Engineering Economics

Module -5

Replacement Analysis and Costing

Replacement Analysis - Deterioration, Obsolescence, Inadequacy, Economic life for cycle replacements, individual replacement, Numerical exercises.
Costing – Elements of cost, Components of cost, Preparation of cost sheet, Numerical exercises.

Introduction

Replacement analysis is one of the crucial analysis in capital budgeting. An asset life may be reduced due to physical impairment, changes in economic requirements and rapid changes in technology that may obsolete an asset prior to expectation. The replacement of assets offers economic opportunity for the firm. In replacement analysis there is two alternatives:

- The assets that are currently being used: The defender
- The assets that we have to buy to replace current assets : The Challenger

Factors to be considered in replacement analysis are listed below.

- Sunk costs to be ignored
- Existing asset value need not be considered
- Income tax to be avoided
- The optimal replacement cycle is one which has lowest equivalent annual cost
- The replacement decision will apply indefinitely.
- Economic life of the challenger and the defender should not be considered.

All industries and military equipment gets worn with time and usage and function with decreasing efficiency.

Eg. Machine requires higher operating cost , transport vehicle requires more maintenance cost etc.

The ever-increasing repair and maintenance cost necessitates the replacement of the equipment. However, there is no sharp, clearly defined time which indicates the need for this replacement. The replacement policy consists of calculating the increased operating cost, maintenance cost, forced idle time cost together with cost of replacing new equipment.

The objective is to minimize the sum of the cost of the item, cost of replacing the item and the cost associated with failure of item.

The equipment needs replacement not because it no longer performs to the designed standards, but because more modern equipment performs higher standards.

Eg. An equipment may have an economic life of 20yrs yet it may become obsolete after 10 yrs because of better technical development.

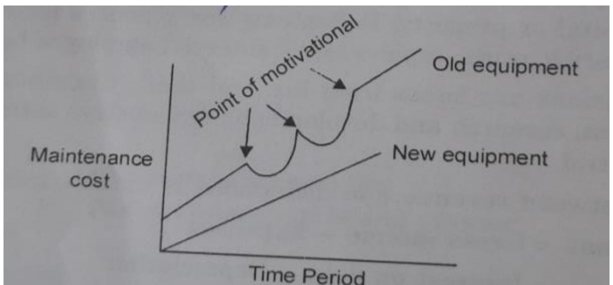

Fig. 7.1 Replacement of machine.

1. Deterioration
2. Obsolescence
3. Inadequacy

Reasons for Replacement in the performance of the equipment as compared to the new equipment identical to the present one.

Deterioration may occur due to wear and tear due to the

(a) Increases the maintenance cost
(b) Reduces the product quality
(c) Decrease the rate of production
(d) Increases labour cost
(e) Reduces efficiency of equipment.

2. **Obsolescence** occurs when the technology of an asset is surpassed by newer and/or different technologies. Changes in technology cause subsequent changes in the market demand for older assets.

Eg. Today's personal computers (PCs) with more RAM, faster clock speeds, larger hard drives, and more powerful central processors have made older, less powerful PCs obsolete, thus obsolete assets may need to be replaced with newer, more technologically advanced ones.

3. **Inadequacy** The gradual loss of market value of an asset as it is being consumed or exhausted. Oil wells and timber tracts are examples of such assets. In most cases the asset will be used until it is depleted, at which time a replacement asset will be obtained.

Limitations of Replacement Analysis

This method assumes that a firm is continually replacing, and therefore determines a once- and-for-all optimal replacement cycle. In practice this is unlikely to be valid due to:

- Changing technology, which can quickly make machines obsolete and shorten replacement cycles. This means that one asset is not being replaced by one exactly similar.
- Inflation, which by altering the cost structure of assets means that the optimal replacement cycle can vary over time
- If inflation affects all variables equally it is best excluded from the analysis by discounting real cash flows at a real interest rate – the optimal replacement cycle will remain valid
- Differential inflation rates mean that the optimal replacement cycle varies over time
- The effects of taxation (ignored in the analysis but they could be incorporated)
- The fact that production is unlikely to continue in perpetuity

Replacement Models

1. **Replacement of items whose maintenance cost increases with time and the value of money remains same during the period.**
2. **Replacement of items whose maintenance cost increases with time and the value of money changes with time.**
3. Group Replacement Policy

Case 1 : **Replacement of items whose maintenance cost increases with time and the value of money remains same during the period.**

Notations: ‘C’ is the capital or purchase cost of the machinery

‘S’ is the scrap value or resale value of the machinery

- Total cost incurred on the item during period ‘Y’

  = capital cost of machine + total maintenance cost during period ‘Y’ – scrap value

i.e, **Total cost = C + M(Y) – S**

- Average cost/unit of time incurred during the period ‘Y’ on the item

  $$G(Y) = \frac{C+M(Y)-S}{Y}$$

Where Y – no. of years , M(Y) – Cumulative maintenance cost in that year.

