EM600 - Engineering Economics and Cost Analysis

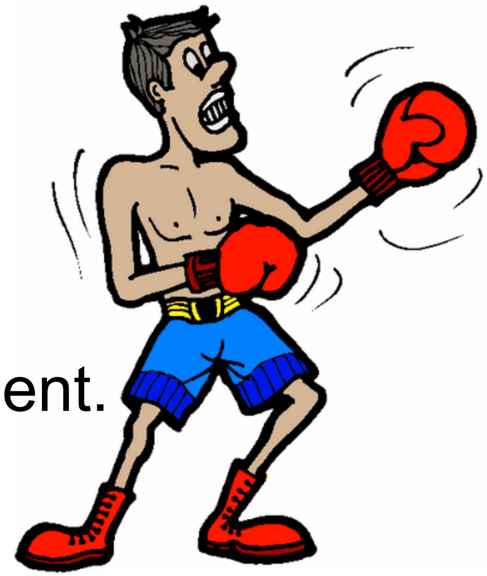
Lecture 09: *Retirements and Replacements*

- References:
  - Park, Chan S. Contemporary Engineering Economics. New Jersey: Pearson Prentice Hall, 2006 (Chapter 14)
  - Ganguly, A. Engineering Economics Using Excel. New Jersey: SSE, 2008

After completing this module you should understand the following:

- Basic Concepts and terminologies
- Economic service life
- Replacement analysis under different conditions
- Replacement Analysis with Tax Considerations (brief overview).

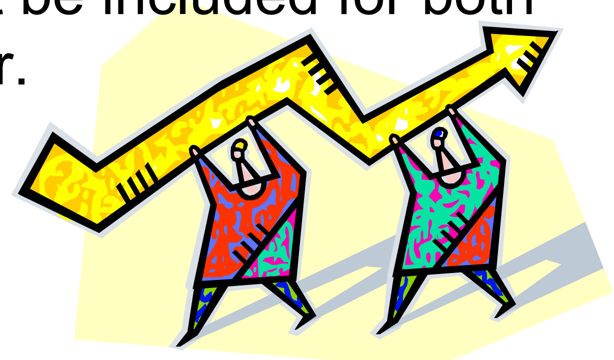
- Basic Concepts and Terminology:
  - Replacement Projects:
    - Decision problems involving the replacement of existing obsolete or worn-out assets.
    - When should existing equipment be replaced with more efficient equipment?
  - Defender:
    - Existing machine or system.
  - Challenger:
    - Best available replacement equipment.



- Basic Concepts and Terminology:
  - Current Market Value:
    - selling price of the defender in the market place.
  - Trade-in Allowance:
    - value offered by the vendor to reduce the price of a new equipment.
  - Note:
    - The current market value and the trade-in allowance typically differ.

- Basic Concepts and Terminology:
  - Sunk Costs:
    - Any past cost that is unaffected by any future investment decision.
    - Costs that have already been incurred and which cannot be recovered to any significant degree.
    - Should NOT be considered when making economic decisions.
    - Economic decisions should be based on the best possible FUTURE results.

