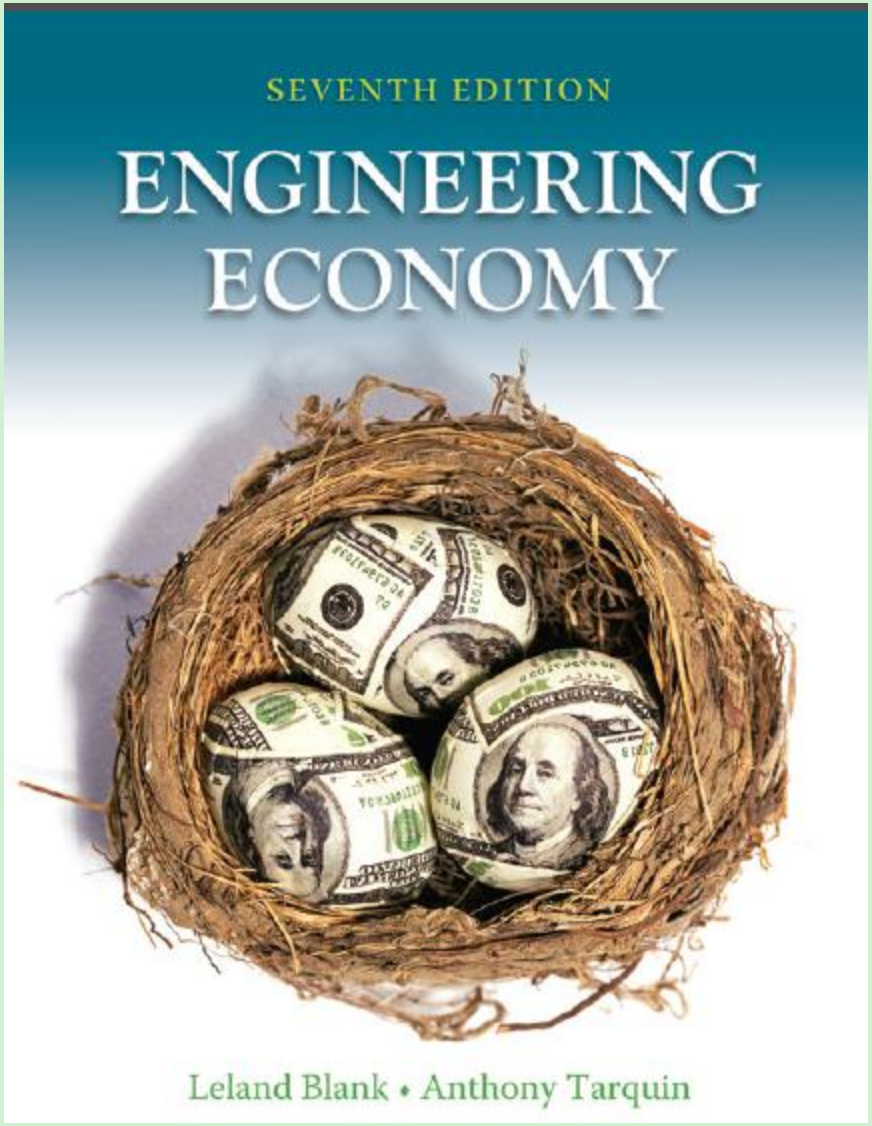


Chapter 11

Replacement & Retention

Lecture slides to accompany

Engineering Economy

7th edition

Leland Blank

Anthony Tarquin

Mc Graw Hill Higher Education

LEARNING OUTCOMES

1. Explain replacement terminology and basics
2. Determine economic service life (ESL)
3. Perform replacement/retention study
4. Understand special situations in replacement
5. Perform replacement study over specified time
6. Calculate trade-in value of defender

Basics of Replacement Study

- **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 – ***Currently installed*** asset

Challenger – ***Potential replacement*** for defender

Market value (MV) – Value of defender if ***sold in open market***

Economic service life – No. of years at which ***lowest AW*** of cost occurs

Defender first cost – ***MV of defender***; used as its first cost (P) in analysis

Challenger first cost – ***Capital to recover*** for challenger (usually its P value)

Sunk cost – A **sunk cost is a prior expenditure or loss of capital (money) that cannot be recovered by a** decision about the future.

Nonowner's viewpoint – ***Outsider's (consultant's) viewpoint*** for objectivity

Example: Replacement Basics

An asset purchased 2 years ago for $40,000 is harder to maintain than expected. It can be sold now for $12,000 or kept for a maximum of 2 more years, in which case its operating cost will be $20,000 each year, with a salvage value of $9,000 two years from now. A suitable challenger will have a first cost of $60,000 with an annual operating cost of $4,100 per year and a salvage value of $15,000 after 5 years. Determine the values of P, A, n, and S for the defender and challenger for an AW analysis.