<u>Note:</u> Running cost = Operating cost = Maintenance cost.

Problems

1. The cost of the machine is Rs. 6100 and its scrap value is Rs.100. The maintenance cost found from experience are as follows :

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Maintenance cost in yrs.	**100**	**250**	**400**	**600**	**900**	**1200**	**1600**	**2000**

Where should the machine be replaced?

(a) **Solution :** C=6100 S=100 n=8

No. of years	Maintenance Cost	Cumulative maintenance cost M(Y)	Total cost C + M(Y) – S	Average cost/unit $\frac{C+M(Y)-S}{Y}$
1	100	100	6100	6100
2	250	350	6350	3175
3	400	750	6750	2250
4	600	1350	7350	1837.5
5	900	2250	8250	1650
6	**1200**	**3450**	**9450**	**1575**
7	1600	5050	11050	1578.57
8	2000	7050	13050	1631.25

<u>Conclusion:</u> We should replace the machinery by the end of 6^{th} year or at the beginning of 7^{th} year as the maintenance cost is more than the average total cost of the machine in the 7^{th} year.

2. A fleet owner finds from his past experience records that cost of the machine is Rs. 6000 and the running costs are given below, at what stage the replacement is due?

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Maintenance cost	**1000**	**1200**	**1400**	**1800**	**2300**	**2800**	**3400**	**4000**
Scrap/resale value 'S'	**3000**	**1500**	**750**	**375**	**200**	**200**	**200**	**200**

Solution: C=6000 n=8

No. of years (Y)	Maintenance Cost	Cumulative maintenance cost M(Y)	Cost scrap value (C – S)	Total cost (C – S) + M(Y)	Average cost/unit $\frac{C-S+M(Y)}{Y}$
1	1000	1000	3000	4000	4000
2	1200	2200	4500	6700	3350
3	1400	3600	5250	8850	2950
4	1800	5400	5625	11025	2756.25
5	**2300**	**7700**	**5800**	**13500**	**2700**
6	2800	10500	5800	16300	2716.66
7	3400	13900	5800	19700	2814.28
8	4000	17900	5800	23700	2962.5

Conclusion: The average cost /unit is greater than the maintenance cost till the end of 5^{th} year but increases suddenly in the 6^{th} year, so till the 5^{th} year ending we will use the same fleet but will have to replace it by a new one at the beginning of 6^{th} year.

3. Cost of equipment= Rs 5, 00,000 Resale value= Rs 1, 00,000

   Maintenance cost is as follows

Year	**1**	**2**	**3**	**4**	**5**
Maintenancecost	**25,000**	**30,000**	**45,000**	**60,000**	**65,000**

When it is economical to replace the equipment?

Solution : C=5,00,000 S=1,00,000 n=5

No. of years	Maintenance Cost	Cumulative maintenance cost M(Y)	Total cost C + M(Y) – S	Average cost/unit $\frac{C+M(Y)-S}{Y}$
1	25000	25000	425000	425000
2	30000	55000	455000	227500

3	45000	100000	500000	166666.67
4	60000	160000	560000	140000
5	65000	225000	625000	125000

Conclusion: Since the average maintenance cost goes on decreasing till 5^{th} year, it is economical to replace the equipment at the end of 5^{th} year.

4. Cost of equipment= Rs 10, 00,000 Resale value= Rs 2, 50,000

   Maintenance cost is as follows

Year	**1**	**2**	**3**	**4**	**5**
Maintenance cost	**22,000**	**25,000**	**25,000**	**40,000**	**45,000**

When it is economical to replace the equipment?

Solution : C=10,00,000 S=2,50,000 n=5

No. of years	Maintenance Cost	Cumulative maintenance cost M(Y)	Total cost C + M(Y) – S	Average cost/unit $\frac{C+M(Y)-S}{Y}$
1	22000	22000	772000	772000
2	25000	47000	797000	398500
3	25000	72000	822000	294000
4	40000	112000	862000	215500
5	45000	157000	907000	181400

Conclusion: Since the average cost goes on decreasing till 5^{th} year, it is economical to replace the equipment at the end of 5^{th} year.

