13

Lecture 21
Replacement Analysis

The $7 Billion Upgrade

The $7 Billion Upgrade, cont'd

- In 2009 Intel Corporation announced it was spending $7 billion in 2009 and 2010 to modernize and update its silicon-wafer manufacturing plants in the US.
- The upgrade will allow Intel to manufacture 32-nanometre (nm) chips in fabs originally built for 45-nm and 65-nm chips. Upgrade work will include re-modelling the plant's interior and purchasing new wafer fabrication tools.

The $7 Billion Upgrade, cont'd

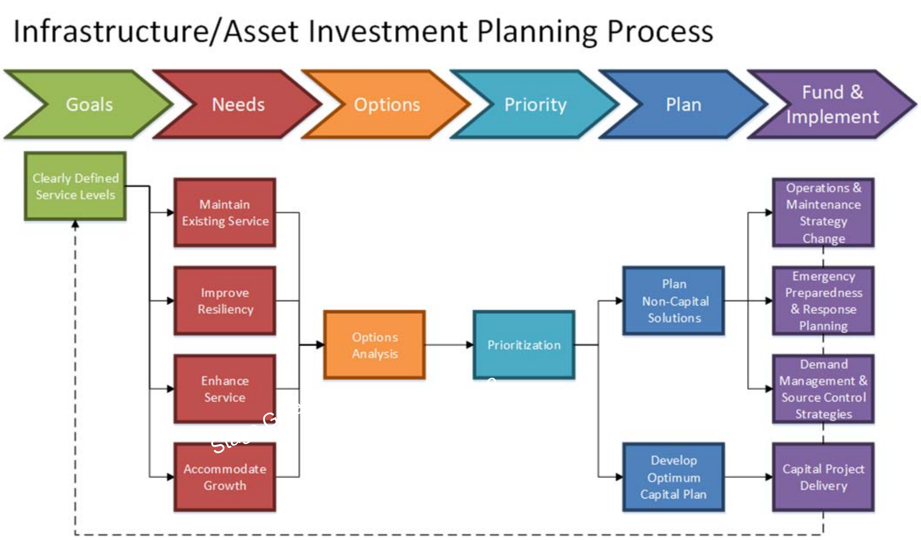
- Despite the price tag for the project, Intel planned on saving money overall by upgrading the existing plants instead of designing and building a new one.
- The company also noted that by deciding to remain in its current locations, it was able to retain its highly skilled workforce.

Learning Objectives

- Recast an equipment reinvestment decision as a *challenger-versus-defender* analysis
- Choose the correct economic analysis technique to apply
- Calculate the *minimum-cost life* of economic challengers
- Use criteria such as *repeatability assumption for replacement analysis* and *marginal cost data for the defender* to choose the appropriate economic analysis techniques
- Perform replacement problems on an after-tax basis

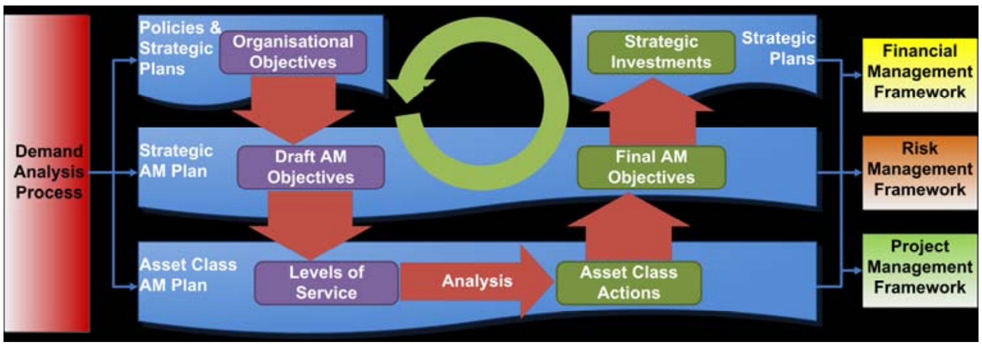
Context

- CH 13 decision making structures are part of Asset Management
- Asset Management Planning is connected to broader capital plans



Context

- AMP process outline



Reasons for Asset Replacement Consideration

- Obsolescence

  Technology of an asset is surpassed by newer or different technologies

- Deterioration due to aging

  Loss of functionality or efficiency due to the aging process

- Depletion

  Loss of market value due to consumption or exhaustion of resource

Replacement Analysis Flow Chart

- Often the question is not 'if' but 'when' an asset should be replaced.