Solution:

Defender: P = $-12,000; A = $-20,000; n = 2; S = $9,000

Challenger: P = $-60,000; A = $-4,100; n = 5; S = $15,000

Economic Service Life

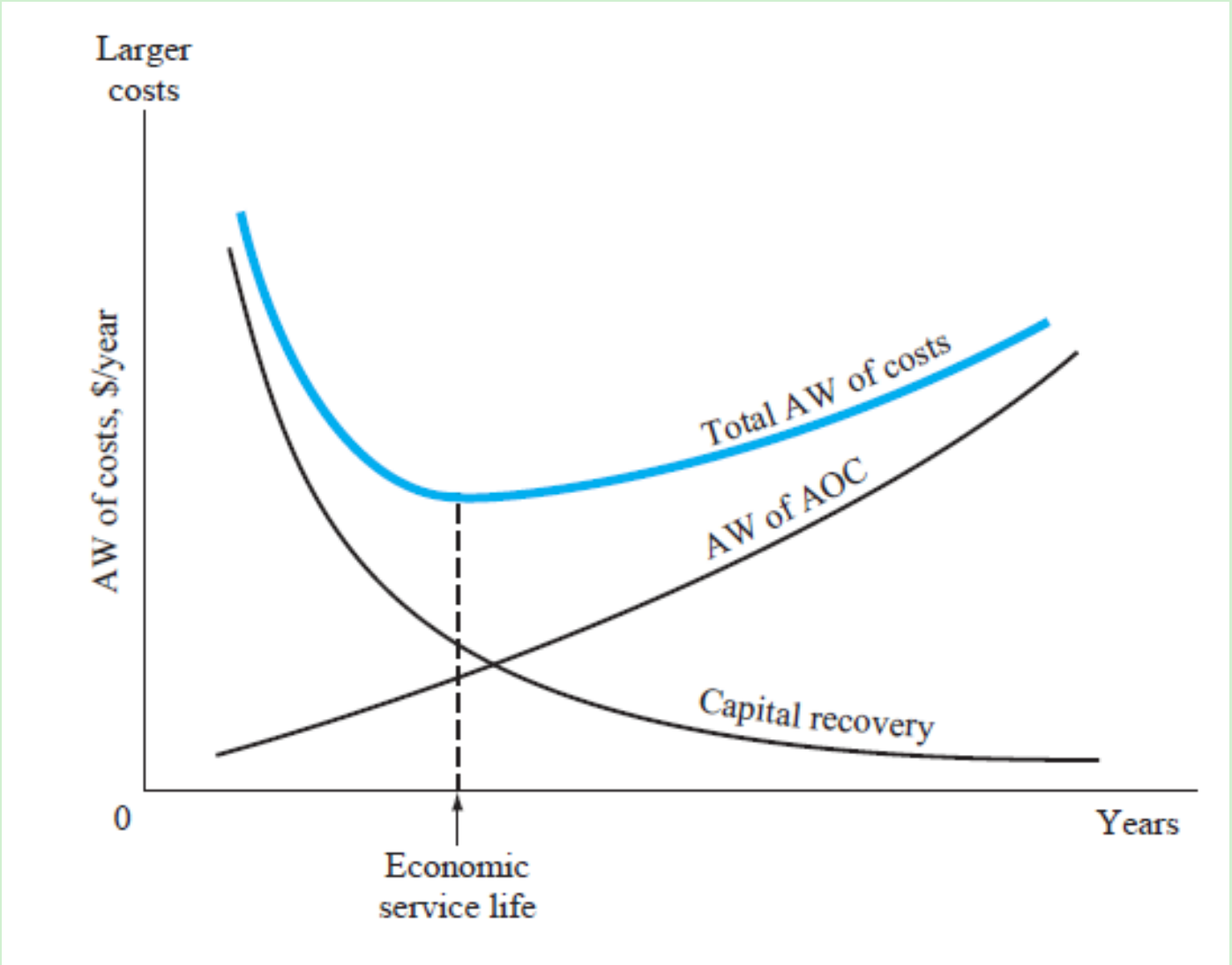
Economic service life (ESL) refers to the asset retention time (n) that yields its *lowest equivalent AW*

Determined by calculating AW for 1, 2, 3,…n years

General equation is:

Total AW = capital recovery – AW of annual operating costs
= CR – AW of AOC

Typical Economic Service Life



Example 11.2

- Defender Asset;
- 3 years old now;
- Market value now $13,000;
- 5-year study period assumed;
- Requires estimates of the future salvage values and annual operating costs for the 5-year period.

