CENG 6108 Construction Economics

Depreciation and Equipment Replacement Decisions

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TO DO

1. Depreciation and Depreciation Accounting
2. Replacement Decisions

Depreciation

- The decline in market value of an asset due to:
  - User-related physical loss: Due to wear out of parts (e.g. Vehicles), usually measures in units of production (e.g. Mileage per km)
  - Time-related physical loss: Physical loss overtime due to environmental factors (e.g. weather)
  - Functional loss: Due to technical changes, legislative changes, etc.
- Value of an Asset:
  - Market value: Value an asset could be sold for in a open market
  - Book value: Depreciated value of an asset for accounting purposes
  - Scrap value: Actual value of an asset at the end of its physical life (broken up for material value of its parts)
  - Salvage value: Actual value of an asset at the end of its physical life (when it is sold)

Depreciation

- We need to develop a good model of depreciation in order to state a book value of an asset for the following reasons:

  (1) In order to make managerial decisions, e.g. give a loan by taking a firm’s building as an asset.

  (2) For planning purposes, e.g. to decide whether to keep an asset or replace it

  (3) Government tax requirement: For calculating income and expense, we need to determine depreciation expenses accurately

- Depreciation Methods
  - Straight-Line Method
  - Declining-Balance Method
  - Sum-of-the-Years’-Digits Method
  - Double-Declining-Balance Method
  - 150%-Declining-Balance Method

Straight-Line Method

$$D_{sl}(n) = \frac{P - S}{N} \qquad BV_{sl}(n) = P - n[\frac{P - S}{N}]$$

$D_{sl(n)}$ = Depreciation charge for period n

$BV_{sl(n)}$ = Book value at the end of period n

P = Purchase price or current market price

S = Salvage value after N periods

N = The useful life of the asset, in periods

Straight-Line Method

$$D_{sl}(n) = \frac{98,000 - 7,000}{7} = 13,000$$

$$BV_{sl}(n) = 98,000 - n * 13,000$$

Example:

$$BV_0 = 98,000$$
$$S = 7,000$$
$$N = 7$$

Straight-Line Depreciation

End of Year	Depreciation Amount	Book Value
n	$D_{sl(n)}$	$BV_{sl(n)}$
0		**$98,000.00**
1	$13,000.00	85,000.00
2	$13,000.00	72,000.00
3	$13,000.00	59,000.00
4	$13,000.00	46,000.00
5	$13,000.00	33,000.00
6	$13,000.00	20,000.00
7	$13,000.00	**7,000.00**

Declining-Balance Method

$$D_{db}(n) = BV_{db}(n-1) * d \qquad BV_{db}(n) = P(1-d)^n$$

$D_{db}(n)$ = the depreciation charge in period n

$BV_{db}(n)$ = the book value at the end of period n

P = Purchase price or current market price

d = the depreciation rate. d can range from 1.25 to 2 depending upon the degree of acceleration desired

- The reasonable depreciation rate d can be determined as:

$$BV_{db}(n) = P(1-d)^n = S \rightarrow (1-d) = \sqrt[n]{\frac{S}{P}}$$

$$d = 1 - \sqrt[n]{\frac{S}{P}}$$

Declining-Balance Method

Example:

$$BV_0 = 98{,}000$$
$$S = 7{,}000$$
$$N = 7$$

$$d = 1 - \sqrt[7]{\frac{7{,}000}{98{,}000}} = 0.31409$$

$$D_{db}(n) = BV_{db}(n-1) * 0.31409$$

$$BV_{db}(n) = 98{,}000(1 - 0.31409)^n$$

Declining-Balance Depreciation

End of Year	Value of	Depreciation Amount	Book Value
0			**98000**
1	0.31	30781	67219
2	0.31	21113	46106
3	0.31	14482	31625
4	0.31	9933	21692
5	0.31	6813	14879
6	0.31	4673	10205
7	0.31	3205	**7000**

Sum-of-the-Years'-Digits Method

- The depreciation rate is calculated as ratio of the remaining years of life to the sum of the digits corresponding to the years of life:

$$D_{sd}(n) = \frac{\text{Year digit}}{\text{Sum of Year's digits (SoY)}} * (BV_0 - S)$$

$$BV_{sd}(n) = BV_{sd}(n-1) - D_{sd}(n)$$

$$Year\ digit = N - (n-1)$$

$$SoY = 1 + 2 + 3 + \cdots + n = \frac{n(n+1)}{2}$$

Sum-of-the-Years'-Digits Method

Example:

$$BV_0 = 98{,}000$$
$$S = 7{,}000$$
$$N = 7$$

$$D_{sd}(n) = \frac{7 - (n-1)}{28} * (98{,}000 - 7{,}000)$$

$$BV_{sd}(n) = BV_{sd}(n-1) - D_{sd}(n)$$

$$Year\ digit = 7 - (n-1) \qquad SoY = \frac{7(7+1)}{2} = 28$$

Sum of the years' Digits Depreciation			
End of Year	**Value of**	**Depreciation Amount**	**Book Value**
n	**n-(N-1)]/[n(n+1)/2]**	**D_{sd}**	**B_{sd}**
0			**$98,000.00**
1	7/28	$22,750.00	75,250.00
2	6/28	19,500.00	55,750.00
3	5/28	16,250.00	39,500.00
4	4/28	13,000.00	26,500.00
5	3/28	9,750.00	16,750.00
6	2/28	6,500.00	10,250.00
7	1/28	3,250.00	**7,000.00**

Replacement Decisions

- The regular evaluation of assets, equipments, and plants used in construction industry is needed. The following mutually exclusive choices will be made: An existing asset/equipment may be:

  1. Kept in its current use without major change.
  2. Overhauled so as to improve its performance.
  3. Removed from use without replacement by another asset/equipment.
  4. Replaced with another asset/equipment.