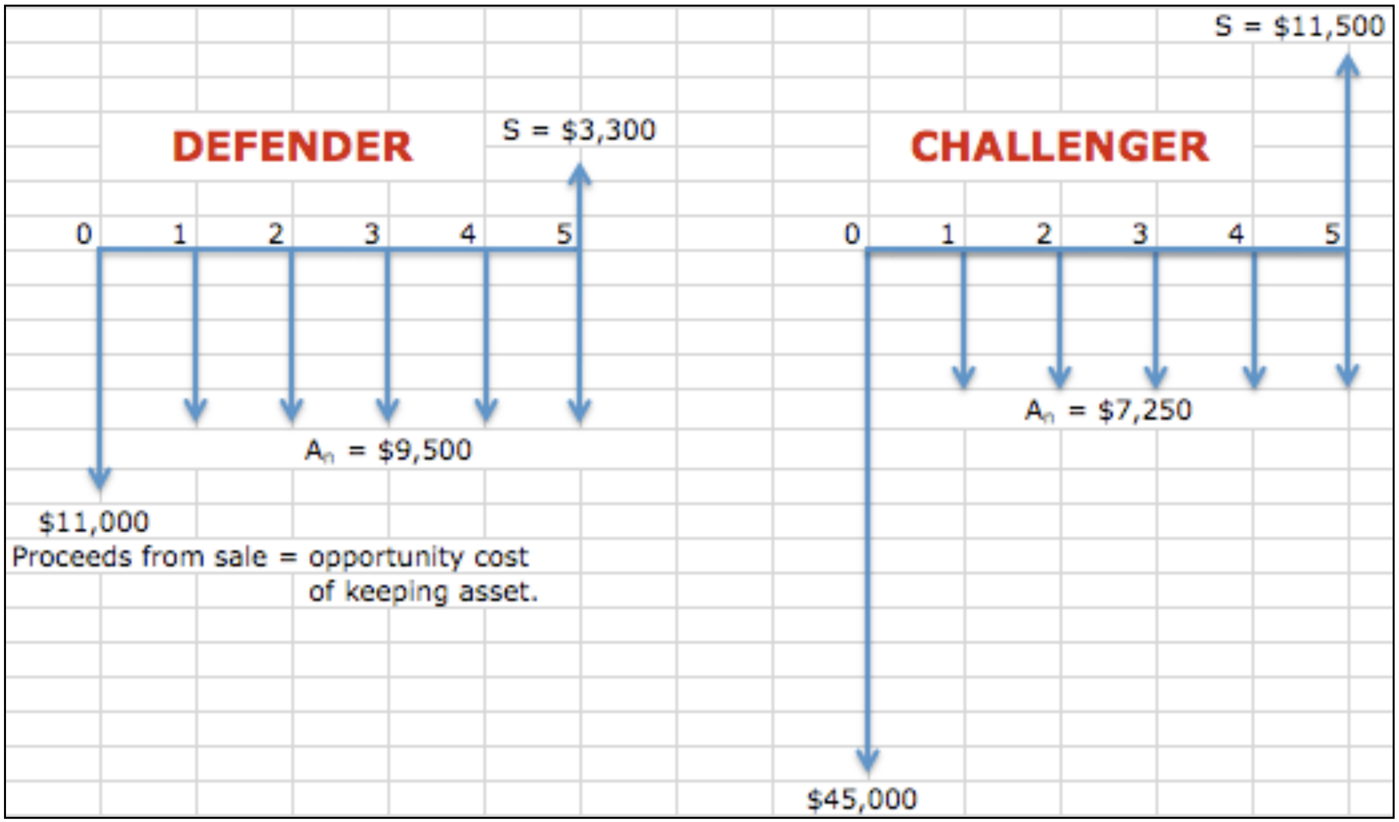
- Basic Concepts and Terminology:
  - Operating Costs:
    - Recurring costs needed to run any business and can be broken down by division, group, system, equipment components, . . . etc.
    - Includes repair and maintenance; operator wages; material costs; energy costs; . . . etc.
    - Replacement decisions can be based on increasing operating costs over time.
    - The same operating costs must be included for both the defender and the challenger.