11.2 Example: Future Market Values

- Estimated Future Market Values and AOC's:

	$MktV_t$	AOC_t
t = 1:	$9,000	$ 2,500
t = 2:	$8,000	$ 2,700
t = 3:	$6,000	$ 3,000
t = 4:	$2,000	$ 3,500
t = 5:	$0	$ 4,500

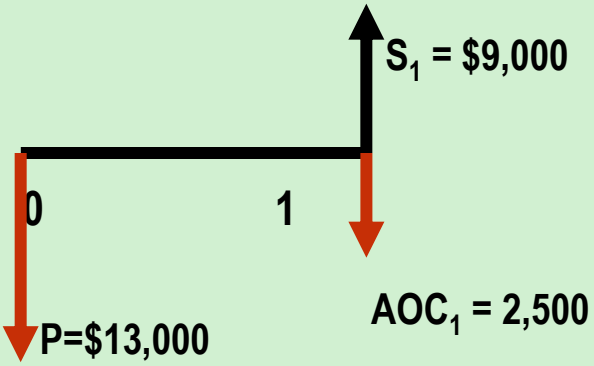
Mkt. Values are decreasing:

AOC's are increasing:

Assume the interest rate is 10% per year.

11.2 Example: Find the ESL

- Period-by-period analysis
- For "k" = 1 year:

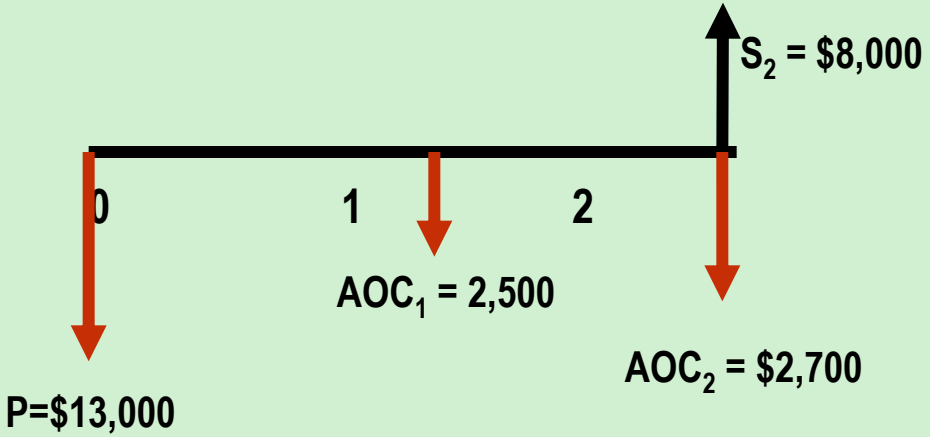


$AW(10\%)_1 = (-13{,}000)(A/P,10\%,1) + 9{,}000 - 2{,}500$

$= \underline{-\$7{,}800}$ (for one year!)

11.2 Example: Find the ESL

- Period-by-period analysis
- For "k" = 2 years:



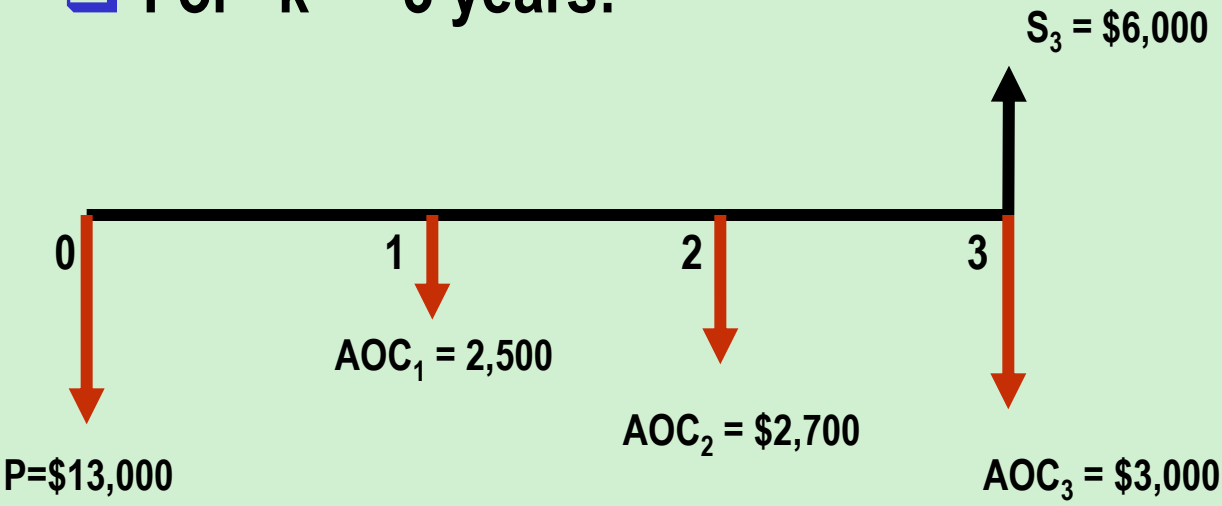
$AW(10\%)_2 = (-13{,}000)(A/P,10\%,2) + 8{,}000(A/F,10\%,2)$

