INDE 301 Engineering Economy

Chapter 11 Replacement and Retention Decisions

- **Reasons for Replacing an Asset**
  - Reduced Performance
    - Wear and tear
    - Decreasing reliability and productivity
    - Increasing operating and maintenance costs
  - Altered Requirements
    - New production needs, accuracy, speed, etc.
  - Obsolescence
    - Current assets may be less productive
    - Not state of the art – need to meet competition

- **Terminology**
  - *Defender Asset*. Currently installed asset.
  - *Challenger Asset*. Could replace the defender asset.
  - *Equivalent Uniform Annual Cost* (EUAC). AW for costs.
  - *Economic Service Life* (ESL). Number of years at which lowest AW of costs occur.
  - *Defender First Cost*. Initial investment in the defender (P).
  - *Market value* (MV_k) *of the defender in year k*. Salvage value of the defender in year k.
  - *Challenger first cost*. Initial cost necessary to acquire and install the challenger.

- **Example 1**

Only 2 years ago, Techtron purchased for $275,000 a fully loaded SCADA (supervisory control and data acquisition) system including hardware and software for a processing plant operating on the Houston ship channel. When it was purchased, a life of 5 years and salvage of 20% of first cost were estimated. Actual M&O costs have been $25,000 per year, and the book value is $187,000. There has been a series of insidious malware infections targeting Techtron's command and control software, plus next-generation hardware marketed only recently could greatly reduce the competitiveness of the company in several of its product lines. Given these factors, the system is likely worth nothing if kept in use for the final 3 years of its anticipated useful life.

Model K2-A1, a new replacement turnkey system, can be purchased for $300,000 net cash, that is, $400,000 first cost and a $100,000 trade-in for the current system. A 5-year life, salvage value of 15% of stated first cost or $60,000, and an M&O cost of $15,000 per year are good estimates for the new system. The current system was appraised this morning, and a market value of $100,000 was confirmed for today; however, with the current virus discovery, the appraiser anticipates that the market value will fall rapidly to the $80,000 range once the virus problem and new model are publicized.

Using the above values as the best possible today, state the correct defender and challenger estimates for P, M&O, S, and n in a replacement study to be performed today.

Solution

Defender: Use the current market value of $100,000 as the first cost for the defender. All others—original cost of $275,000, book value of $187,000, and trade-in value of $100,000—are irrelevant to a replacement study conducted today. The estimates are as follows:

First cost	$P = \$-100{,}000$
M&O cost	$A = \$-25{,}000$ per year
Expected life	$n = 3$ years
Salvage value	$S = 0$

Challenger: The $400,000 stated first cost is the correct one to use for P, because the trade-in and market values are equal.

First cost	$P = \$-400{,}000$
M&O cost	$A = \$-15{,}000$ per year
Expected life	$n = 5$ years
Salvage value	$S = \$60{,}000$

Comment

If the replacement study is conducted next week when estimates will have changed, the defender's first cost will be $80,000, the new market value according to the appraiser. The challenger's first cost will be $380,000, that is, $P - (\text{TIV} - \text{MV}) = 400{,}000 - (100{,}000 - 80{,}000)$.

- **Economic Service Life (ESL)**
  - ESL is the number of years *n* at which the equivalent annual worth *AW* of costs is the minimum considering the most current cost estimates over all possible years that the asset may provide a needed service.
  - Total AW of costs is the sum of capital recovery (CR), which is the initial investment and any salvage value, and the AW of the estimated annual operating cost (AOC)

    Total AW = CR – AW of AOC
  - Capital Recovery = *-P(A/P, i, n) + S (A/F, i, n)*
  - The salvage value, *S*, which usually decreases with time, is the estimated market value (MV) in that year.
  - The complete equation for total AW of costs over *k* years (*k* = 1, 2, 3,…)

$$Total\ AW_k = -P(A/P, i, k) + S_k(A/F, i, k) - \left[\sum_{j=1}^{j=k} AOC_j(A/F, i, j)\right](A/P, i, k)$$