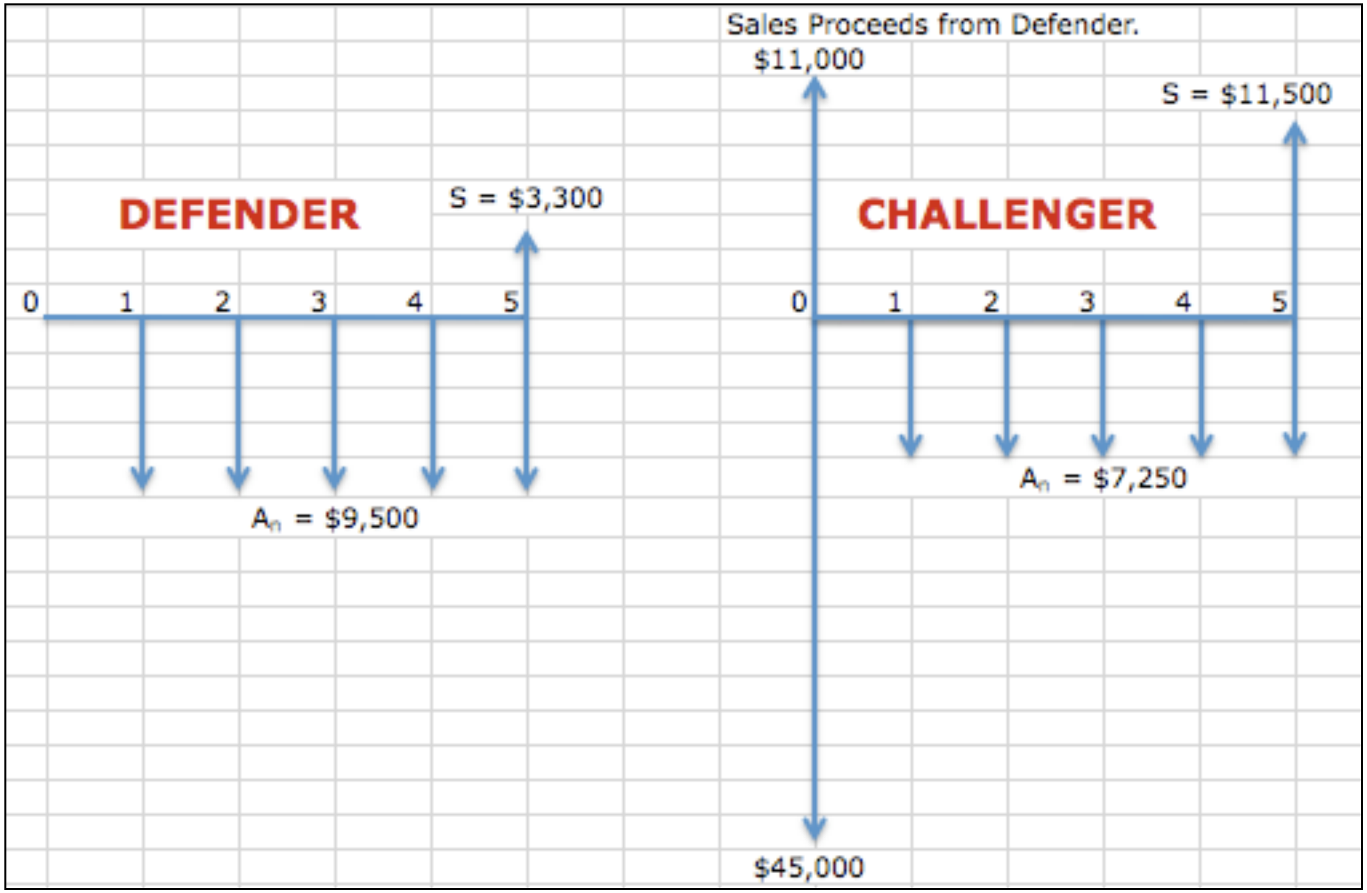
- Basic Concepts and Terminology:
  - Cash Flow Approach:
    - Treat the proceeds from sale of the old machine as down payment toward purchasing the new machine.
    - This approach is meaningful when both the defender and challenger have the same service life
  - Opportunity Cost Approach:
    - Keeping the defender means the potential sales receipt is forgone.
    - Treat the proceeds from sale of the old machine as the investment required to keep the old machine.
    - This approach is more commonly practiced in replacement analysis.

- Basic Concepts and Terminology:
  - Consider the following situation:
    - Defender:
      - Current Market Value = $11,000
      - Useful Life = additional 5 years
      - Operating Costs = $9,500
      - Salvage Value = $3,300
    - Challenger:
      - Purchase Cost = $45,000
      - Useful Life = 5 years
      - Operating Costs = $7,250
      - Salvage Value = $11,500
  - Compare the opportunity cost approach and cash flow approach using cash flow diagrams.

- Basic Concepts and Terminology:
  - Opportunity Cost Approach:



- Basic Concepts and Terminology:
  - Cash Flow Approach:



- Economic Service Life:
  - Definition: (Chan S. Park)
    - *The remaining useful life of an asset that results in the minimum annual equivalent cost.*
  - Costs to be considered: (Ref: Lecture 3)
    - Capital Recovery Costs
      - Initial investment, I
        - » Defender = Opportunity Cost
        - » Challenger = Purchase Cost
      - Salvage value, S
    - Operating Costs
      - Includes repair and maintenance; operator wages; material costs; energy costs; . . . etc

- Economic Service Life:
  - Equivalent Uniform Annual Cost (EUAC)
    - Capitalized Recovery Costs, CR(i)
      - typically a decreasing function of N i.e. the longer the asset is kept, the lower the capital recovery cost
      - $CR(i) = I(A/P,i,N) - S(A/F,i,N)$