5. A firm is considering replacement of an equipment, whose first cost is Rs. 4,000 and the scrap value is negligible at the end of any year. Based on experience, it was found that the maintenance cost is zero during the first year and it increases by Rs. 200 every year thereafter.
   When should the equipment be replaced?

Solution: C=4000

No. of years	Maintenance Cost	Cumulative maintenance cost M(Y)	Total cost C + M(Y) – S	Average cost/unit $\frac{C+M(Y)-S}{Y}$
1	0	0	4000	4000
2	200	200	4200	2100
3	400	600	4600	1533.34
4	600	1200	5200	1300

5	800	2000	6000	1200
6	**1000**	**3000**	**7000**	**1166.66**
7	1200	4200	8200	1171.42

Conclusion: We should replace the machinery by the end of 6^{th} year or at the beginning of 7^{th} year as the maintenance cost is more than the average total cost of the machine in the 7^{th} year.

6. A machine is purchased for Rs 20, 00,000 the maintenance cost and the resale value at the end of each year is shown below. When it is economical to replace the machine?

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
M.Cost	**50000**	**60000**	**65000**	**72000**	**78000**	**90000**	**100000**	**125000**	**150000**	**178000**
Resale Value	**18,00,000**	**17,00,000**	**15,00,000**	**14,50,000**	**14,00,000**	**13,00,000**	**12,00,000**	**11,00,000**	**900,000**	**725000**

Solution :

C=20,00,000 n=10

No. of years (Y)	Maintenance Cost	Cumulative maintenance cost M(Y)	Cost scrap value (C – S)	Total cost (C – S) + M(Y)	Average cost/unit $\frac{C-S+M(Y)}{Y}$
1	50000	50000	2,00,000	2,50,000	2,50,000
2	**60000**	**110000**	**3,00,000**	**4,10,000**	**2,05,000**
3	65000	175000	5,00,000	6,75,000	2,25,000
4	72000	247000	5,50,000	7,97,000	1,99,250
5	78000	325000	6,00,000	9,25,000	1,85,000
6	**90000**	**415000**	**7,00,000**	**11,15,000**	**1,85,833.33**
7	100000	515000	8,00,000	13,15,000	1,87,857.14
8	125000	640000	9,00,000	15,40,000	1,92,500
9	150000	790000	11,00,000	18,90,000	2,10,000
10	178000	968000	12,75,000	22,43,000	2,24,300

Conclusion: Since the average cost decreases at the end of 2^{nd} year and suddenly increases at 3^{rd} year. But again it decreases till end of 6^{th} year…so its economical to replace at beginning of 3^{rd} year or feasible to replace at end of 6^{th} year.

Case 2 : **Replacement of items whose maintenance cost increases with time and the value of money also changes with time.**

to get the maintainance cost multiply it by V,
and to get the average cost divide the net maintainance cost with cumulative discount factor(V)

The maintenance cost varies with time and we want to find the optimum value of time at which the item should be replaced. The value of money decreases with a constant rate which is known as **Depreciation ratio or Discount factor**.

Given by , $V = \frac{1}{(1+i)^{n-1}}$ for the value of Re. 1

Where , i is the interest or discount factor

n is the year

1 the value of Re. on which discount is considered in that year.

In this we made an assumption that the maintenance cost spent on the equipment or an item is at the beginning of each year.

Problems

1. A company buys a machine for Rs. 6000 and gives us a 20% declining method of depreciation. Maintenance costs are expected to be Rs. 300 in each of the first 2 years and then to go up annually as follows :
   Rs. 700 , Rs. 1000 , Rs.1500, Rs.2000, Rs.2500.
   When should the machine be replaced?