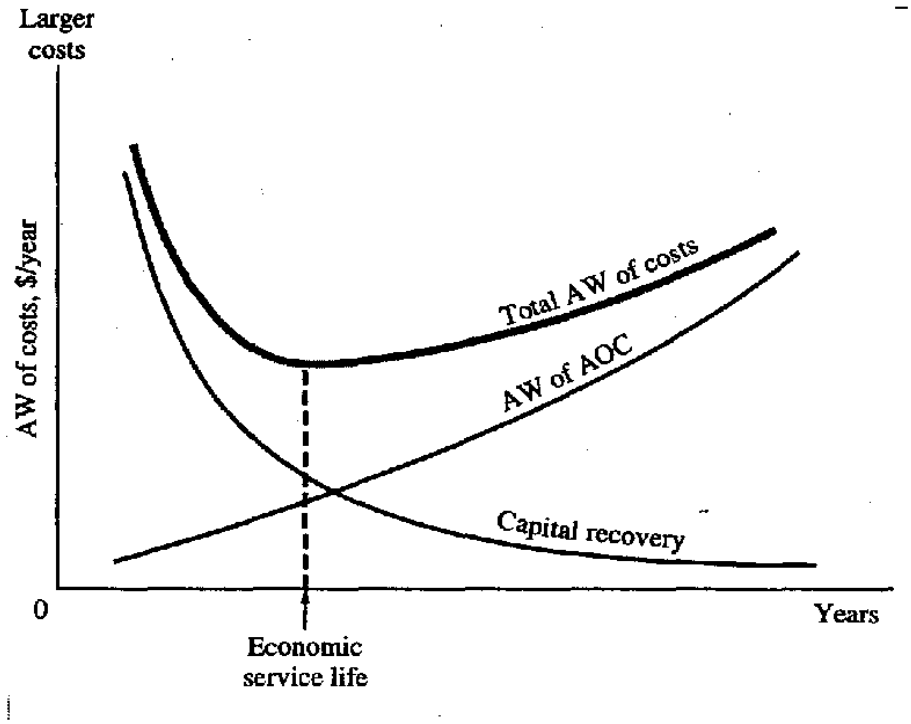
$$Total\ AW_k = -MV_0(A/P, i, k) + MV_k(A/F, i, k) - \left[\sum_{j=1}^{j=k} AOC_j(A/F, i, j)\right](A/P, i, k)$$

    P = initial investment or current market value

    S_k = salvage value or market value after *k* years

    AOC_j = annual operating cost for year *j*
  - Usually, AOC increase with time, *k* and CR decreases with *k*.
  - The ESL, k^*, strikes a balance between these two costs.

- High CR means that the asset has been utilized long enough and generated enough value.



Example 2

A 3-year-old backup power system is being considered for early replacement. Its current market value is $20,000. Estimated future market values and annual operating costs for the next 5 years are given in the below table, columns 2 and 3.
What is the economic service life of this defender if the interest rate is 10 % per year? Solve by hand.

Year j (1)	MV_j, $ (2)	AOC_j, $ (3)
1	10,000	−5,000
2	8,000	−6,500
3	6,000	−8,000
4	2,000	−9,500
5	0	−12,500

Solution

- Calculate capital recovery for the $20,000 current market value (j = 0) plus 10% return (column 4)
- Calculate the equivalent AW of AOC for k years (column 5)

i.e: the computation of total AW for k = 3 is

$$Total\ AW_3 = -P(A/P, i, 3) + MV_3(A/F, i, 3) - [PW\ of\ AOC_1, AOC_2\ and\ AOC_3](A/P, i, 3)$$

= -6230-6405= $ -12,635

Year j (1)	MV_j, $ (2)	AOC_j, $ (3)	Capital Recovery, $ (4)	AW of AOC, $ (5)	Total AW_k, $ (6) = (4) + (5)
1	10,000	−5,000	−12,000	−5,000	−17,000
2	8,000	−6,500	−7,714	−5,714	−13,428
3	6,000	−8,000	−6,230	−6,405	−12,635
4	2,000	−9,500	−5,878	−7,072	−12,950
5	0	−12,500	−5,276	−7,961	−13,237

- **Special cases for ESL**
  - If AOC are the same for all years, then k^*. Then, set k^*at the maximum possible number of years.
  - If AOC is increasing with time and MV is the same for all years, then replace in year 1. Then, $k^* = 1$.