- Complex Decision: Establishing replacement costs for assets out of service and Service lives, and Validating assumptions on how replacement will be carried out

Equipment Replacement Decisions

- Three components of the economics of equipment management decision making:
  - Equipment life: Determining the economic useful life for a given piece of equipment.
  - Replacement analysis: Analytical tools to compare alternatives to replace a piece of equipment that has reached the end of its useful life.
  - Replacement equipment selection: Methods to make a logical decision as to which alternative furnishes the most promising solution to the equipment replacement decision.
    - Theoretical replacement methods: Intuitive, Minimum cost, Maximum profit, Payback period, Mathematical modeling
    - Practical replacement methods: Empirical data, Experience

Equipment Replacement Decisions

- Equipment life can be mathematically defined in three different ways:
  - Physical life: is the age at which the machine is worn out and can no longer reliably produce. At this point, it will usually be abandoned or scrapped.
  - Profit life: is the life over which the equipment can earn a profit. The retention beyond that point will create an operating loss.
  - Economic life: equates to the time period that maximizes profits over the equipment's life.
  - Determination of the appropriate timing to replace a piece of equipment depends on ownership and operating costs: depreciation, inflation, investment, maintenance, repair, downtime, and obsolescence costs.

Equipment Replacement Decisions

- Equipment life:

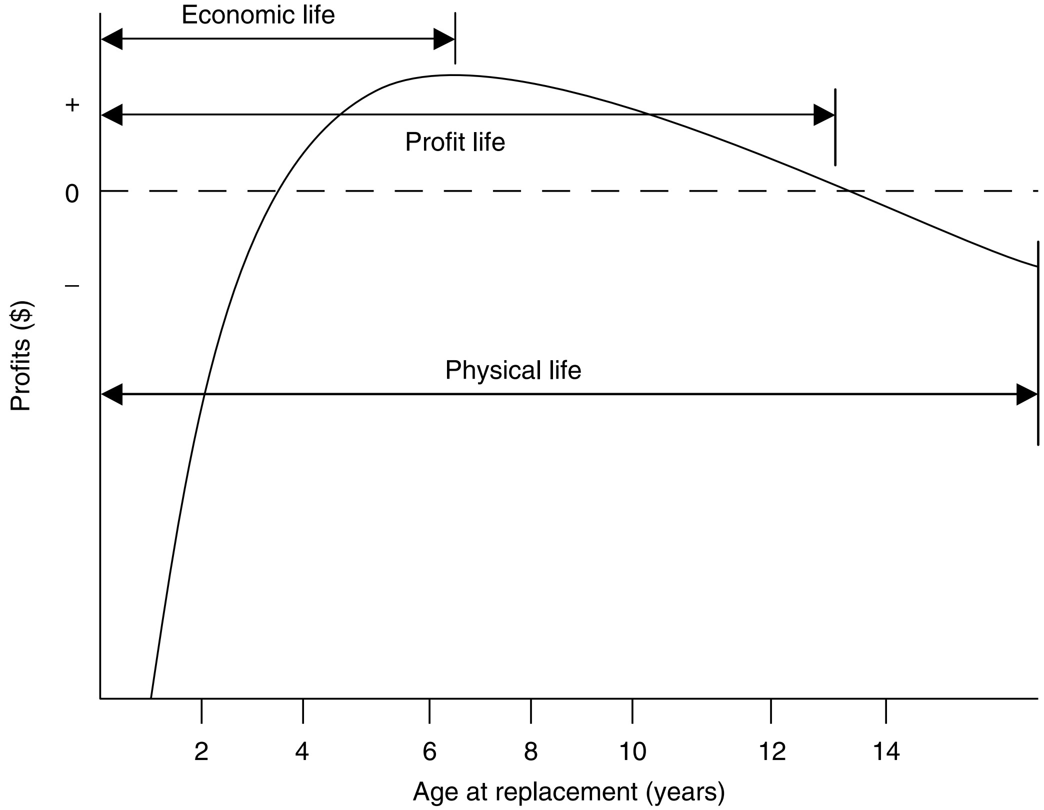


FIGURE 3.1 Equipment life definitions after Douglas. (From J. Douglas. *Construction Equipment Policy,* New York: McGraw-Hill, 1975, pp. 47–60.)

Equipment Life

- Let us take the life of a hypothetical piece of equipment:
- Hourly Depreciation and Replacement Costs:
  - Annual increase of the average cost of construction equipment is approximately 5% per year.

