. Otherwise, we calculate the cost of running the defender for a second year. If this cost  $> AE_C^*$ , the defender should be replaced one year after its economic life. The process should be repeated. This approach is called marginal analysis.

## Example

- A company is considering replacing a machine in a critical stage of the production line.
- The current machine can be used for another 6 years with maintenance, with no salvage value.
- The market value is expected to be 4,000 riyals and will decline by 25% annually.
- The operating cost is estimated at 3,500 riyals in the first year and will increase by 1,000 riyals annually thereafter.
- The alternative will be to replace the current machine by a new one.

- The new machine costs 12,000 riyals and will have an operating cost of 2,300 riyals and it will increase by 20% annually.
- The salvage value is expected to be 8,000 riyals after one year in service and will decline by 30% annually.
- If  $MARR = 12\%$ , when should the current machine be changed?

- First, the economic service life the current machine should be determined:

$$\begin{aligned} AEC_1 &= 4,000 (A/P, 12\%, 1) \\ &\quad - 4,000 (1 - 0.25) + 3,500 \\ &= 4,980 \text{ riyals} \end{aligned}$$

$$\begin{aligned} AEC_2 &= 4,000 (A/P, 12\%, 2) \\ &\quad - 4,000 (1-0.25)^2 (A/F, 12\%, 2) + 3,500 \\ &\quad + 1,000 (P/G, 12\%, 2)(A/P, 12\%, 2) = 5,277 \text{ riyals} \end{aligned}$$

- Therefore, the economic service life of the current machine is one year:

$$N_D^* = 1 \text{ year}$$

$$AEC_D^* = 4,980 \text{ riyals}$$

- Similarly, the economic service life of the challenger can be found:

$$N_C^* = 5 \text{ years}$$

$$AEC_C^* = 6,312 \text{ riyals}$$

- Since  $AEC_D^* < AEC_C^*$ , the defender should not be replaced now.
- The cost of keeping the defender until the end of the second year is
$$3 (A/P, 12\%, 1) + 4.5 - 2.25 = 5,610 \text{ riyals.}$$
- Since it costs less to keep the defender for a second year than to replace it by the challenger, the defender should not be replaced.

- The cost of keeping the defender until the end of the third year is

$$2.25 (A/P, 12\%, 1) + 5.5 - 1.688 = 6,332 \text{ riyals}$$

- Since it will cost more to keep the defender for a third year than to replace it, the defender should be replaced at the end of the second year.