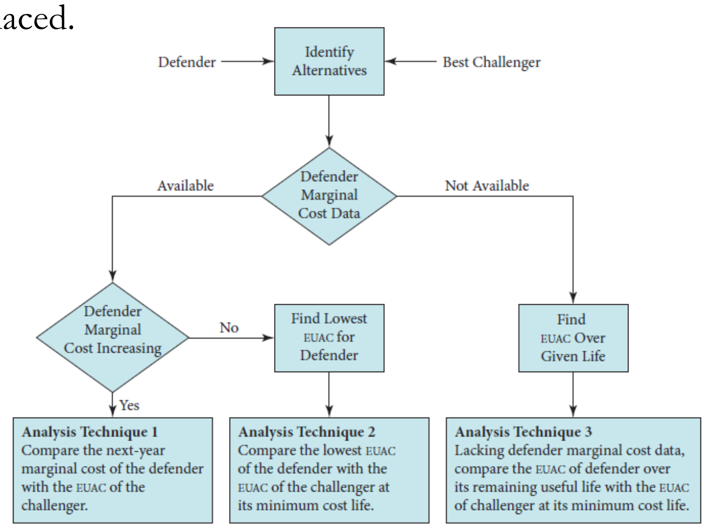


FIGURE 13-1 Replacement analysis flow chart.

Replacement Analysis Flow Chart, cont'd

- Analysis is based on the "most economical alternative" over its respective life.
- Steps 1 and 2 in all cases: Identify alternatives, and gather cost data (if available).
  - If the "defender" (the existing asset) proves more economical, it will be kept. If the "challenger" (a possible replacement) proves more economical, it will be installed.

Data to gather: Minimum-Cost Life of a New Asset (The "Challenger")

- Minimum cost life of an asset is the number of years where the equivalent uniform annual cost (EUAC) is minimized.
  - Must calculate EUAC for each year

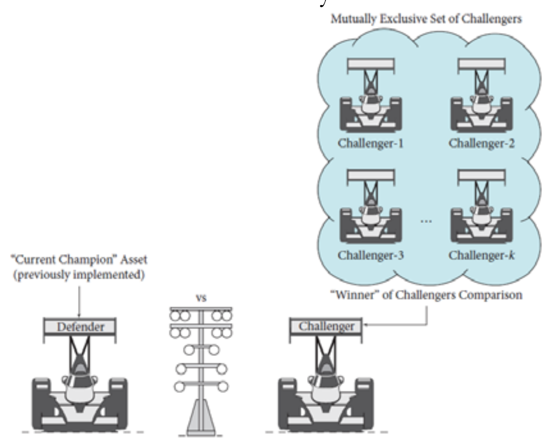


FIGURE 13-2 Defender–challenger comparison.

Data to gather: Minimum-Cost Life of a New Asset (The "Challenger") continued

EXAMPLE 13-1

A piece of machinery costs $7,500 and has no salvage value after it is installed. The manufacturer's warranty will pay the first year's maintenance and repair costs. In the second year, maintenance costs will be $900, and they will increase on a $900 arithmetic gradient in subsequent years. Also, operating expenses for the machinery will be $500 the first year and will increase on a $400 arithmetic gradient in the following years. If interest is 8%, compute the useful life of the machinery that minimizes the EUAC.

SOLUTION

	If Retired at the End of Year n			
Year, n	EUAC of Capital Recovery Costs: $7,500 ($A/P$, 8%, n)	EUAC of Maintenance and Repair Costs: $900 ($A/G$, 8%, n)	EUAC of Operating Costs: (A/G, 8%, n)	EUAC Total
1	$8,100	$ 0	$ 500	$8,600
2	4,206	433	692	5,331
3	2,910	854	880	4,644
4	2,264	1,264	1,062	4,589←
5	1,878	1,661	1,238	4,779
6	1,622	2,048	1,410	5,081
7	1,440	2,425	1,578	5,443
8	1,305	2,789	1,740	5,834
9	1,200	3,142	1,896	6,239
10	1,117	3,484	2,048	6,650
11	1,050	3,816	2,196	7,063
12	995	4,136	2,338	7,470
13	948	4,446	2,476	7,871
14	909	4,746	2,609	8,265
15	876	5,035	2,738	8,648

The total EUAC data are plotted in Figure 13-3. We see that the minimum-cost life of the machinery is four years, with a minimum EUAC of $4,589.