$-[2{,}500(P/F,10\%,1) + 2{,}700(P/F,10\%,2)](A/P,10\%,2)$

= -$6,276/yr for 2 years.

11.2 Example: Find the ESL

- Period-by-period analysis
- For "k" = 3 years:



$AW(10\%)_3 = (-13{,}000)(A/P,10\%,3) + 6{,}000(A/F,10\%,3)$

$-[2500(P/F,10\%,1) + 2{,}700(P/F,10\%,2) + 3{,}000(P/F,10\%,3](A/P,10\%,3) =$

-$6,132/yr for 3 years.

11.2 Example – Continued

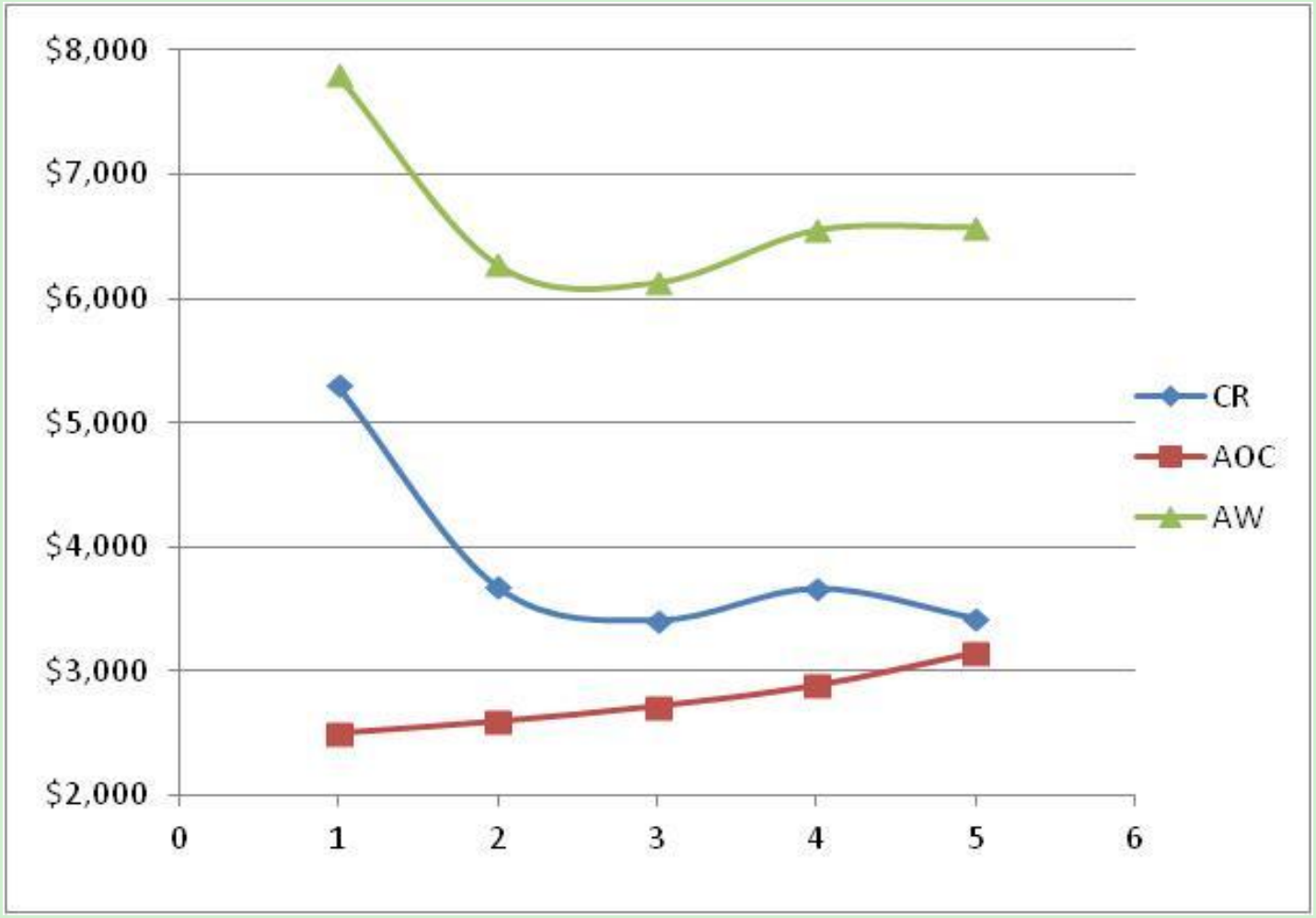
- A similar analysis for k = 4 and 5 is conducted;
- The $AW(10)_k$, K = {1,2,3,4,5} are tabulated as:

	Total AW_k
k=1:	-7,800
k=2:	-6,276
k=3:	-6,132
k=4:	-6,556
k=5:	-6,579

Min. Cost Year = 3 years

1	**Example 11.2 - Finding ESL**					
2						
3	**MV0**	$13,000		MARR	10%	
4						
5	**Year, j**	**MV**	**AOC**	**CR**	**AW(AOC)**	**AW**
6	1	$9,000	-$2,500	-$5,300	-$2,500	-$7,800
7	2	$8,000	-$2,700	-$3,681	-$2,595	-$6,276
8	3	$6,000	-$3,000	-$3,415	-$2,718	-$6,132
9	4	$2,000	-$3,500	-$3,670	-$2,886	-$6,556
10	5	$0	-$4,500	-$3,429	-$3,150	-$6,580
11						
12						
13						
14	**Year, j**	**MV**	**AOC**	**|CR|**	**|AW(AOC)|**	**|AW|**
15	1	$9,000	-$2,500	$5,300	$2,500	$7,800
16	2	$8,000	-$2,700	$3,681	$2,595	$6,276
17	3	$6,000	-$3,000	$3,415	$2,718	$6,132
18	4	$2,000	-$3,500	$3,670	$2,886	$6,556
19	5	$0	-$4,500	$3,429	$3,150	$6,580
20						

Plots for Example 11.2



Economic Service Life=ESL = 3 Years

Example: Economic Service Life

Determine the ESL of an asset which has the costs shown below. Let i = 10%

Year	Cost,$/year	Salvage value,$
0	- 20,000	-
1	-5,000	10,000
2	-6,500	8,000
3	- 9,000	5,000
4	-11,000	5,000
5	-15,000	3,000

Solution:

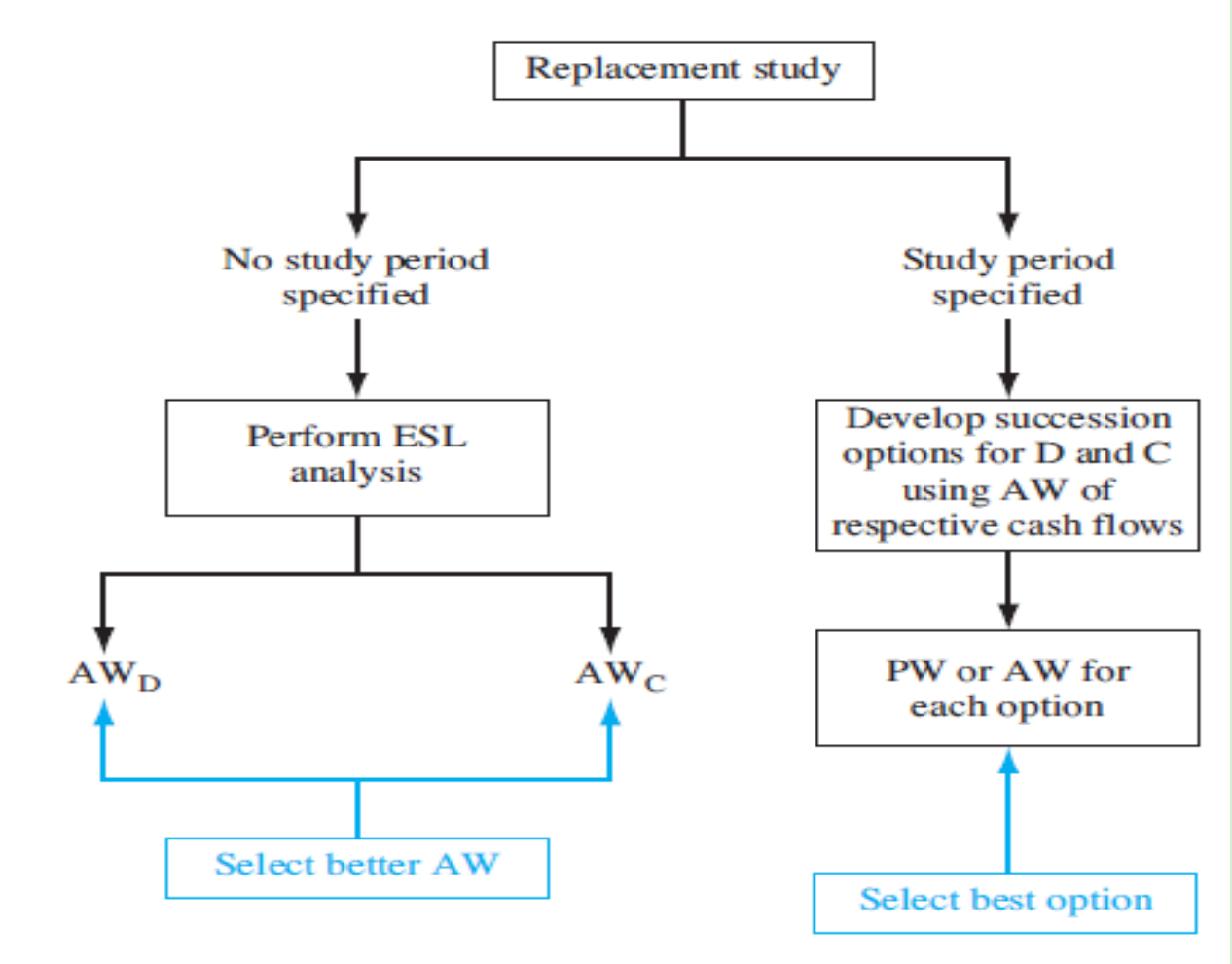
AW_1 = - 20,000(A/P,10%,1) – 5000(P/F,10%,1)(A/P,10%,1) + 10,000(A/F,10%,1) = $ -17,000

AW_2 = - 20,000(A/P,10%,2) – [5000(P/F,10%,1) + 6500(P/F,10%,2)](A/P,10%,2)
+ 8000(A/F,10%,2)
= $ -13,429

Similarly, AW_3 = $ -13,239 AW_4 = $ -12,864 AW_5 = $ -13,623

Economic service life is 4 years

Performing a Replacement Study



Overview of a Replacement Study

- Replacement studies are applications of the AW method
- Study periods (planning horizons) are either specified or unlimited
- Assumptions for unlimited study period:
  1. Services provided for indefinite future
  2. Challenger is best available now and for future, and will be repeated in future life cycles
  3. Cost estimates for each life cycle for defender and challenger remain the same
- If study period is specified, assumptions do not hold
- Replacement study procedures differ for the two cases

Performing a Replacement Study --Unlimited Study Period

The replacement study procedure is:

New replacement study:

1. **Calculate the ESL of defender and challenger. On the basis of the better AW_C or AW_D value, select the challenger C or defender D. When the challenger is selected**, replace the defender now, and expect to keep the challenger for n_C years. This replacement study is complete. **If the defender is selected,** plan to retain it for up to n_D *more years. Next year, perform the* following steps.

One-year-later analysis:

2. **Determine if all estimates are still current for both alternatives, especially first cost, market** value, and AOC. If not, proceed to step 3. If yes and this is year n_D *, replace the defender. If* this is not year n_D *, retain the defender for another year and repeat this same step. This step* may be repeated several times.
3. **Whenever the estimates have changed, update them and determine new AW_C and AW_D values.** Initiate a new replacement study (step 1).

Example 11.4

Two years ago, Toshiba Electronics made a $15 million investment in new assembly line machinery. It purchased approximately 200 units at $70,000 each and placed them in plants in 10 different countries. The equipment sorts, tests, and performs insertion-order kitting on electronic components in preparation for special-purpose circuit boards. This year, new international industry standards will require a $16,000 retrofit on each unit, in addition to the expected operating cost. Due to the new standards, coupled with rapidly changing technology, a new system is challenging the retention of these 2-year-old machines. The chief engineer at Toshiba USA realizes that the economics must be considered, so he has asked that a replacement study be performed this year and each year in the future, if need be. The *i is 10% and the* estimates are below.