TABLE 3.1
Depreciation and Replacement Costs

End of Year	Replacement Cost	Book Value	Loss on Replacement	Cumulative Use (h)	Cumulative Cost per Hour
0	30,000	30,000	0	0	0
1	31,500	22,500	9,000	2,000	4.50
2	33,000	18,000	15,000	4,000	3.75
3	34,500	15,100	19,400	6,000	3.23
4	36,000	12,800	23,200	8,000	2.90
5	37,500	10,600	26,900	10,000	2.69
6	39,000	9,100	29,900	12,000	2.49
7	40,500	7,900	32,600	14,000	2.33
8	42,000	6,800	35,200	16,000	2.20

Equipment Life

- Hourly Investment Cost: includes interest, insurance, taxes, and license fees beyond the initial acquisition cost of equipment.
  - Assuming investment cost is 15% per year.

TABLE 3.2
Investment Costs

Year	Investment Start of Year	Depreciation	Investment End of Year	Investment Cost	Cumulative Investment Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	30,000	7,500	22,500	4,500	4,500	2,000	2.25
2	22,500	4,500	18,000	3,375	7,875	4,000	1.97
3	18,000	2,900	15,100	2,700	10,575	6,000	1.76
4	15,100	2,300	12,800	2,265	12,840	8,000	1.61
5	12,800	2,200	10,600	1,920	14,760	10,000	1.48
6	10,600	1,500	9,100	1,590	16,350	12,000	1.36
7	9,100	1,200	7,900	1,365	17,715	14,000	1.27
8	7,900	1,100	6,800	1,185	18,900	16,000	1.18

Equipment Life

- Hourly Maintenance and Repair Costs: includes cost of labor and parts used to maintain and repair.
  - Type of equipment, Age of the equipment, Operating conditions, Operating skill of the operator, Daily care by the operator, Maintenance department, Frequency and level of preventive maintenance.

TABLE 3.3
Maintenance and Repair Costs

Year	Annual Maintenance and Repair Cost	Cumulative Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	970	970	2,000	0.49
2	2,430	3,400	4,000	0.85
3	2,940	6,340	6,000	1.06
4	3,280	9,620	8,000	1.20
5	4,040	13,660	10,000	1.37
6	4,430	18,090	12,000	1.51
7	5,700	23,790	14,000	1.70
8	6,290	30,080	16,000	1.88

Equipment Life

- Hourly Downtime Cost: covers the time when equipment does not work due to repairs or mechanical adjustments and the associated costs for ownership cost, operating cost, operator cost, and productivity loss.

TABLE 3.4
Downtime Costs Example

Year	Downtime (%)	Operating Cost	Downtime Cost per Hour	Downtime Cost per Year	Cumulative Downtime Cost	Cumulative Use (h)	Cumulative Cost per Hour	Productivity Factor	Cumulative Cost per Hour	Productivity Adjusted Cumulative Cost per Hour
1	3	7	0.21	420	420	2,000	0.21	1.00	0.21	0.21
2	6	7	0.42	840	1,260	4,000	0.32	0.99	0.32	0.32
3	9	7	0.63	1,260	2,520	6,000	0.42	0.98	0.43	0.44
4	11	7	0.77	1,540	4,060	8,000	0.51	0.96	0.53	0.55
5	13	7	0.91	1,820	5,880	10,000	0.59	0.95	0.62	0.65
6	15	7	1.05	2,100	7,980	12,000	0.67	0.94	0.71	0.76
7	17	7	1.19	2,380	10,360	14,000	0.74	0.93	0.80	0.86
8	20	7	1.40	2,800	13,160	16,000	0.82	0.92	0.89	0.97

Equipment Life

- Hourly Obsolescence Cost: is reduction in value and marketability due to the competition between newer and more productive models.
- Types: Technological [f(productivity)] or Market Preference [f(customers' taste)].

TABLE 3.5
Obsolescence Costs per Hour for the Life of the Equipment

Year	Obsolescence Factor	Equipment Cost per Hour	Obsolescence Cost per Hour	Obsolescence Cost per Year	Cumulative Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	0.00	7.00	0.00	0	0	2,000	0.00
2	0.06	7.00	0.42	840	840	4,000	0.21
3	0.11	7.00	0.77	1,540	2,380	6,000	0.40
4	0.15	7.00	1.05	2,100	4,480	8,000	0.56
5	0.20	7.00	1.40	2,800	7,280	10,000	0.73
6	0.26	7.00	1.82	3,640	10,920	12,000	0.91
7	0.32	7.00	2.24	4,480	15,400	14,000	1.10
8	0.37	7.00	2.59	5,180	20,580	16,000	1.29

Equipment Life

- Summary of Cost: Costs for each component are accumulated and the piece of equipment's economic life can be measured by identifying the year in which the minimum cost per hour occurs.