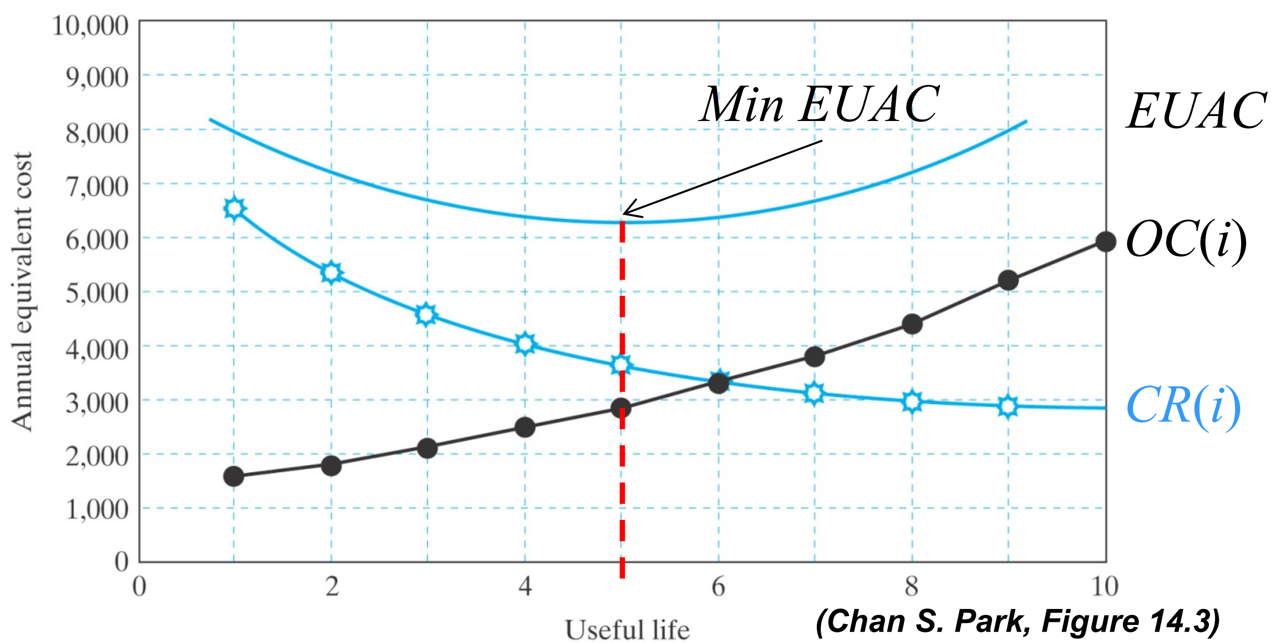
        $CR(i) = (I - S)(A/P,i,N) + iS$
    - Operating Costs, OC(i)
      - typically an increasing function of N i.e. the longer the asset is kept, the higher the operating cost.
      - $OC(i) = \left(\sum_{n=1}^{N} OC_n (P/F,i,n)\right)(A/P,i,N)$ where,

        OC_n = the total operating costs in year n of the ownership period

- Economic Service Life:
  - Equivalent Uniform Annual Cost (EUAC)
    - Also known as the Annual Equivalent Cost (AEC).
    - Calculated through the summation of the capital recovery costs [CR(i)] and the operating costs [OC(i)].
    - $EUAC(i) = CR(i) + OC(i)$

- Economic Service Life:
  - Objective:
    - MINIMIZE the Equivalent Uniform Annual Cost (EUAC).
  - 4 Cases:
    - **Case 1:** CR(i) is a decreasing function of N and OC(i) is an increasing function of N
    - **Case 2:** S is constant and equals I, and OC(i) is an increasing function of N
    - **Case 3:** S is < I and decreases with N, and OC(i) is constant
    - **Case 4:** S is constant and equals I, and OC(i) is constant
  - ***Focus point for this class = Case 1***

- Economic Service Life:
  - **Case 1:** CR(i) is a decreasing function of N and OC(i) is an increasing function of N
    - Most typical scenario
    - EUAC will be a convex function of N with a unique minimum point.