Example 11.4

Challenger:

First cost: $50,000

Future market values: decreasing by 20% per year

Estimated retention period: no more than 10 years

AOC estimates: $5000 in year 1 with increases of $2000 per year thereafter

Defender:

Current international market value: $15,000

Future market values: decreasing by 20% per year

Estimated retention period: no more than 3 more years

AOC estimates: $4000 next year, increasing by $4000 per year thereafter, plus the $16,000 retrofit next year

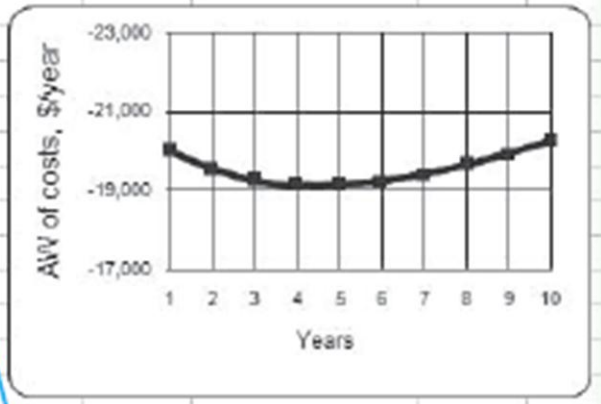
(a)Determine the AW values and economic service lives necessary to perform the replacement study.

(b) Perform the replacement study now.

(c) After 1 year, it is time to perform the follow-up analysis. The challenger is making large inroads to the market for electronic components assembly equipment, especially with the new international standards features built in. The expected market value for the defender is still $12,000 this year, but it is expected to drop to virtually nothing in the future—$2000 next year on the worldwide market and zero after that. Also, this prematurely outdated equipment is more costly to keep serviced, so the estimated AOC next year has been increased from $8000 to $12,000 and to $16,000 two years out. Perform the follow-up replacement study analysis.

ESL Analysis of Challenger

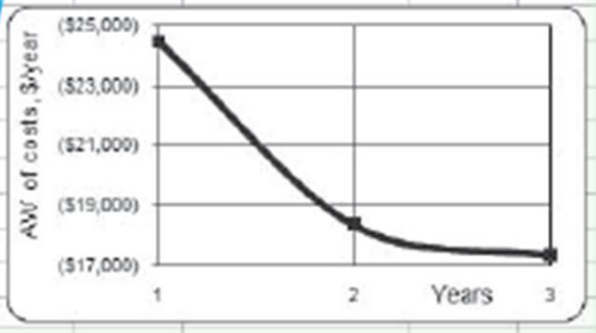
Interest rate	10%				
First cost	$ 50,000				
	Market				Total AW
Year	Value	AOC	Capital Recovery	AW of AOC	of costs
1	40,000	-5,000	-15,000	-5,000	-20,000
2	32,000	-7,000	-13,571	-5,952	-19,524
3	25,600	-9,000	-12,372	-6,873	-19,245
4	20,480	-11,000	-11,361	-7,762	-19,123
5	16,384	-13,000	-10,506	-8,620	-19,126
6	13,107	-15,000	-9,782	-9,447	-19,229
7	10,486	-17,000	-9,165	-10,243	-19,408
8	8,389	-19,000	-8,639	-11,009	-19,648
9	6,711	-21,000	-8,188	-11,745	-19,933
10	5,369	-23,000	-7,800	-12,451	-20,251
Formulas, year 10	'= B13*0.8	'= $C13-2000	'= PMT($B$1, $A14,NPV($B$1,$C$5:$C 14)+0)	'= -PMT($B$1, $A14,NPV($B$1,$C$5:$C 14)+0)	'= E14+D14



ESL results

ESL Analysis of Defender

Interest rate	10%				
Market value	$ 15,000				
	Market				Total AW
Year	Value	AOC	Capital Recovery	AW of AOC	of costs
1	12,000	-20,000	-4,500	-20,000	-24,500
2	9,600	-8,000	-4,071	-14,286	-18,357
3	7,680	-12,000	-3,711	-13,595	-17,307



The lowest AW cost (numerically largest) values for the replacement study are as follows:

Challenger: AW_C -$19,123 for n_C =*4 years*

Defender: AW_D -$17,307 for n_D =*3 years*

To perform the replacement study now, apply only the first step of the procedure. Select the defender because it has the better AW of costs ($17,307), and expect to retain it for 3 more years. Prepare to perform the one-year-later analysis 1 year from now.

One year later, the situation has changed significantly for the equipment Toshiba retained last year. Apply the steps for the one-year-later analysis:

After 1 year of defender retention, the challenger estimates are still reasonable, but the defender market value and AOC estimates are substantially different. Go to step 3 to perform a new ESL analysis for the defender.