Switch to Excel to unpack this

Data to gather: Minimum-Cost Life of a New Asset (The "Challenger") continued

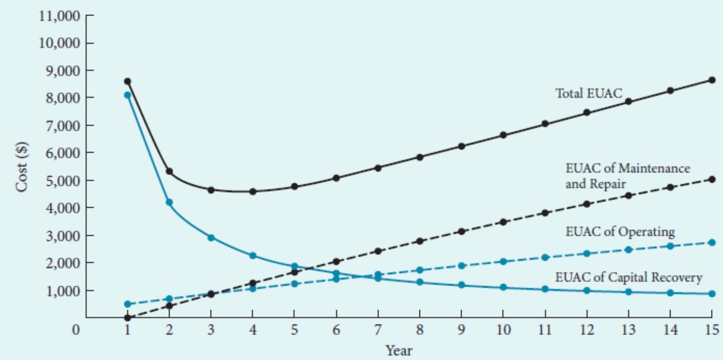


FIGURE 13-3 Plot of costs for Example 13-1.

Data to Gather: Defender's Marginal Cost Data

EXAMPLE 13-3

An asset purchased five years ago for $75,000 can be sold today for $15,000. Operating expenses will be $10,000 this year but will increase by $1,500 per year. It is estimated that the asset's market value will decrease by $1,000 per year over the next five years. If the MARR used by the company is 15%, calculate the total marginal cost of ownership of this old asset (that is, the defender) for each of the next five years.

- Switch to Excel

Defender's Marginal Cost Data, cont'd

EXAMPLE 13-3

An asset purchased five years ago for $75,000 can be sold today for $15,000. Operating expenses will be $10,000 this year but will increase by $1,500 per year. It is estimated that the asset's market value will decrease by $1,000 per year over the next five years. If the MARR used by the company is 15%, calculate the total marginal cost of ownership of this old asset (that is, the defender) for each of the next five years.

SOLUTION

We calculate the total marginal cost of maintaining the old asset for the next five-year period as follows:

Year, n	Loss in Market Value in Year n	Interest in Year n	Operating Cost in Year n	Marginal Cost in Year n
1	$15,000 − 14,000 = 1,000	$15,000 (0.15) = 2,250	$10,000	$13,250
2	14,000 − 13,000 = 1,000	14,000 (0.15) = 2,100	11,500	14,600
3	13,000 − 12,000 = 1,000	13,000 (0.15) = 1,950	13,000	15,950
4	12,000 − 11,000 = 1,000	12,000 (0.15) = 1,800	14,500	17,300
5	11,000 − 10,000 = 1,000	11,000 (0.15) = 1,650	16,000	18,650

- In this case, we have marginal cost data, and it is increasing.

Three Possible Analysis Techniques ("Cases")

- Two questions (seen on decision map):
  - Do we have marginal cost data for the defender?
  - Are the defender's marginal costs increasing from year-to-year?

- If the answers are 'yes' and 'yes', then Case 1 rules apply.
- If the answers are 'yes' and 'no', then Case 2 rules apply.
- If the first answer is 'no', then Case 3 rules apply.

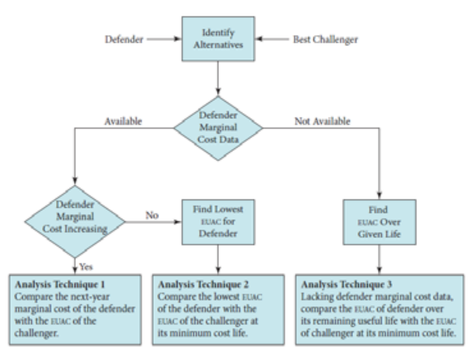


FIGURE 13-1 Replacement analysis flow chart.

Case 1: Defender Marginal Costs Can be Computed and Are Increasing

(These conditions were met in Example 13-3.)