TABLE 3.6
Summary of Cumulative Costs per Hour

	Year							
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Depreciation and replacement ($/h)	4.5	3.75	3.23	2.9	2.69	2.49	2.33	2.2
Investment ($/h)	2.25	1.97	1.76	1.61	1.48	1.36	1.27	1.18
Maintenance and repairs ($/h)	0.49	0.85	1.06	1.2	1.37	1.51	1.7	1.88
Downtime (productivity adjusted) ($/h)	0.21	0.32	0.44	0.55	0.65	0.76	0.86	0.97
Obsolescence ($/h)	0	0.21	0.4	0.56	0.73	0.91	1.1	1.29
Total ($/h)	7.45	7.10	6.89	6.82	6.92	7.03	7.26	7.52

- Minimum Cost = $6.82/hr and Economic Life = 4th Year

Equipment Replacement Decisions

- Replacement Analysis:

- Example: An aggregate producing company presently owns a fleet of 7.5 cubic yard on highway dump trucks that cost $65,000 each. These trucks are currently 1-year-old and the annual maintenance and operating cost is $30,000 per truck for the first year and increases by $2,000 each year. The revenue of each truck is $70,000 for the first year and decreases by about $1,750 per year thereafter. The owner of the company visits a national equipment show and after talking to one of the salespersons at the show comes back and asks his equipment fleet manager to take a look at replacing the current dump trucks with a new model that employs a new technology, which will reduce maintenance expenditure. The new proposed replacement trucks are of the same size and cost $70,000 each. The annual maintenance and operating cost is $30,000 per truck for the first year but only increases by $1,500 per year thereafter. The revenue of each truck is the same as for current model truck. This company uses the double-declining balance method for calculating depreciation. The trucks currently in use will be called as the “current trucks” and the new model trucks will be called as the “proposed truck”.

Replacement Analysis

- Replacement Analysis:
  - Intuitive Method: As the potential reduction in maintenance costs ($1,750 - $1,500=$250) does not seem to be particularly dramatic, the owner will probably choose to keep using the current trucks that cost $5,000 less than the proposed trucks.
  - Minimum Cost Method:
  - Applicable to public agencies where generation of revenue to offset equipment costs is limited.
  - Focuses on minimizing equipment costs based on not only cost to operate and maintain (O&M costs) a piece of equipment but also the decline in its book value due to depreciation.
  - Economic life of a machine can be determined by the year in which the average annual cumulative cost is minimized.

Replacement Analysis

- Minimum Cost Method:
  - End of the 8th year for the current truck

TABLE 3.8
Average Annual Cumulative Costs of the Current Trucks

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$39,000	$26,000	$56,000	$56,000	$56,000
2	$32,000	$23,400	$15,600	$47,600	$103,600	$51,800
3	$34,000	$14,040	$9,360	$43,360	$146,960	$48,987
4	$36,000	$8,424	$5,616	$41,616	$188,576	$47,144
5	$38,000	$5,054	$3,370	$41,370	$229,946	$45,989
6	$40,000	$3,033	$2,022	$42,022	$271,967	$45,328
7	$42,000	$1,820	$1,213	$43,213	$315,180	$45,026
8	$44,000	$1,092	$728	$44,728	$359,908	$44,989
9	$46,000	$655	$437	$46,437	$406,345	$45,149
10	$48,000	$393	$262	$48,262	$454,607	$45,461
11	$50,000	$236	$157	$50,157	$504,764	$45,888
12	$52,000	$141	$94	$52,094	$556,859	$46,405

Replacement Analysis

- Minimum Cost Method:
  - End of the 9th year for the proposed truck

TABLE 3.9
Average Annual Cumulative Costs of the Proposed Trucks

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$42,000	$28,000	$58,000	$58,000	$58,000
2	$31,500	$25,200	$16,800	$48,300	$106,300	$53,150
3	$33,000	$15,120	$10,080	$43,080	$149,380	$49,793
4	$34,500	$9,072	$6,048	$40,548	$189,928	$47,482
5	$36,000	$5,443	$3,629	$39,629	$229,557	$45,911
6	$37,500	$3,266	$2,177	$39,677	$269,234	$44,872
7	$39,000	$1,960	$1,306	$40,306	$309,540	$44,220
8	$40,500	$1,176	$784	$41,284	$350,824	$43,853
9	$42,000	$705	$470	$42,470	$393,295	$43,699
10	$43,500	$423	$282	$43,782	$437,077	$43,708
11	$45,000	$254	$169	$45,169	$482,246	$43,841
12	$46,500	$152	$102	$46,602	$528,848	$44,071

Replacement Analysis

- Minimum Cost Method: the decision to replace equipment is made when the estimated annual cost of the current machine for the next year exceeds the minimum average annual cumulative cost of the replacement.

TABLE 3.10
Comparison of Average Annual Cumulative Costs

		Average Annual Cumulative Cost	
End of Year	**Annual Cost**	**Current Trucks**	**Proposed Trucks**
1	56,000	56,000	58,000
2	47,600	51,800	53,150
3	43,360	48,987	49,793
4	41,616	47,144	47,482
5	41,370	45,989	45,911
6	42,022	45,328	44,872
7	43,213	45,026	44,220
8	44,728	44,989	43,853
9	46,437	45,149	43,699
10	48,262	45,461	43,708
11	50,157	45,888	43,841
12	52,094	46,405	44,071

- The current truck's estimated annual cost for next year (i.e., end of Year 2) is $47,600.
- Minimum average annual cumulative cost of the proposed truck is $43,853.
- Decision: Replace the current year old trucks with the newer model.