Year k	Market Value, $	AOC, $	Total AW If Retained k More Years, $
0	12,000	—	—
1	2,000	−12,000	−23,200
2	0	−16,000	−20,819

The AW and *n values for the new replacement study are as follows:*

Challenger: unchanged at AW_C=-$19,123 for n_C =*4 years*
Defender: new AW_D=-$20,819 for n_D=*2 more years*

Now select the challenger based on its favorable AW value. Therefore, replace the defender now, not 2 years from now. Expect to keep the challenger for 4 years, or until a better challenger appears on the scene.

Example: Replacement Analysis

An asset purchased 2 years ago for $40,000 is harder to maintain than expected. It can be sold now for $12,000 or kept for a maximum of 2 more years, in which case its operating cost will be $20,000 each year, with a salvage value of $10,000 after 1 year or $9000 after two years. A suitable challenger will have an annual worth of $-24,000 per year for ESL of 5 years. At an interest rate of 10% per year, should the defender be replaced now, one year from now, or two years from now?

Solution: First, determine ESL for defender

$AW_{D1} = -12{,}000(A/P,10\%,1) - 20{,}000 + 10{,}000(A/F,10\%,1) = \$-23{,}200$

$AW_{D2} = -12{,}000(A/P,10\%,2) - 20{,}000 + 9{,}000(A/F,10\%,2) = \$-22{,}629$

ESL is n = 2 years; $AW_D = \$-22{,}629$

$AW_C = \$-24{,}000$, ESL is n = 5 years

Lower AW = $-22,629 Replace defender in 2 years

Note: *conduct one-year-later analysis next year*

Replacement Analysis Over Specified Study Period

Same procedure as before, except *calculate AW values over study period* instead of over ESL years of n_D and n_C

- **It is necessary to develop *all viable defender-challenger combinations* and calculate AW or PW for each one *over study period***

- **Select option with lowest cost or highest income**

Example: Replacement Analysis; Specified Period

An asset purchased 2 years ago for $40,000 is harder to maintain than expected. It can be sold now for $12,000 or kept for a maximum of 2 more years, in which case its operating cost will be $20,000 each year, with a salvage value of $10,000 after 1 year or $9000 after two. A suitable challenger will have an annual worth of $-24,000 per year for ESL of 5 years. At an interest rate of 10% per year and over a study period of exactly 3 years, determine when the defender should be replaced.

Solution: From previous analysis, AW_D for 1 and 2 years, and AW_C are:

AW_{D1} = $-23,200 AW_{D2} = $-22,629 AW_C = $-24,000

Option	Year 1, $	Year 2, $	Year 3, $	AW, $
1 (C, C, C)	-24,000	-24,000	-24,000	-24,000
2 (D, C, C)	-23,200	-24,000	-24,000	-23,708
3 (D, D, C)	-22,629	-22,629	-24,000	-23,042

Decision: Option 3; **Keep D for 2 years**, then replace

Replacement Value

***Replacement value* (RV) is market/trade-in value of defender that renders AW_D and AW_C equal to each other**

Set up equation **$AW_D = AW_C$** except **use RV in place of P** for the defender; **then solve for RV**

If defender can be sold for amount > RV, *challenger is the better option,* because it will have a lower AW value

Example: Replacement Value

An asset purchased 2 years ago for $40,000 is harder to maintain than expected. It can be sold now for $12,000 or kept for a maximum of 2 more years, in which case its operating cost will be $20,000 each year, with a salvage value of $10,000 at the end of year two. A suitable challenger will have an initial cost of $65,000, an annual cost of $15,000, and a salvage value of $18,000 after its 5 year life. Determine the RV of the defender that will render its AW equal to that of the challenger, using an interest rate of 10% per year. Recommend a course of action.

Solution: Set $AW_D = AW_C$

$$- RV(A/P,10\%,2) - 20{,}000 + 10{,}000(A/F,10\%,2) = - 65{,}000(A/P,10\%,5) - 15{,}000 + 18{,}000(A/F,10\%,5)$$

RV = $24,228

Market value of defender < $24,228, *select Defender*

Summary of Important Points

- In replacement study, **P** for presently-owned asset is its ***market value***
- **Economic service life** is the n value that yields lowest AW
- In replacement study, if **no study period** is specified, *calculate AW over the respective life of each alternative*
- When study period is specified, *must consider all viable defender-challenger combinations* in analysis
- **Replacement value (RV)** is *P value for defender that renders its AW equal to that of challenger*