In this case, the following technique applies:

- Keep existing asset ("defender") as long as the marginal cost of ownership for one more year is less than the minimum EUAC of the recommended replacement ("challenger").
- When the marginal cost of the defender becomes greater than the minimum EUAC of the challenger, then replace the defender with the challenger.

Case 1: Defender Marginal Costs Can be Computed and Are Increasing (cont)

EXAMPLE 13-4

Taking the machinery in Example 13-2 as the *challenger* and the machinery in Example 13-3 as the *defender*, use *replacement analysis technique 1* to determine when, if at all, a replacement decision should be made.

Example 13-2:
A new piece of production machinery has the following costs:
Investment cost = $25,000
Annual operating and maintenance cost = $2,000 in year 1, then increasing by $500 per year
Annual cost for risk of breakdown = $5,000 per year for 3 years, then increasing by $1,500 per year
Useful life = 7 years
MARR = 15%

Example 13-2:
Estimates of each year's market value are:

Year	Market Value
1	$18,000
2	$13,000
3	$9,000
4	$6,000
5	$4,000
6	$3,000
7	$2,500

Example 13-3:
An asset purchased five years ago for $75,000 can be sold today for $15,000. Operating expenses will be $10,000 this year but will increase by $1,500 per year. It is estimated that the asset's market value will decrease by $1,000 per year over the next five years. … the MARR used by the company is 15%…

- Switch to Excel

Case 1: Defender Marginal Costs Can be Computed and Are Increasing (cont)

EXAMPLE 13-4

Taking the machinery in Example 13-2 as the *challenger* and the machinery in Example 13-3 as the *defender*, use *replacement analysis technique 1* to determine when, if at all, a replacement decision should be made.

SOLUTION

Replacement analysis technique 1 should be used only in the condition of increasing marginal costs for the defender. Since these marginal costs *are* increasing for the defender (from Example 13-3), we can compare the marginal costs of the defender against the minimum EUAC of the challenger. In Example 13-2 we calculated only the marginal costs of the challenger; now it is necessary to calculate the challenger's minimum EUAC. The EUAC of keeping this asset for each year of its useful life is worked out as follows.

Year, n	Challenger Total Marginal Cost in Year n	Present Cost If Kept through Year n (PC_n)	EUAC If Kept through Year n
1	\$17,750	[17,750(P/F, 15%, 1)]	× (A/P, 15%, 1) = \$17,750
2	15,200	PC_1 + 15,200(P/F, 15%, 2)	× (A/P, 15%, 2) = 16,560
3	13,950	PC_2 + 13,950(P/F, 15%, 3)	× (A/P, 15%, 3) = 15,810
4	14,350	PC_3 + 14,350(P/F, 15%, 4)	× (A/P, 15%, 4) = 15,520
5	14,900	PC_4 + 14,900(P/F, 15%, 5)	× (A/P, 15%, 5) = 15,430
6	15,600	PC_5 + 15,600(P/F, 15%, 6)	× (A/P, 15%, 6) = 15,450
7	16,950	PC_6 + 16,950(P/F, 15%, 7)	× (A/P, 15%, 7) = 15,580

A minimum EUAC of \$15,430 is attained for the challenger at Year 5, which is the challenger's *minimum-cost life*. We proceed by comparing this value with the *marginal* costs of the defender from Example 13-3:

Year, n	Defender Total Marginal Cost in Year n	Challenger Minimum EUAC	Comparison Result and Recommendation
1	\$13,250	\$15,430	Since \$13,250 is *less than* \$15,430, keep defender.
2	14,600	15,430	Since \$14,600 is *less than* \$15,430, keep defender.
3	15,950	15,430	Since \$15,950 is *greater than* \$15,430, replace defender.
4	17,300		
5	18,650		

On the basis of the data given for the challenger and for the defender, we would keep the defender for two more years and then replace it with the challenger because at that point the defender's marginal cost of another year of ownership would be greater than the challenger's minimum EUAC.