Replacement Analysis

- Maximum Profit Method: Applicable organizations that are able to generate revenue and hence profits from their equipment.
  - Decision is based on the economic life of equipment, the year in which the average annual cumulative profit is maximized

TABLE 3.11
Average Annual Cumulative Profits of the Current Trucks

End of Year (1)	Annual Revenue (2)	Annual Cost (3)	Annual Profit (4) = (2) – (3)	Cumulative Profit (5)	Average Annual Cumulative Profit (6) = (5)/(1)
1	$70,000	$56,000	$14,000	$14,000	$14,000
2	$68,250	$47,600	$20,650	$34,650	$17,325
3	$66,500	$43,360	$23,140	$57,790	$19,263
4	$64,750	$41,616	$23,134	$ 80,924	$20,231
5	$63,000	$41,370	$21,630	$102,554	$20,511
6	$61,250	$42,022	$19,228	$121,783	$20,297
7	$59,500	$43,213	$16,287	$138,070	$19,724

Replacement Analysis

- Maximum Profit Method:
  - Current Trucks: End 4th year (because the average annual cumulative profit is maximized in that year by $20,511).
  - Purposed Trucks: End 4th year (because the average annual cumulative profit is maximized in that year by $24,486).
  - Decision: Replace as annual cumulative profit of Proposed > Current

TABLE 3.12
Average Annual Cumulative Profits of Proposed Trucks

End of Year (1)	Annual Revenue (2)	Annual Cost (3)	Annual Profit (4) = (2) – (3)	Cumulative Profit (5)	Average Annual Cumulative Profit (6) = (5)/(1)
1	$70,000	$48,300	$21,700	$21,700	$21,700
2	$68,250	$43,080	$25,170	$46,870	$23,435
3	$66,500	$40,548	$25,952	$72,822	$24,274
4	$64,750	$39,629	$25,121	$97,943	$24,486
5	$63,000	$39,677	$23,323	$121,266	$24,253
6	$61,250	$40,306	$20,944	$142,210	$23,702
7	$59,500	$41,284	$18,216	$160,426	$22,918
8	$57,750	$42,470	$15,280	$175,705	$21,963

Replacement Analysis

- Payback Period Method: is the time required for a piece of equipment to return its original investment by generating profit. It does not focus on the economic life of the equipment or effects beyond the payback period.
  - Current Truck:
    - Initial cost of the current truck = $65,000
    - Cumulative profits for the first 3 years = $57,790
    - Difference = $65,000 – $57,790 = $7,210
    - Profit of the fourth year = $23,134
    - Proportional fraction of the third year = $7,210/$23,134 = 0.31
    - Payback period for the current trucks = 3+0.31 = 3.31 years.

Replacement Analysis

- Payback Period Method:
  - Proposed Truck:
  - Initial cost of the current truck = $70,000
  - Cumulative profits for the first 2 years = $46,870
  - Difference = $70,000 – $46,870 = $23,130
  - Profit of the fourth year = $25,952
  - Proportional fraction of the third year = $23,130/$25,952 = 0.89
  - Payback period for the current trucks = 2+0.89 = 2.89 years.
  - Decision: Replace as 2.89 year payback period of the proposed replacement trucks is shorter than that of the 3.31 year payback period of the current trucks.

Equipment Replacement Decisions

- Replacement Equipment Selection:
  - Usually, “defender–challenger analysis” is used to methodically compare alternatives using engineering economic theory.
  - However, rather than using present worth approached, commonly annual worth approaches are used for economic evaluation.

- Equivalent Annual Cost (EAC): is the annualized cost of purchasing and salvaging an equipment, assuming replacement periods:
- $EAC_{Total} = EAC_{Capital\ costs} + EAC_{Costs\ for\ Repair, Maintenenace, Operation, etc.}$

- $EAC_{Capital\ costs}$ is determined using Capital Recovery Formula

Equipment Replacement Decisions

- Capital Recovery Formula considers an equipment purchased at a cost of P on the basis of that it will recover annual savings of A and will be sold for salvage value S after useful life n:
- $A = P(A/P, i, n) - S(A/F, i, n)$
- $(A/F, i, n) = (A/P, i, n) - i$
- $A = P(A/P, i, n) - S(A/P, i, n) + S * i$
- $A = (P - S)(A/P, i, n) + S * i$
- Therefore,
- $EAC_{Capital\ costs} = (P - S)(A/P, i, n) + S * i$
  - P = Purchase price
  - S = Salvage Value of the asset at the end of n-years and can be calculated from $BV_{db}(n) = P(1 - d)^n$

Replacement Equipment Selection

- Replacement Cases:
  1. Defender and Challenger are identical and repeat indefinitely
  2. Challenger repeats indefinitely, but is different from Defender
  3. Challenger is different from Defender, but does not repeat
- Case I: Defender and Challenger are identical and repeat indefinitely
- As all assets/equipments require replacement, the decision is usually when rather than whether.
- Assumptions:
  - Technologically identical and the asset technology is not changing rapidly
  - Lives of equipments is assumed to be short relative to the time horizon over which the equipments are required
  - Relative prices and interest rates are assumed to be constant over the time horizon
- Example: Consider an equipment with $7500 initial cost; $900 arithmetic gradient maintenance and repair cost; and $500 uniform cost and $400 arithmetic gradient operating cost