- **Marginal Costs**

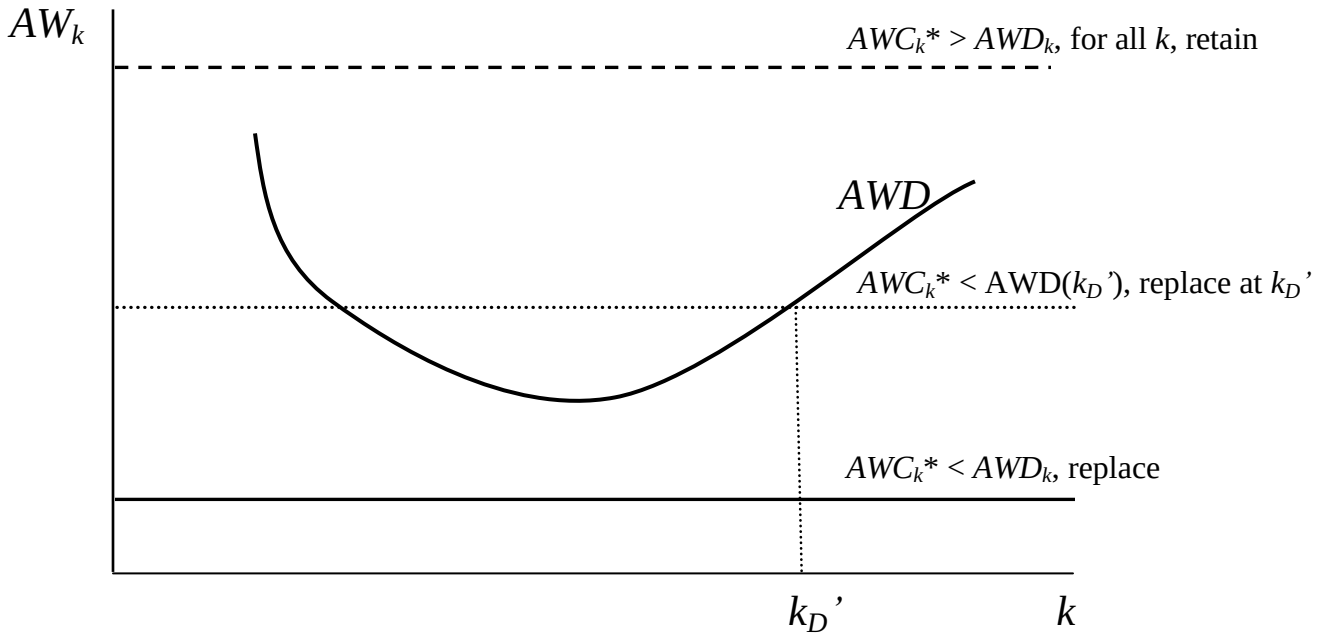
  Marginal costs (MC) are year-by-year estimates of the costs to own and operate an asset for that year. Three components are added to determine the marginal cost:

  1. Cost of ownership (loss in the market value is the best estimate of this cost)
  2. Forgone interest on the market value at the beginning of the year
  3. AOC for each year

  AW of marginal costs = total AW of costs

- **Replacement with an identical challenger**
  - Suppose an asset is to be replaced with an identical challenger. Let k_0 be the age of the defending asset.
  - Then, replace the asset if $k_0 \geq k^*$, where k^* is the ESL. Otherwise (if $k_0 < k^*$), then keep the asset.
  - This will minimize the long run cost assuming that replacement is only possible with identical assets.
  - For example, an asset with $k^* = 3$ should be replaced if its age is 3 or more years, and retained, otherwise.

- **Replacement with a nonidentical asset**
  - Suppose now an asset is to be replaced with a challenger having different characteristics.
  - Let k_D* and AWD_k* be the ESL and corresponding AW of the defender, and k_C* and AWC_k* be those of the challenger.
  - Then, replace the defender *immediately* if AWC_k * < AWD_k* .
  - Otherwise,
    - If AWC_k* > AWD_k*, but AWC_k* < AWD_k for some year k_D' > k_D*, then replace the defender at year k_D'. If no such k_D' exists, then keep defender.
    - If AWC_k* > AWD_k, for all k, then keep the defender as long as possible.



- The assumption here is that no other challenger will be identified in future years.

- **Generalized replacement models**
  - Sometimes one can expect emergence of future challengers.
  - In these cases, one should include future alternatives in the analysis.
  - This complicates the replacement problem since many options are now possible.
  - For example, suppose there is a challenger now and a challenger next year. The options are:
    (i) Replace now with current challenger and retain current challenger thereafter.
    (ii) Retain now and replace with next year's challenger.
    (iii) Retain defender throughout.