Case 1: Replacement Repeatability Assumptions

- Analysis method 1 works, under two assumptions:
  - The currently available best challenger will continue to be available in subsequent years and will be unchanged in economic costs. When the defender is ultimately replaced it will be replaced with this challenger. Any challengers put into service will also be replaced with the same currently available challenger.
  - The period of needed service of the asset is Indefinitely long

    Thus the challenger asset once put into service, will continuously replace itself in repeating, unchanged cycles.
- Realistically: _________

Realistically, challengers in the future usually will have improved features. For this reason, the calculations are not exact but the assumptions allow us to make the best decisions with the data we have

What if Replacement Repeatability Assumption Isn't Valid?

- The repeatability assumption may not always be applicable: Future challengers may prove to be better alternatives.

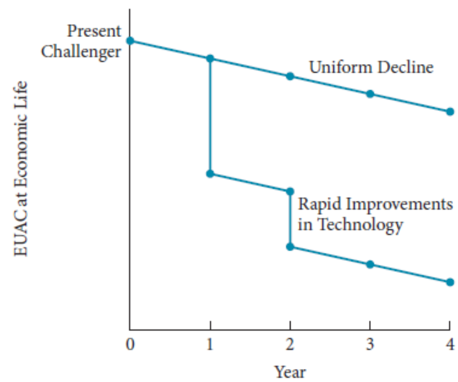
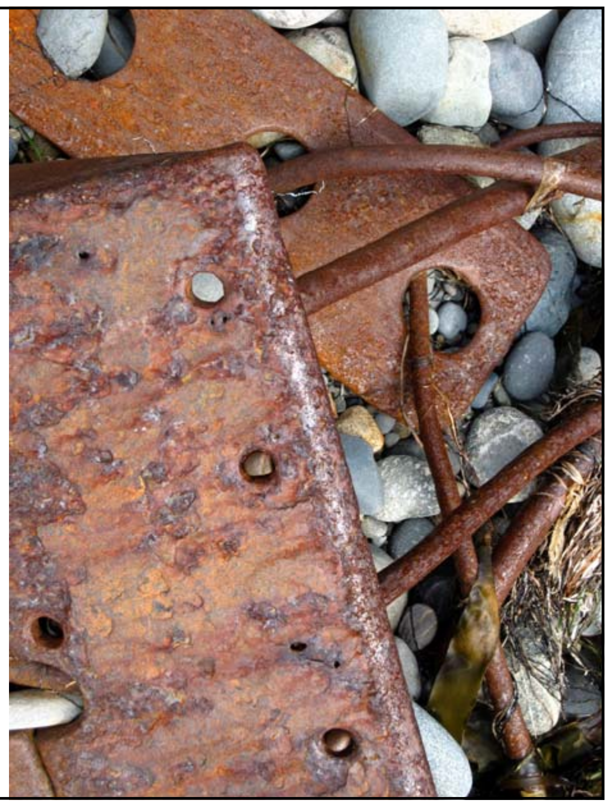


FIGURE 13-5 Two possible ways the euac of future challengers may decline.

Potential break point



Case 2: Defender Marginal Costs Can Be Computed and Are Not Increasing

- When the defender's marginal cost is NOT increasing:
  - Check the defender's minimum EUAC to see whether the replacement should occur immediately.
  - Otherwise, the replacement will occur when the marginal cost is increasing - replace when the defender's increasing marginal cost exceeds the challenger's minimum EUAC.

Case 2: Defender Marginal Costs Can Be Computed and Are Not Increasing (cont)

EXAMPLE 13-5

Let us look again at the defender and challenger assets in Example 13-4. This time let us arbitrarily change the defender's marginal costs for its five-year useful life. Now when, if at all, should the defender be replaced with the challenger?

Year, *n*	Defender Total Marginal Cost in Year *n*
1	$16,000
2	14,000
3	13,500
4	15,300
5	17,500

- Switch to Excel

Case 2: Defender Marginal Costs Can Be Computed and Are Not Increasing (cont)

EXAMPLE 13-5

Let us look again at the defender and challenger assets in Example 13-4. This time let us arbitrarily change the defender's marginal costs for its five-year useful life. Now when, if at all, should the defender be replaced with the challenger?

Year, n	Defender Total Marginal Cost in Year n
1	\$16,000
2	14,000
3	13,500
4	15,300
5	17,500

SOLUTION

In this case the total marginal costs of the defender are *not* consistently increasing from year to year. However, if we ignore this fact and apply *replacement analysis technique 1*, the recommendation would be to replace the defender now, because the defender's marginal cost for the first year (\$16,000) is greater than the minimum EUAC of the challenger (\$15,430). This would be the wrong choice.