Replacement Equipment Selection

Year	EUAC of Capital Recovery Costs	EUAC of Maintenance and Repair Costs	EUAC of Operating Costs	EUAC Total	Interest rate
Initial year	-7500	0	-500		8%
Arithmetic gradient		-900	-400		
1	$8,100.00	$0.00	$500.00	$8,600.00	
2	$4,205.77	$432.69	$692.31	$5,330.77	
3	$2,910.25	$853.87	$879.50	$4,643.62	
4	$2,264.41	$1,263.56	$1,061.58	$4,589.55	<-----MIN
5	$1,878.42	$1,661.82	$1,238.59	$4,778.84	
6	$1,622.37	$2,048.71	$1,410.54	$5,081.62	
7	$1,440.54	$2,424.30	$1,577.47	$5,442.31	
8	$1,305.11	$2,788.67	$1,739.41	$5,833.19	
9	$1,200.60	$3,141.93	$1,896.41	$6,238.94	
10	$1,117.72	$3,484.18	$2,048.53	$6,650.43	
11	$1,050.57	$3,815.55	$2,195.80	$7,061.93	
12	$995.21	$4,136.17	$2,338.30	$7,469.68	
13	$948.91	$4,446.19	$2,476.08	$7,871.18	
14	$909.73	$4,745.75	$2,609.22	$8,264.69	
15	$876.22	$5,035.01	$2,737.78	$8,649.02	

Replacement Equipment Selection

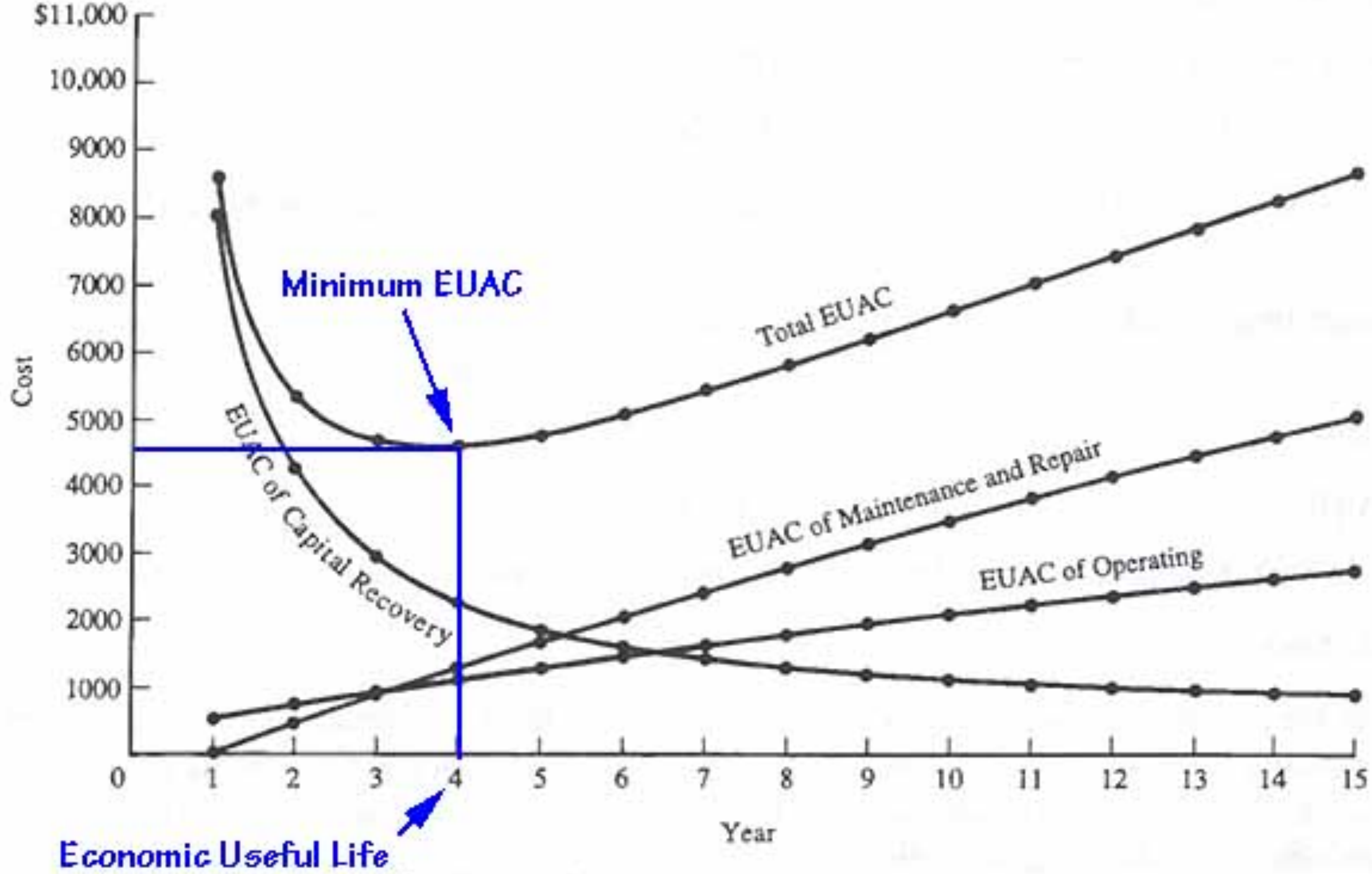


Figure 12-3 Plot of costs for Example 12-1.