(Chan S. Park, Figure 14.3)

- Economic Service Life:
  - **Case 2:** S is constant and equals I, and OC(i) is an increasing function of N
    - EUAC is an increasing function of N
    - EUAC therefore is a minimum at N = 1
    - Replace the asset as soon as is possible
  - **Case 3:** S is < I and decreases with N, and OC(i) is constant
    - EUAC is an decreasing function of N
    - Delay the replacement of the asset as much as is possible
  - **Case 4:** S is constant and equals I, and OC(i) is constant
    - EUAC will be constant
    - The timing for asset replacement has no economic benefit

- Economic Service Life:
  - Example 1:
    - A drug manufacturer is considering purchasing a conveyance system for to make it easier to transport finished drugs around the factory. The system will cost $55,000 and have operating costs that start at $9,000 the first year and increase by 15% year-on-year. The system will have a salvage value of $41,500 at the end of the first year. The salvage value will decrease at a rate of 20% year-on-year. The system has a maximum life of 7 years. An overhaul is required during the 5th &7th years at a cost of $2,500 and $4,500 to maintain the system.
    - The MARR for this project is 15%.
    - ***Calculate the economic service life of the truck***.
    - ***Show calculations in Excel***

- Economic Service Life:
  - Example 1:
    - Step 1: Calculate OC_n and S_n for each year ($n = 1, \ldots, 7$)

Year	Annual S	Annual OC
0	-	-
1	$41,500	$9,000
2	$33,200	$10,350
3	$26,560	$11,903
4	$21,248	$13,688
5	$16,998	$18,241
6	$13,599	$18,102
7	$10,879	$25,318

- Economic Service Life:
  - Example 1:

$$\boxed{CR(i) = I(A/P,i,N) - S(A/F,i,N)}$$

    - Step 2: Calculate CR(i) for each year (n = 1, . . . , 7)

Year	I	(A/P, i, N)	Annual S	(A/F, i, N)	CR(i)
0	$55,000	-	-	-	-
1		1.1500	$41,500	1.0000	$21,750
2		0.6151	$33,200	0.4651	$18,389
3		0.4380	$26,560	0.2880	$16,441
4		0.3503	$21,248	0.2003	$15,011
5		0.2983	$16,998	0.1483	$13,886
6		0.2642	$13,599	0.1142	$12,978
7		0.2404	$10,879	0.0904	$12,239

- Economic Service Life:
  - Example 1:

$$\boxed{OC(i) = \left(\sum_{n=1}^{N} OC_n(P/F,i,n)\right)(A/P,i,N)}$$

    - Step 3: Calculate OC(i) for each year (n = 1, . . . , 7)

Year	Annual OC	(P/F, i, n)	(A/P, i, N)	OC(i)
0	-	-	-	-
1	$9,000	0.8696	1.1500	$9,000
2	$10,350	0.7561	0.6151	$9,628
3	$11,903	0.6575	0.4380	$10,283
4	$13,688	0.5718	0.3503	$10,966
5	$18,241	0.4972	0.2983	$12,044
6	$18,102	0.4323	0.2642	$12,734
7	$25,318	0.3759	0.2404	$13,875

- Economic Service Life:
  - Example 1:

$$OC(i) = \left(\sum_{n=1}^{N} OC_n (P/F, i, n) \right) (A/P, i, N)$$

    - Step 3: Calculate OC(i) for each year (n = 1, . . . , 7)

