Chapter 10

Replacement Analysis

10-1
One of the four ovens at a bakery is being considered for replacement. Its salvage value and maintenance costs are given in the table below for several years. A new oven costs $80,000 and this price includes a complete guarantee of the maintenance costs for the first two years, and it covers a good proportion of the maintenance costs for years 3 and 4. The salvage value and maintenance costs are also summarized in the table.

	Old Oven		New Oven	
Year	Salvage Value at End of Year	Maintenance Costs	Salvage Value at End of Year	Maintenance Costs
0	$20,000	$ -	$80,000	$ -
1	17,000	9,500	75,000	0
2	14,000	9,600	70,000	0
3	11,000	9,700	66,000	1,000
4	7,000	9,800	62,000	3,000

Both the old and new ovens have similar productivities and energy costs. Should the oven be replaced this year, if the MARR equals 10%?

Solution

The old oven ("defender")

Year	S Value at EOP	EAC Capital Recovery (P-S) × (A/P, 10%, n) + Si	Main. Costs	EAC Maintenance 9,500 + 100(A/G, 10%, n)	EAC Total
0	P = 20,000	-	-	-	-
1	17,000	5,000.00	9,500	9,500.00	14,500.00
2	14,000	4,857.20	9,600	9,547.60	14,404.80
3	11,000	4,718.90	9,700	9,593.70	14,312.60*
4	7,000	4,801.50	9,800	9,638.10	14,439.60

*Economic life = 3 years, with EAC = $14,312.60

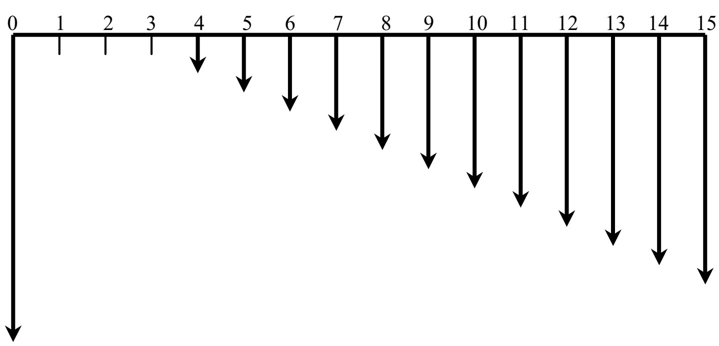
The new oven ("challenger")

Year	S Value at EOP	EAC Capital Recovery (P-S) × (A/P, 10%, n) + Si	Main. Costs	EAC Maintenance 9,500 + 100(A/G, 10%, n)	EAC Total
0	P = 80,000	-	-	-	-
1	75,000	13,000.00	0	0	13,000.00
2	70,000	12,762.00	0	0	12,762.00
3	66,000	12,229.40	1,000	302.10[a]	12,531.50*
4	62,000	11,879.00	3,000	883.55[b]	12,762.55

[a] 1,000(A/F, 10%, 3) = $302.10
[b] [1,000(F/P, 10%, 1) + 3000](A/F, 10%, 4) = $883.55
*Economic life = 3 years, with EAC = $12,531.50

Since EAC defender > EAC challenger (14,312.6 > 12,531.5) replace oven this year.

10-2
The cash flow diagram below indicates the costs associated with a piece of equipment. The investment cost is $5,000 and there is no salvage. During the first 3 years the equipment is under warranty so there are no maintenance costs. Then the estimated maintenance costs over 15 years follow the pattern shown in the cash flow diagram. Determine the equivalent annual cost (EAC) for n = 12 if the minimum attractive rate of return (MARR) = 15%. Use gradient and uniform series factors in your solution.



Solution

EAC = 5,000(P/A, 15%, 12) + 150(F/A, 15%, 9)(A/F, 15%, 12)
+ 100(P/G, 15%, 7)(P/F, 15%, 5)(A/P, 15%, 12)
= $1,103

10-3
A hospital is considering purchasing a new $40,000 diagnostic machine that will have no salvage value after installation, as the cost of removal equals any sale value. Maintenance is estimated to be $2,000 per year as long as the machine is owned. After ten years the radioactive ion source will have caused sufficient damage to machine components that safe operation is no longer possible and the machine must be scrapped. The most economic life of this machine is

a. One year since it will have no salvage after installation.
b. Ten years because maintenance doesn't increase.
c. Less than ten years but more information is needed to determine the economic life.