Since the defender's marginal cost is greater than the challenger's minimum EUAC in the second to fourth years, we must calculate the EUAC of keeping the defender asset each of its remaining five years when $i = 15\%$.

Year, n	Present Cost If Kept n Years (PC_n)	EUAC If Kept n Years
1	16,000 $(P/F, 15\%, 1)$	$\times (A/P, 15\%, 1) =$ \$16,000
2	PC_1 + 14,000 $(P/F, 15\%, 2)$	$\times (A/P, 15\%, 2) =$ 15,070
3	PC_2 + 13,500 $(P/F, 15\%, 3)$	$\times (A/P, 15\%, 3) =$ 14,618
4	PC_3 + 15,300 $(P/F, 15\%, 4)$	$\times (A/P, 15\%, 4) =$ 14,754
5	PC_4 + 17,500 $(P/F, 15\%, 5)$	$\times (A/P, 15\%, 5) =$ 15,162

Case 2: Defender Marginal Costs Can Be Computed and Are Not Increasing (cont)

Criteria summary:

- If defender MC aren't rising, must calculate defender minimum EUAC
  - If defender minimum EUAC < challenger minimum EUAC, keep defender until the year of the defender's minimum EUAC
- Once defender MC starts rising, can switch to case/method 1: compare defender MC with challenger minimum EUAC
  - Keep defender as long as defender MC < challenger minimum EUAC
  - Switch to challenger when defender MC > challenger minimum EUAC

Case 3: Defender Marginal Cost Data Not Available

- In this case, methods 1 and 2 can't be applied.
- Simply compare the defender's EUAC over a stated useful life to the challenger's minimum EUAC, and choose the option with the lower EUAC.

Example 13-8 covers this situation:

- Equipment purchased 2 years ago for $1,600
- Straight-line depreciation, four year life, no salvage value.
- Current market value $200.
- Current price of a new unit (older model): $995
- Option to trade in with $350 credit on a $1,200 purchase of a newer model (net $850 cost).
- Without a credit, cost of newer model is $1,050.

What costs and values are needed for replacement analysis?
If interest rate is 10%, should you keep or replace the old equipment?

<turn to Excel>

Potential break point

Complications in Replacement Analysis

- We use EUAC for such analyses because the expected lives of the different asset options aren't the same.
- The salvage value of replacing a defender may affect the conclusion if not handled correctly.

- Opportunity Cost Perspective
  - Only the market salvage value of the defending asset matters. Book estimates, original cost, and "trade in value" are unhelpful or distort true costs
- Potential analysis error: subtract defender salvage value from the cost of the challenger
  - This assumes a simple cash flow perspective on the problem.
  - Subtracting the salvage value of the defender from the challenger's capital cost often yields incorrect results because the remaining life of the defender usually differs from the life of the challenger.

Replacement Analysis: Problem 1

For a study period of 10 years, perform a replacement analysis on the following two alternatives at an interest rate (discount rate) of 11% per year

	Current ($)	**Proposed ($)**
Purchase Price	100,000	50,000
Current Value	30,000	———
Estimated Value in 10 Years	2000	12,000
Operating Costs/Year	6000	2000

Replacement Analysis: Problem 1 Solution

Determine EUAW over the 10-year study period

Option 1: Keep existing.

$EUAW_{current} = 2000(A/F, 11\%, 10) - 6{,}000$

$= 2000(0.05980) - 6000$

$= -\$5{,}880$

Option 2: Sell existing, buy new.

$EUAW_{proposed}$

$= +30{,}000(A/P, 11\%, 10) - 50{,}000(A/P, 11\%, 10) + 12{,}000(A/F, 11\%, 10) - 2000$

$= +30{,}000(0.1698) - 50{,}000(0.16980) + 12{,}000(0.05980) - 2000$

$= -\$4{,}678$

EUAW proposed < EUAW existing: Replace the equipment.

Replacement Analysis: Problem 2

A door-to-door salesperson wants to know how often to purchase a new pair of shoes, which cost \$50.00.