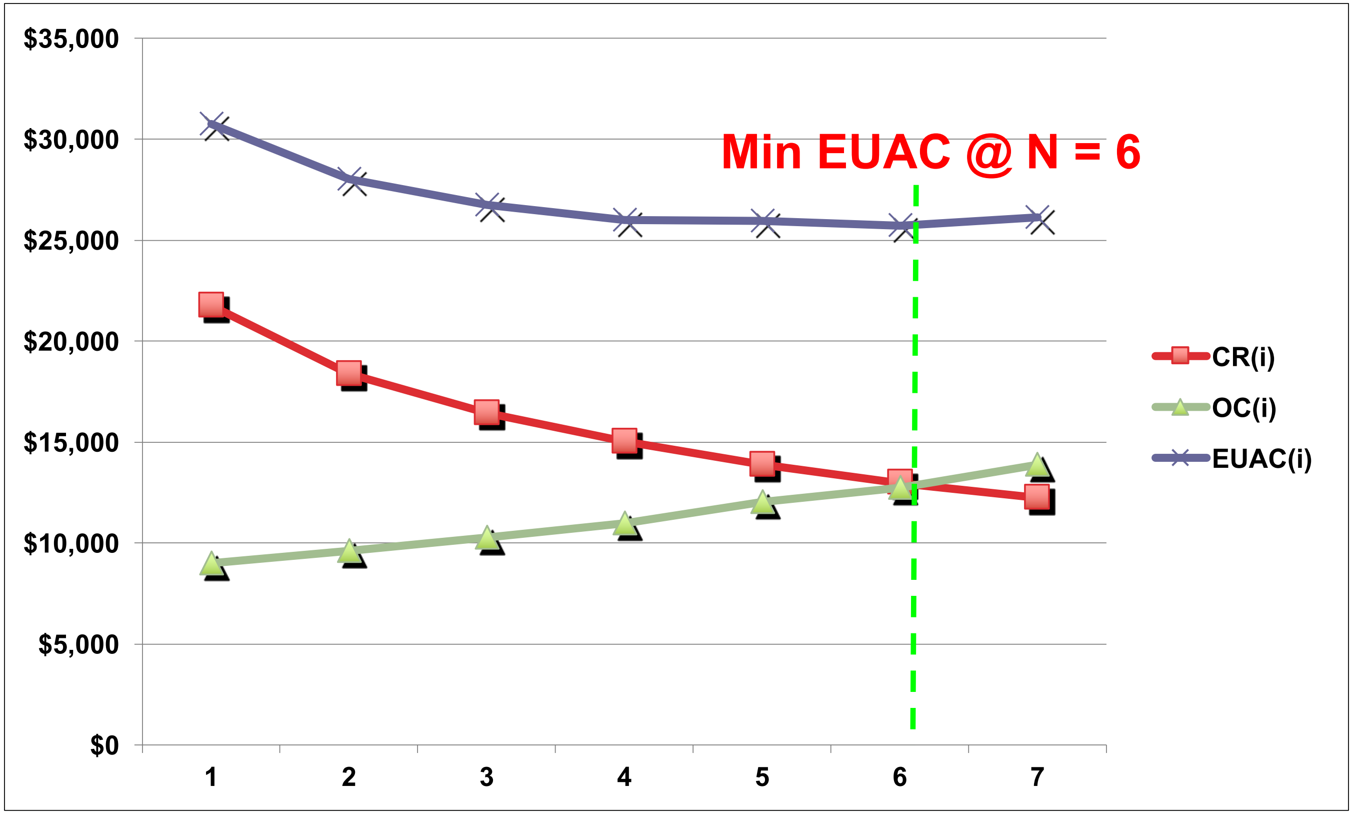
Year	OC_n	(P/F, i, n)	OC_n(P/F, i, n)	ΣOC_n(P/F, i, n)	(A/P, i, N)	OC(i)
0	-	-	-	-	-	-
1	$9,000	0.8696	$7,826	$7,826	1.1500	$9,000
2	$10,350	0.7561	$7,826	$15,652	0.6151	$9,628
3	$11,903	0.6575	$7,826	$23,478	0.4380	$10,283
4	$13,688	0.5718	$7,827	$31,305	0.3503	$10,966
5	$18,241	0.4972	$9,069	$40,374	0.2983	$12,044
6	$18,102	0.4323	$7,825	$48,200	0.2642	$12,734
7	$25,318	0.3759	$9,517	$57,717	0.2404	$13,875

- Economic Service Life:
  - Example 1:
    - Step 4: Calculate EUAC(i) for each year (n = 1, . . . , 7)

Year	CR(i)	OC(i)	EUAC(i)
0	-	-	-
1	$21,750	$9,000	$30,750
2	$18,389	$9,628	$28,017
3	$16,441	$10,283	$26,724
4	$15,011	$10,966	$25,977
5	$13,886	$12,044	$25,929
6	$12,978	$12,734	**$25,712**
7	$12,239	$13,875	$26,114

Minimum EUAC if kept for 6 years

- Economic Service Life:
  - Example 1:
    - Step 5: Plot Results



- Economic Service Life:
  - Example 1:
    - Step 6: Conclusion

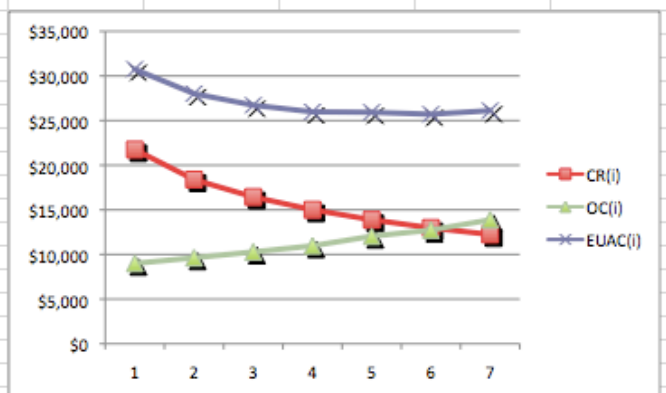
      A life span of 6 years results in the lowest annual cost.