Solution

The correct answer is b.

10-4

A petroleum company, whose minimum attractive rate of return is 10%, needs to paint the vessels and pipes in its refinery periodically to prevent rust. "Tuff-Coat", a durable paint, can be purchased for $8.05 a gallon while "Quick-Cover", a less durable paint, costs $3.25 a gallon. The labor cost of applying a gallon of paint is $6.00. Both paints are equally easy to apply and will cover the same area per gallon. Quick-Cover is expected to last 5 years. How long must Tuff-Coat promise to last to justify its use?

Solution

This replacement problem requires that we solve for a breakeven point. Let N represent the number of years Tuff-Coat must last. The easiest measure of worth to use in this situation is equivalent annual worth (EAW). Although more computationally cumbersome, others could be used and if applied correctly they would result in the same answer.

Find N such that $EAW_{TC} = EAW_{QC}$

$14.05(A/P, 10\%, N) = 9.25\ (A/P, 10\%, 5)$

$(A/P, 10\%, N) = 0.17367$

Searching the i = 10% table N = 9 years

Tuff-Coat must last at least 9 years. Notice that this solution implicitly assumes that the pipes need to be painted indefinitely (i.e., forever) and that the paint and costs of painting never change (i.e., no inflation or technological improvements affecting the paint or the cost to produce and sell paint, or to apply the paint).

10-5

Ten years ago Hyway Robbery, Inc. installed a conveyor system for $8,000. The conveyor system has been fully depreciated to a zero salvage value. The company is considering replacing the conveyor because maintenance costs have been increasing. The estimated end-of-year maintenance costs for the next five years are as follow:

Year	Maintenance
1	$1,000
2	1,250
3	1,500
4	1,750

5	2,000

At any time the cost of removal just equals the value of the scrap metal recovered from the system. The replacement the company is considering has an equivalent annual cost (EAC) of $1,028 at its most economic life. The company has a minimum attractive rate of return (MARR) of 10%.

a. Should the conveyor be replaced now? Show the basis used for the decision.
b. Now assume the old conveyor could be sold at any time as scrap metal for $500 more than the cost of removal. All other data remain the same. Should the conveyor be replaced?

Solution

a. Since the current value ($0.00) is not changing but maintenance costs are increasing, the most economic life is one year.

Year	Cash Flow
0	0
1	-1,000
S	0

Defender uniform equivalent cost: EAC_D = $1,000

Since $EAC_D < EAC_C$, keep the old conveyor for now.

b.

Year	Cash Flow
0	-500
1	-1,000
S	+500

EAC_D = 1,000 + 500(A/P, 10%, 1) - 500(A/F, 10%, 1) = $1,050.

Since $EAC_D > EAC_C$, replace the old conveyor.

10-6

Ten years ago, the Cool Chemical Company installed a heat exchanger in its plant for $10,000. The company is considering replacing the heat exchanger because maintenance costs have been increasing. The estimated maintenance costs for the next 5 years are as follow:

Year	Maintenance
1	$1,000
2	1,200
3	1,400
4	1,600
5	1,800

Whenever the heat exchanger is replaced, the cost of removal will be $1,500 more than the heat exchanger is worth as scrap metal. The replacement the company is considering has an equivalent annual cost (EAC) = $900 at its most economic life. Should the heat exchanger be replaced now if the company's minimum attractive rate of return (MARR) is 20%?

Solution

Since the current value ($-1,500) is not changing but maintenance costs are increasing, the most economic life is one year.

Year	Cash Flow	
0	+1,500	(Foregone salvage)
1	-1,000	(Maintenance)
S	-1,500	(Negative Salvage)

Equivalent annual cost of the defender:

EAC_D = 1,000 + 1,500(A/F, 20%, 1) - 1,500(A/P, 20%, 1) = $700

Since $EAC_D < EAC_C$, keep the old heat exchanger for now.