Solution : C=6000 i=20%=0.2

Discount factor (first year)= $\frac{1}{(1+0.2)^{1-1}} = 1$

Second year = 0.8333

Present value of maintenance cost(PVMC) = discount factor * maintenance cost

1	2	3	4	5	6	7	8
No. of years	Maintenance Cost	Discount Factor	Present value of the maintenance cost(PVMC)	Cumulative of PVMC M(Y)	=5 + Cost of m/c =M(Y) + C	Cumulative Discount factor	Weighted Average cost = 6 / 7
1	300	1	300	300	6300	1	6300
2	300	0.8333	249.99	549.99	6549.99	1.8333	3572.78

3	700	0.6944	486.08	1036.07	7036.07	2.5277	2783.58
4	1000	0.5787	578.7	1614.77	7614.77	3.1064	2451.31
5	1500	0.482	723	2337.77	8337.77	3.5884	2323.53
6	**2000**	**0.4018**	**803.6**	**3141.37**	**9141.37**	**3.9902**	**2290.96**
7	2500	0.3348	837	3978.37	9978.37	4.325	2307.14

Conclusion: It is clear from the table that the maintenance cost is less than the weighted average cost till the end of 6th year but gets increased in the beginning of 7th year, so it is advisable to replace the machine with a new one at the beginning of 7th year in order to overcome it.

2. A manufacturer is offered 2 machine's A and B. A is priced at Rs.5000 and running costs are estimated at Rs.800 at each of the first 5 years increasing by Rs.200 / year in the 6th and subsequent years, machine B which has the same capacity as A costs Rs.2500 but will have running cost of Rs.1200/year for 1st 6 years increasing by Rs.200 / year thereafter. If money is worth of 10% / year which machine should be purchased? Assume that the scrap value is zero at the end.

   Solution: Machine A : C=5000 i=10%=0.1

No. of years	Maintenance Cost	Discount Factor	Present value of the maintenance cost(PVMC)	Cumulative of PVMC M(Y)	=5 + Cost of m/c =M(Y) + C	Cumulative Discount factor	Weighted Average cost = 6 / 7
1	800	1	800	800	5800	1	5800
2	800	0.9090	727.2	1527.2	6527.2	1.9090	3419.17
3	800	0.8264	661.12	2188.32	7188.32	2.7354	2627.88
4	800	0.7513	601.04	2789.36	7789.36	3.4867	2234.02
5	800	0.6830	546.4	3335.76	8335.76	4.1697	1999.12
6	1000	0.6209	620.9	3956.66	8956.66	4.7906	1869.63
7	1200	0.5645	677.4	4634.06	9634.06	5.3551	1799.04
8	1400	0.5132	718.48	5352.54	10,352.54	5.8683	1764.14
9	**1600**	**0.4665**	**746.4**	**6098.94**	**11,098.94**	**6.3348**	**1752.05**
10	1800	0.4241	763.38	6862.32	11,862.32	6.7589	1755.06

Machine B : C=2500 i=10%=0.1

No. of years	Maintenance Cost	Discount Factor	Present value of the maintenance cost(PVMC)	Cumulative of PVMC M(Y)	=5 + Cost of m/c =M(Y) + C	Cumulative Discount factor	Weighted Average cost = 6 / 7
1	1200	1	1200	1200	3700	1	3700

2	1200	0.9090	1090.8	2290.8	4790.8	1.9090	2509.58
3	1200	0.8264	991.68	3282.48	5782.48	2.7354	2113.94
4	1200	0.7513	901.56	4184.04	6684.04	3.4867	1917.01
5	1200	0.6830	819.6	5003.64	7503.64	4.1697	1799.56
6	1200	0.6209	745.08	5748.72	8248.72	4.7906	1721.85
7	1400	0.5645	790.3	6539.02	9039.02	5.3551	1687.92
8	**1600**	**0.5132**	**821.12**	**7360.14**	**9860.14**	**5.8683**	**1680.23**
9	1800	0.4665	839.7	8199.84	10,699.84	6.3348	1689.05

Conclusion: Machine A should be replaced by the end of 9th year and machine B should be replaced by the end of 8th year and the average cost of the machine B is less than A, so purchase machine B.

3. A machine costs Rs.10,000 operating costs are Rs.500/year for the first 5 years, in the 6th year and the subsequent years operating cost increases by Rs.100 each year. Assuming money is worth 10% year, find the optimum length of time to hold the machine before replacement.