      The economic service life of the system is therefore 6 years.

N = 6

- Economic Service Life:
  - Example 1: (EXCEL)

	M	N	O	P	Q	R	S	T	U	V
1	I	$55,000								
2	S	$41,500	year 1							
3	OC	$9,000	year 1							
4										
5	OC increase	15%	each year							
6	S decrease	20%	each year							
7										
8	Overhaul:									
9	year 5	$2,500								
10	year 7	$4,500								
11										
12	MARR	15%								
13										
14	Year	I	Annual S	Annual OC	(A/P, i, N)	(A/F, i, N)	CR(i)	(P/F, i, N)	OC(i)	EUAC(i)
15	0	$55,000	-	-	-	-	-	-	-	-
16	1		$41,500	$9,000	1.1500	1.0000	$21,750	0.8696	$9,000	$30,750
17	2		$33,200	$10,350	0.6151	0.4651	$18,389	0.7561	$9,628	$28,017
18	3		$26,560	$11,903	0.4380	0.2880	$16,441	0.6575	$10,283	$26,724
19	4		$21,248	$13,688	0.3503	0.2003	$15,011	0.5718	$10,966	$25,977
20	5		$16,998	$18,241	0.2983	0.1483	$13,886	0.4972	$12,044	$25,929
21	6		$13,599	$18,102	0.2642	0.1142	$12,978	0.4323	$12,734	$25,712
22	7		$10,879	$25,318	0.2404	0.0904	$12,239	0.3759	$13,875	$26,114



- Economic Service Life:
  - Example 1: (EXCEL)

	M	N	O	P	Q	R	S	T	U	V
1	I	$55,000								
2	S	$41,500	year 1							
3	OC	$9,000	year 1							
4										
5	OC increase	15%	each year							
6	S decrease	20%	each year							
7										
8	Overhaul:									
9	year 5	$2,500								
10	year 7	$4,500								
11										
12	MARR	15%								
13										
14	Year	I	Annual S	Annual OC	(A/P, i, N)	(A/F, i, N)	CR(i)	(P/F, i, N)	OC(i)	EUAC(i)
15	0	$55,000	-	-	-	-	-	-	-	-
16	1		$41,500	$9,000	1.1500	1.0000	$21,750	0.8696	$9,000	$30,750
17	2		$33,200	$10,350	0.6151	0.4651	$18,389	0.7561	$9,628	$28,017
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22	7		$10,879	$25,318	0.2404	0.0904	$12,239	0.3759	$13,875	$26,114

=O16-O16*N$6

=P18*(1+N$5) . . . No overhaul to account for, just apply increase to previous year

=P19*(1+N$5)+N9 . . . Include Overhaul after applying increase to previous year

=(P20-N9)*(1+N$5) . . . Remove Overhaul from previous year before applying increase

- Economic Service Life:
  - Example 1: (EXCEL)

$$CR(i) = I(A/P,i,N) - S(A/F,i,N)$$

$$OC(i) = \left(\sum_{n=1}^{N} OC_n (P/F,i,n)\right)(A/P,i,N)$$

◇	M	N	O	P	Q	R	S	T	U	V
1	I	$55,000								
2	S	$41,500	year 1							
3	OC	$9,000	year 1							
4										
5	OC increase	15%	each year							
6	S decrease	20%	each year							
7										
8	Overhaul:									
9	year 5	$2,500								
10	year 7	$4,500								
11										
12	MARR	15%								
13										
14	Year	I	Annual S	Annual OC	(A/P, i, N)	(A/F, i, N)	CR(i)	(P/F, i, N)	OC(i)	EUAC(i)
15	0	$55,000	-	-	-	-	-	-	-	-
16	1		$41,500	$9,000	1.1500	1.0000	$21,750	0.8696	$9,000	$30,750
17	2		$33,200	$10,350	0.6151	0.4651	$18,389	0.7561	$9,628	$28,017
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22	7		$10,879	$25,318	0.2404	0.0904	$12,239	0.3759	$13,875	$26,114