- After three months, new heels are required at a cost of \$2.50 per shoe
- After six months, new heels (@ \$2.50 per shoe) and half-soles (\$10 per shoe) are needed
- After nine months, new heels (@ \$2.50 per shoe) and full soles (\$22.50 per shoe) are necessary
- After one year the shoes are no longer repairable and must be replaced. Of course, the shoes can be replaced prior to that time.

The same type of shoes will be purchased in the future. Assume MARR is a nominal annual rate of 6% compounded quarterly. How often should the shoes be replaced?

Replacement Analysis: Problem 2, cont'd

Solution

N	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
0	−$50.00	−50.00	−50.00	−50.00
1		−5.00	−5.00	−5.00
2			−20.00	−20.00
3				−45.00
EUCF (per quarter)	−50.75	−28.05	**−25.38**	−30.08

The shoes should be replaced at the end of each three-quarters of a year.

<detailed analysis available in Excel>

After-Tax Replacement Analysis

- The effect of after-tax analysis can also affect replacement decisions.
- Most depreciation methods reduce after-tax cost by larger amounts early in the asset's life, and by smaller amounts later.

After-Tax Replacement Analysis, cont'd

EXAMPLE 13-9

Refer to Example 13-2, where we calculated the before-tax marginal costs for a new piece of production machinery. Calculate the after-tax marginal costs of the asset considering this additional information:

- Depreciation is by the straight-line method, $S = \$0$, and $n = 5$ years, so $d_t = (\$25{,}000 - \$0)/5 = \$5{,}000$.
- Ordinary income, recaptured depreciation, and losses on sales are taxed at a rate of 40%.
- The after-tax MARR is 10%.

Since some classes may have skipped the explanation of expected value in Chapter 8 or not yet covered it, the expected cost for risk of breakdowns is described here as an insurance cost.

Example 13-2:	Example 13-2:
A new piece of production machinery has the following costs: Investment cost = \$25,000 Annual operating and maintenance cost = \$2,000 in year 1, then increasing by \$500 per year Annual cost for risk of breakdown = \$5,000 per year for 3 years, then increasing by \$1,500 per year Useful life = 7 years MARR = 15%	Estimates of each year's market value are: Year Market Value 1 \$18,000 2 \$13,000 3 \$9,000 4 \$6,000 5 \$4,000 6 \$3,000 7 \$2,500

- Switch to Excel

After-Tax Replacement Analysis, cont'd

EXAMPLE 13-9

Refer to Example 13-2, where we calculated the before-tax marginal costs for a new piece of production machinery. Calculate the after-tax marginal costs of the asset considering this additional information:

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- The after-tax MARR is 10%.

Since some classes may have skipped the explanation of expected value in Chapter 8 or not yet covered it, the expected cost for risk of breakdowns is described here as an insurance cost.

Solution observations:
- MC is at minimum in same year
- EUAC is at minimum in same year

Broader implications of After-Tax Analysis:
- Depreciation methods alter the shape of the EUAC curve and shift the EUAC minimum point, which can affect decisions.
- If the challenger had different tax implications of depreciation, it could alter the recommendation of whether to keep or replace.

- <Book solution, for your reference>

After-Tax Replacement Analysis, cont'd

EXAMPLE 13-9

Refer to Example 13-2, where we calculated the before-tax marginal costs for a new piece of production machinery. Calculate the after-tax marginal costs of the asset considering this additional information:

- Depreciation is by the straight-line method, $S = \$0$, and $n = 5$ years, so $d_t = (\$25{,}000 - \$0)/5 = \$5{,}000$.
- Ordinary income, recaptured depreciation, and losses on sales are taxed at a rate of 40%.
- The after-tax MARR is 10%.

Since some classes may have skipped the explanation of expected value in Chapter 8 or not yet covered it, the expected cost for risk of breakdowns is described here as an insurance cost.

SOLUTION

The after-tax marginal cost of ownership will involve the following elements: incurred or forgone loss or recaptured depreciation, interest on invested capital, tax savings due to depreciation, and annual after-tax operating/maintenance and insurance. Figure 13-6 shows examples of cash flows for the marginal cost detailed in Table 13-1.

As a refresher of the recaptured depreciation calculations in Chapter 12,

The market value in Year 0 = 25,000.