10-7

An engineer is trying to determine the economic life of new metal press. The press costs $10,000 initially. First year maintenance costs are $1,000. Maintenance costs are forecast to increase $1,000 per year for each year after the first. Fill in the table below and determine the economic life of the press. Consider only maintenance and capital recovery in your analysis. Interest is 5%.

Year	Maintenance Cost	EAC of Capital Recovery	EAC of Maintenance	Total EAC
1	$1,000			
2	2,000			
↓	↓			
8	8,000			

Solution

Year	Maintenance Cost	EAC of Capital Recovery	EAC of Maintenance	Total EAC
1	$1,000	$11,500	$1,000	$12,500
2	2,000	6,151	1,465	7,616
3	3,000	4,380	1,907	6,287
4	4,000	3,503	2,326	5,829
5	5,000	2,983	2,723	5,706
6	6,000	2,642	3,097	5,739
7	7,000	2,404	3,450	5,854
8	8,000	2,229	3,781	6,010

Economic Life = 5 yrs (EAC = minimum)

EAC of Capital Recovery = $10,000 (A/P, 15%, n)

EAC of Maintenance = $1,000 + 1,000 (A/G, 15%, n)

10-8

A manufacturer is contemplating the purchase of an additional forklift truck to improve material handling in the plant. He is considering two popular models, the Convair T6 and the FMC 340. The relevant financial data are shown below. The manufacturer's MARR is 12%.

Model	First Cost	Life	Salvage Value	Annual Operating Cost
Convair T6	$20,000	6 years	$2,000	$8,000
FMC 340	29,000	7 years	4,000	4,000

a. Which model is more economical?
b. List two important assumptions that are implicit in your computations in (a).

Solution

a. Compute the EAW for each model.

Convair: EAW = -20,000(A/P, 12%, 6) + 2,000(A/F, 12%, 6) - 8,000
= -$12,617.60

FMC: EAW = -29,000(A/P, 12%, 7) + 4,000(A/F, 12%, 7) - 4,000
= -$9,957.50

The FMC is more economical.

b. That either truck can be
1) repeated with identical costs indefinitely
2) the service to be provided (material handling) is required forever.

10-9

A graduate of an engineering economy course has complied the following set of estimated costs and salvage values for a proposed machine with a first cost of $15,000; however, he has forgotten how to find the most economic life. Your task is to show him how to do this by calculating the equivalent annual cost (EAC) for n = 8, if the minimum attractive rate of return (MARR) is 15%.

Life (n) Years	Estimated End-of-Year Maintenance	Estimated Salvage if Sold in Year n
1	$ 0	$10,000
2	$ 0	9,000
3	300	8,000
4	300	7,000
5	800	6,000
6	1,300	5,000
7	1,800	4,000
8	2,300	3,000
9	2,800	2,000
10	3,300	1,000

Remember: Calculate only one EAC (for n = 8). You are not expected to actually find the most economical life.

Solution

First Cost	EAC = 15,000(A/P, 15%, 8) = $3,344
Salvage Value	EAC = -3,000(A/F, 15%, 8) = -$219
Maintenance	EAC = 300(F/A, 15%, 6)(A/F, 15%, 8) + 500(P/G, 15%, 5)(P/F, 15%, 3)(A/P, 15%, 8) = $615
Total	EAC_8 = $3,740

(A complete analysis would show that the most economic life is 7 years, with EAC = $3,727)

10-10

One year ago machine A was purchased for $15,000, to be used for five years. The machine has not performed as expected and costs $750 per month for repairs, adjustments and down-time. Machine B, designed to perform the same functions, can be purchased for $25,000 with monthly costs of $75. The expected life of machine B is five years. Operating costs are substantially equal for the two machines and salvage values are negligible. Using 6% the incremental annual net equivalent of machine B is nearest to

a. $2,165
b. $2,886
c. $4,539
d. $5,260

Solution

ΔEUAW = -25,000(A/P, 6%, 5) + 12(750 - 75)
= $2,165

The answer is a.

10-11

An existing machine has operating costs of $300 per year and a salvage value of $100 (for all years). A new replacement machine would cost $1,000 to purchase, and its operating cost over the next period of t years (not per year) is $M = 200t + 10t^2$. Assume i = zero percent.

a. What is the most economic life t* for the new machine?
b. Should the old machine be replaced with the new one?