Solution : C=10,000 i=10%=0.1

No. of years	Maintenance Cost	Discount Factor	Present value of the maintenance cost(PVMC)	Cumulative of PVMC M(Y)	=5 + Cost of m/c =M(Y) + C	Cumulative Discount factor	Weighted Average cost = 6 / 7
1	500	1	500	500	10,500	1	10,500
2	500	0.9090	454.5	954.5	10,954.5	1.9090	5758.34
3	500	0.8264	413.2	1367.7	11,367.7	2.7354	4155.77
4	500	0.7513	375.65	1743.35	11,743.35	3.4867	3368.04
5	500	0.6830	341.5	2084.85	12,084.85	4.1697	2898.25
6	600	0.6209	372.54	2457.39	12,457.39	4.7906	2600.38
7	700	0.5645	395.15	2852.54	12,852.54	5.3551	2400.05
8	800	0.5132	410.56	3263.1	13,263.1	5.8683	2260.13
9	900	0.4665	419.85	3682.95	13,682.95	6.3348	2159.97
10	1000	0.4241	425.1	4107.05	14,107.05	6.7589	2087.18
11	1100	0.3855	424.05	4531.1	14,531.1	7.1444	2033.91
12	1200	0.3505	420.6	4951.7	14,951.7	7.4949	1994.91
13	1300	0.3186	414.18	5365.88	15,365.88	7.8135	1966.58
14	1400	0.2896	405.44	5771.32	15,771.32	8.1031	1946.33
15	1500	0.2632	394.8	6166.12	16,166.12	8.3663	1932.29
16	1600	0.2392	382.72	6548.84	16,548.84	8.6055	1923.05
17	1700	0.2175	369.75	6918.5	16,918.5	8.823	1917.55
18	1800	0.1977	355.86	7274.45	17,274.45	9.0207	1914.97

19	**1900**	**0.1797**	**341.43**	**7615.88**	**17,615.88**	**9.2004**	**1914.68**
20	2000	0.1634	326.8	7942.68	17,942.68	9.3638	1916.18

Conclusion: Till the 19th year, average cost is greater than the maintenance cost but increases on 20th year i.e, maintenance cost is greater than the average weighted cost, so we will replace the machinery at the beginning of the 20th year.

4. A person is considering to purchase a machine for his factory. The related data about the alternative machine's are as follows:

	Machine A	MachineB	Machine C
Present Investment	10,000	12,000	15,000
Total annual maintenance cost/running cost	2,000	1,500	1,200
Life in years	10	10	10
Salvage value in Rs.	500	1000	1200

As an advisor of the company, you have been asked to select the best machine. Consider 12% nominal rate of return/year.

Solution : To calculate discount factor for each year

I=12% = 0.12

No. of years	Discount factor
1	1
2	0.8928
3	0.7971
4	0.7117
5	0.6355
6	0.5672
7	0.5066
8	0.4521
9	0.4036
10	0.3606
Total discount factor	**6.3267**

for 10yrs	

Total maintenance for machine A for 10yrs with discount factor

= 2000 * 6.3267 = 12,653.4

Total maintenance for machine B for 10yrs with discount factor

= 1500 * 6.3267 =9490.05

Total maintenance for machine C for 10yrs with discount factor

= 1200 * 6.3267 =7592.04

The salvage value of the machine will be considered in the 10^{th} year , so we will consider only the discount factor of 10^{th} year (i.e, 0.3606)

Salvage value of machine A = 500 * 0.3606 = 180.3

Salvage value of machine B = 1000 * 0.3606 =360.6

Salvage value of machine C = 1200 * 0.3606 =432.72

Total present value of machine A

= initial Investment + maintenance cost – salvage value

=10,000 + 12,653.4 – 180.3 = **22,473.1**

Total present value of machine B

= initial Investment + maintenance cost – salvage value

=12,000 + 9490.05 – 360.6 = **21,129.45**

Total present value of machine C

= initial Investment + maintenance cost – salvage value

=15,000 + 7592.04 – 432.72 = **22,159.32**

Conclusion: We will consider machine B , as the total cost of machine B is less than the costs of A and C.

Problems to be solved

5. A company has a 2 year old machine purchased at a cost of Rs.10,000. Now a new machine is available at Rs.12,000. The operation and maintenance cost of the existing machine is Rs.600 for the 1^{st} year, Rs.800 for the 2^{nd} year and then it increases by Rs.300/year. The operation and maintenance cost of the new machine

is Rs.400 for the first year, then it increases by Rs.150/year. The capacities of the machine's are same and they have no resale value. The company expects a minimum of 12% return on its capital investments. Determine whether the existing machine should be replaced by the new machine?

6. A truck is priced at Rs.60,000 and running costs are estimated at Rs.6000 for each of the 1st 4 years, increasing by Rs.2000/year in the 5th and subsequent years. If the money is worth 10% / year, when should the truck be replaced? Assume the truck has no scrap value.