The market value decreases to $18,000 at Year 1.

The book value at Year 1 = 25,000 − 5,000 = $20,000.

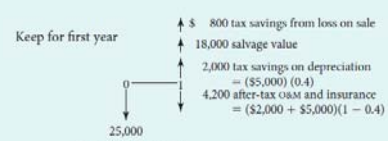
So loss on depreciation = 20,000 − 18,000 = $2,000.

This results in a tax savings of (2,000)(0.4) = $800.

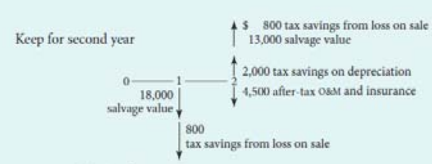
- <Book solution, for your reference>

After-Tax Replacement Analysis, cont'd

The marginal cost in each year is much lower after taxes than the pre-tax numbers shown in Example 13-2. That is because depreciation and expenses can be subtracted from taxable income. However, the pattern of declining and then increasing marginal costs is the same, and Year 3 is still the year of lowest marginal costs.



$$\text{Marginal cost} = F_{\text{end-of-year}} = 25{,}000\,(1 + 0.1) + 4{,}200 - 800 - 18{,}000 - 2{,}000 = \$10{,}900$$



$$\text{Marginal cost} = F_{\text{end-of-year}} = 18{,}800\,(1.1) + 4{,}500 - 800 - 13{,}000 - 2{,}000 = \$9{,}380$$

FIGURE 13-6 Cash flow diagrams and calculations for marginal cost.

- <Book solution, for your reference>

After-Tax Replacement Analysis, cont'd

Table 13.1 Marginal Costs of Ownership

Year	Market Value	Book Value	Recaptured Depreciation or Loss	Taxes or Tax Savings	After-tax Market Value
0	$25,000	$25,000			$25,000
1	18,000	20,000	−$2,000	−$ 800	18,800
2	13,000	15,000	−2,000	−800	13,800
3	9,000	10,000	−1,000	−400	9,400
4	6,000	5,000	1,000	400	5,600
5	4,000	0	4,000	1,600	2,400
6	3,000		3,000	1,200	1,800
7	2,500		2,500	1,000	1,500

Year	Col. B After-tax Market Value	Col. C Start of Year Value × (1 + i)	Col. D Tax Savings from Depreciation Deduction	O&M and Insurance Cost	Col. F After-tax Annual Expense	= C + D + F − B Marginal Cost
0	$25,000					
1	18,800	$27,500	−$2,000	$ 7,000	$4,200	$10,900
2	13,800	20,680	−2,000	7,500	4,500	9,380
3	9,400	15,180	−2,000	8,000	4,800	8,580
4	5,600	10,340	−2,000	10,000	6,000	8,740
5	2,400	6,160	−2,000	12,000	7,200	8,960
6	1,800	2,640	0	14,000	8,400	9,240
7	1,500	1,980	0	16,000	9,600	10,080

- <I believe Col. D in the book is wrong, and there are two other errors. See Excel example.>

- "Spreadsheets are very useful"

Spreadsheet and Replacement Analysis

	A	B	C	D	E	F
1		Table 13-2	Table 13-3	6% Interest Rate		
2		O&M & Depr.				
3	Year	ATCF	ATCF	PW	EUAC	
4	0			−100,000		
5	1	0	64,000	−39,623	42,000	=PMT(D1,A5,D5)
6	2	1,800	50,800	−53,186	29,010	
7	3	−3,660	40,660	−67,332	25,190	
8	4	−8,202	32,662	−82,096	23,692	
9	5	−12,101	26,163	−97,460	23,137	optimal life
10	6	−15,551	20,714	−115,049	23,397	
11	7	−18,686	16,000	−136,553	24,461	
12	8	−21,600	11,800	−155,103	24,977	
13	9	−24,360	7,960	−171,546	25,221	
14	10	−27,012	4,372	−186,476	25,336	=PMT(D1,A14,D14)
15						
16			=NPV(D1,B5:B14)+D4+PV(D1,A14,0,−C14)			
17			=NPV(i, B column) + year 0 + present value of a future salvage			

FIGURE 13-7 Spreadsheet for life with minimum after-tax cost.