Solution

a) Cost per year = $AC = \frac{1{,}000}{t} + \frac{M}{t} = \frac{1{,}000}{t} + 200 + 10t$

$$\frac{dAC}{t} = \frac{1{,}000}{t^2} + 10 = 0 \quad \Rightarrow \quad t^* = +10 \text{ years}$$

b) $AC^* = AC\ (10) = \frac{1,000}{10} + 200 + 10\ (10)$

$= 400 \geq$ Annual cost of old machine for any number of years

∴ No, keep old one.

10-12

A truck salesperson is quoted as follows:

"Even though our list price has gone up to $42,000, I'll sell you a new truck for the old price of $40,000, an immediate savings of $2,000, and give you a trade-in allowance of $21,000, so your cost is only ($40,000 - 21,000) = $19,000. The book value of your old truck is $12,000, so you're making an additional ($21,000 - 12,000) = $9,000 on the deal." The salesperson adds, "Actually I am giving you more trade-in for your old truck than the current market value of $19,500, so you are saving an extra ($21,000 - 19,500) = $1,500."

a) In a proper replacement analysis, what is the first cost of the defender?
b) In a proper replacement analysis, what is the first cost of the challenger?

Solution

a) $19,500

The defender 1st cost is always the current market value, not trade-in or book value.

b) $38,500

With an inflated trade-in value of $1,500 (21,000 - 19,500), the new truck can be purchased for $40,000. Therefore, the appropriate value used for replacement analysis is: $40,000 - $1,500 = $38,500.

10-13

The computer system used for production and administration control at a large cannery is being considered for replacement. Of the available replacement system, "Challenger I" has been considered the best. However, it is anticipated that after one year, the "Challenger II" model will become available, with significant technological modifications. The salvage value projections for these three systems are summarized below. Assuming that their performance would otherwise be comparable, should we replace the existing system either this year or next year? Assume the MARR equals 12%, and a useful life of 5 years on all alternatives.

	Salvage Value at End of the Year		
Year	Existing Computer	Challenger I	Challenger II
0	$20,000	$25,000	$24,000
1	16,000	22,000	23,000

2	13,000	21,000	23,000
3	11,000	20,000	22,000
4	8,000	16,000	16,000
5	3,000	10,000	10,000

Solution

Existing Computer (defender)

Year	Salvage Value at End of Year	EAC Capital Recovery = (P - S) × (A/P, 12%, n) + Si
0	P = 20,000	-
1	16,000	6,400.00
2	13,000	5,701.90
3	11,000	5,066.70
4	8,000	4,910.40*
5	3,000	5,075.80

*Economic life = 4 yrs
EAC = $4,910.40

Challenger I

Year	Salvage Value at End of Year	EAC Capital Recovery = (P - S) × (A/P, 12%, n) + Si
0	P = 25,000	-
1	22,000	6,000.00
2	21,000	4,886.80
3	20,000	4,481.50*
4	16,000	4,882.80
5	10,000	5,361.00

*Economic life = 3 yrs
EAC = $4,481.50

Challenger II

Year[1]	Salvage Value at End of Year	EAC Capital Recovery = (P - S) × (A/P, 12%, n) + Si
0	P = 24,000	-
1	23,000	3,880.00
2	23,000	3,351.70*
3	22,000	3,472.60
4	16,000	4,553.60
5	10,000	5,083.60

*Economic life = 2 yrs
EAC = $4,910.40

[1]Year numbers do not refer to same time scale as for Challenger 1

Note $EAC_{\text{Challenger II}} < EAC_{\text{Challenger I}} < EAC_{\text{Defender}}$, but should we replace it now or should we wait one year for the Challenger II?

Alternative A: Don't wait

$EAC_A = EAC_{\text{Challenger I}} = \$4,481.50$

Alternative B: Wait one year for replacement.

EAC_B = [6,400(P/A, 12%, 1) + (3,351,7(P/A, 12%, 2)(P/F, 12%, 1)](A/P,12%, 3)
cost of keeping one more year — cost of challenger II at its best (2 year economic life)
= $4,484.49

Since $EAC_A \approx EAC_B$ we should preferably wait one year, although strictly speaking we can choose either option.