Replacement Equipment Selection

- Case I: Defender and Challenger are identical and repeat indefinitely
- Example: ABC construction company produces prefabricated building elements. They are considering to install a new automated molding system. The molder costs \$20,000 and installation costs are estimated to be \$5,000. Operating and maintenance costs are expected to be \$30,000 in the first year and will rise at the rate of 5% per year. The depreciation cost will be estimated using declining-balance model using a rate of 40%, and the company uses a MARR of 15% for capital investments. How long should the company keep the molder before replacing it with a new model? In other words, what is the economic life of the automated molding system?

- $EAC_{Total} = EAC_{Capital\ costs} + EAC_{Operating\ and\ Maintenance\ Costs}$
- Let:
- $P = Current\ Value\ of\ Equipment = Purchase\ Price + Installation\ Costs$
- $S = Salvage\ value\ for\ the\ equipment\ n\ years\ in\ the\ future$

Replacement Equipment Selection

- For example for Year 4,
- $BV_{db}(n) = P(1-d)^n$
- $BV_{db}(4) = \$20{,}000(1-0.4)^4 = \$2{,}592$
- $EAC_{Capital\ costs} = (P-S)(A/P, i, n) + S * i$
- $EAC_{Capital\ costs} = (\$20{,}000 - \$2{,}592)(A/P, 15\%, 4) + \$2{,}592 * 0.15 = \$8{,}238$
- $EAC_{Operating\ and\ Maintenance\ Costs} = \$30{,}000[(P/F, 15\%, 1) + (1.05)(\mathrm{P/F}, 15\%, 2) + (1.05)^2\,(P/F, 15\%, 3) + (1.05)^3\,(P/F, 15\%, 4)](\mathrm{A/P}, 15\%, 4) = \$32{,}052$
- $EAC_{Total} = EAC_{Capital\ costs} + EAC_{Operating\ and\ Maintenance\ Costs}$
- $EAC_{Total} = \$8{,}238 + \$32{,}052 = \$40{,}290$

Replacement Equipment Selection

Life	Salvage Value	EAC Capital	EAC Oper. and Main.	EAC Total
0	$20,000.00			
1	12,000.00	$16,750.00	$30,000.00	$46,750.00
2	7,200.00	12,029.07	30,697.67	42,726.74
3	4,320.00	9,705.36	31,382.29	41,087.65
4	2,592.00	8,237.55	32,052.47	40,290.02
5	1,555.20	7,227.23	32,706.94	39,934.17
6	933.12	6,499.33	33,344.56	39,843.88
7	559.87	5,958.42	33,964.28	39,922.70
8	335.92	5,546.78	34,564.20	40,111.98
9	201.55	5,227.34	35,146.55	40,373.89
10	120.93	4,975.35	35,707.69	40,683.04

The economic life of the equipment is 6 years.

Replacement Equipment Selection

- Case II: Challenger is Different from Defender: Challenger repeats indefinitely
- Procedure:

1. Determine the economic life of the challenger and its associated EAC
2. Determine the remaining economic life of the defender and its associated EAC.
   - One Year Principle is commonly used. It states that if the capital costs for the defender are small compared to the operating costs, and the yearly operating costs are monotonically increasing, the economic life of the defender is one year and its total EAC is the cost of using the defender for one more year.
3. If the EAC of the defender is greater than the EAC of the challenger, replace the defender now. Otherwise, do not replace now.
   - Using the One Year Principle: If the EAC of keeping the defender one more year exceeds the EAC of the challenger at its economic life, the defender should be replaced immediately.

Replacement Equipment Selection

- Example: ABC construction company pays a custom molder \$0.25 per element (excluding material costs) to produce building prefab elements. Demand is forecast to be 200,000 elements per year. ABC is considering installing the automated molding system to produce the elements themselves. Should they do so?
- Defender is the current technology (Subcontractor).
- Challenger is the automated molding system.
- Unit Cost of Challenger:
  - EAC (molder) = \$39,844
  - Unit Cost (molder) = EAC/Unit = \$39,844 / 200,000 = \$0.1992
- Unit Cost of Defender:
  - Unit Cost (in house) = \$0.25
- Decision: Replace as Unit-cost of Challenger < Defender

Replacement Equipment Selection

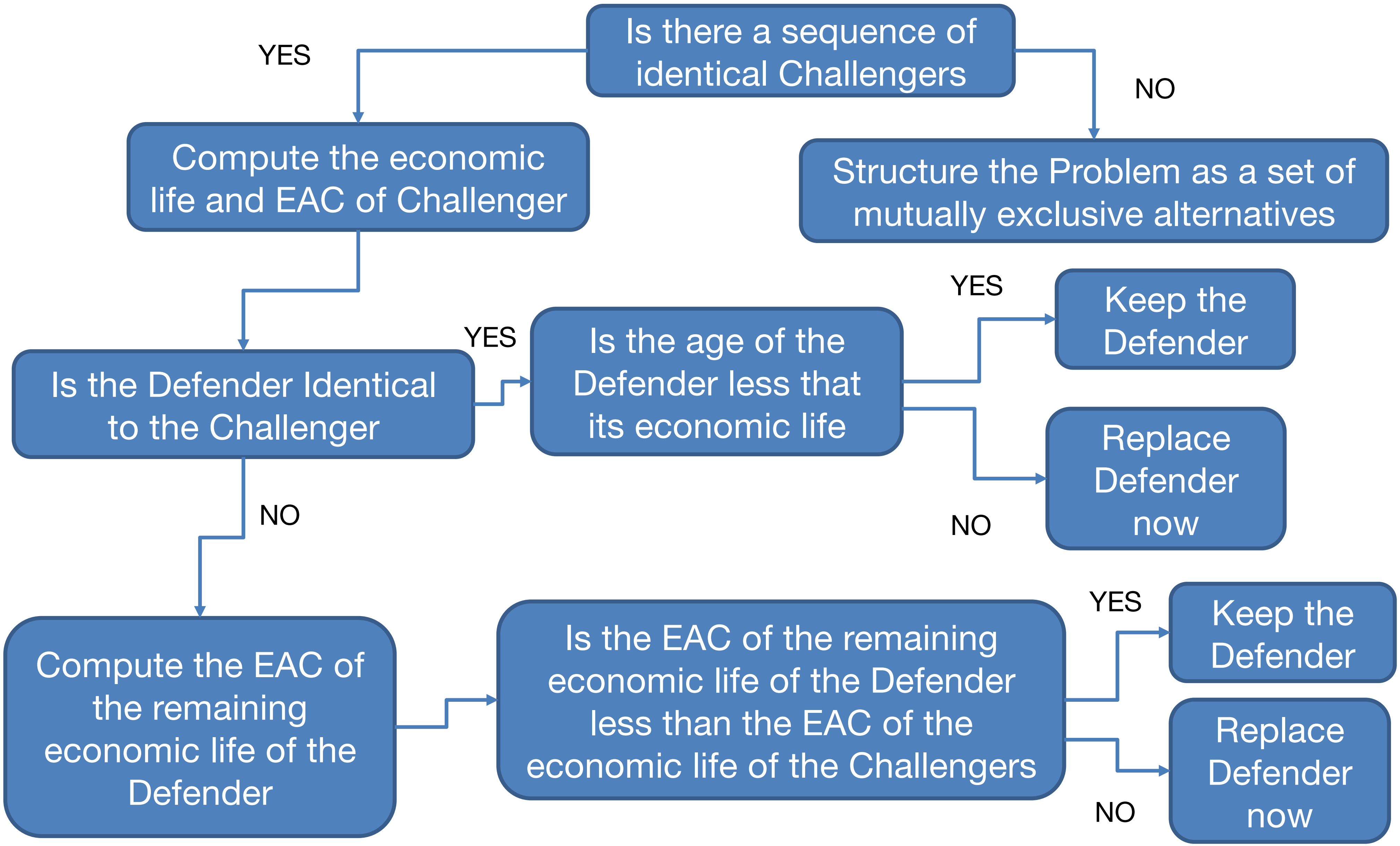
- Case III: Challenger is Different from Defender: Challenger does not repeat
- In this case it is recognized that the future challengers will be available and we expect them to be better than the current challenger.
- Example: Derba cement is examining the possibility of replacing the kiln controllers. They have information about existing controllers and the best replacement on the market. They also have information about new controller design that will be available in three years. Debra has five-year time horizon for the problem. What replacement alternatives should Derba consider?
- To determine the minimum cost over 5 year horizon is to determine the cost of all possible combinations of the defender and the two challengers.
- However, as the defender and challenger can replace one another at any time, it is not possible to determine all possible combinations.
- Assuming the period is one year (yearly investment cycle), we can compare them as mutually exclusive alternatives:

Replacement Equipment Selection

Decision Alternative	Defender Life in Years	First Challenger Life in Years	Second Challenger Life in Years
1	5	0	0
2	4	1	0
3	4	0	1
4	3	2	0
5	3	1	1
6	3	0	2
7	2	3	0
8	2	2	1
9	2	1	2
10	1	4	0
11	1	3	1
12	1	2	2
13	0	5	0
14	0	4	1
15	0	3	2

- Alternative 1:Keep Defender for 5 years
- Alternative 2: Keep Defender for 4 years, then purchase Challenger 4 years from now and keep it for one year
- Alternative 15: Replace Defender now with first Challenger, keep it for 3 years, then replace it with the second Challenger, and keep the second Challenger for the remaining of 2 years
- Comparison: using PW, AW, or IRR

Replacement Decision Flow Chart



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