=(P16*T16+P17*T17)*Q17

=(P16*T16+P17*T17+P18*T18+P19*T19+P20*T20+P21*T21)*Q21

=N$15*Q18-O18*R18

=S17+U17

- When should the defender be replaced?
  - Required Assumptions and Decision Frameworks:
    - Planning horizon (study period)
    - Technology
    - Revenue and cost patterns over the life of an asset.
    - Decision Frameworks
    - Decision Criterion

- When should the defender be replaced?
  - Required Assumptions and Decision Frameworks:
    - Planning horizon (study period)
      - Service period required by the defender and a sequence of future challengers.
      - Infinite Planning Horizon
        - » Unable to predict when the project under consideration will be terminated.
      - Finite Planning Horizon
        - » Project has a definite and predictable duration.
        - » A replacement policy can be put in place.

- When should the defender be replaced?
  - Required Assumptions and Decision Frameworks:
    - Technology
      - Refers to the development of new challengers that may replace those under study.
      - Is technological change and obsolescence likely?

- When should the defender be replaced?
  - Required Assumptions and Decision Frameworks:
    - Revenue and cost patterns over the life of an asset.
      - Different ways to predict patterns of cost, revenue and salvage value over the life of an asset.
      - Replacement analysis directed towards
        - » Cost minimization (constant revenue)
        - » Profit maximization (varying revenue)

- When should the defender be replaced?
  - Required Assumptions and Decision Frameworks:
    - Decision Frameworks
      - Details how long the defender will be kept before replacement, and how long each subsequent challenger will be kept before replacement.
    - Decision Criterion
      - The correct replacement time depends on data from both the challenger and the defender.
      - Infinite planning horizon: use annual equivalence
      - Finite planning horizon: use present worth

- Replacement Strategies:
  - Infinite Planning horizon:
    - Replacement problem is not *whether* to replace the defender, but *when* to do so.
    - Defender is always replaced by challenger.
    - Identical challenger (no tech change) or new challenger (tech change) can then replace the challenger repeatedly.
    - Two options:
      - Replace the defender now.
      - Replace the defender x years later.

- Replacement Strategies:
  - Infinite Planning Horizon:
    - Replace the defender now.
      - The cash flows of the challenger estimated today will be used.
      - An identical challenger will be used thereafter if replacement becomes necessary again in the future.
      - Stream of cash flows is equivalent to a cash flow of $EUAC_C$* (EUAC of challenger at economic service life, N_C*) each year for an infinite number of years.
    - Replace the defender x years later.
      - The cash flows of the defender will be used in the first x years.
      - Starting in year x+1,the cash flows of the challenger will be used indefinitely thereafter.

- Replacement Strategies:
  - Infinite Planning Horizon
    - Example 2: (Chan S. Park, example 14.4)
      - Consider the following data for a defender and challenger:

	Defender	Challenger	Year
N	5	5	
Overhaul	$1,200	-	0
Investment, I	Calculate	$10,000	0
S	$5,000	$6,000	0 / 1
S (decrease)	$1,000	15%	
OC	$2,000	$2,000	1/1
OC (increase)	$1,500	$800	
MARR	15%	15%	

- Replacement Strategies:
  - Infinite Planning Horizon
    - Example 2: (Chan S. Park, example 14.4)
      - Deliverables:
        - » Calculate the economic service life for each option.
        - » Determine when the defender should be replaced.

- Example 2: (Chan S. Park, example 14.4)
  - **DEFENDER:**
    - Step 1: Calculate I (n = 0) and OC_n & S_n for each year (n = 1, . . . , 5)

Year	I	Annual OC	Annual S
0	$6,200	$0	$5,000
1	$0	$2,000	$4,000
2	$0	$3,500	$3,000
3	$0	$5,000	$2,000
4	$0	$6,500	$1,000
5	$0	$8,000	$0

Note:

I = (Overhaul) + (Opportunity Cost of NOT selling)

I = $1,200 + $5,000 = $6,200

Market / Salvage value year 0

- Example 2: (Chan S. Park, example 14.4)
  - **DEFENDER:**
    - Step 2: Calculate CR(i) for each year (n = 1, . . . , 5)

Year	I	(A/P, i, N)	Annual S	(A/F, i, N)	CR(i)
0	$6,200	-	$5,000	-	-
1		1.1500	$4,000	1.0000	$3,130
2		0.6151	$3,000	0.4651	$2,418
3		0.4380	$2,000	0.2880	$2,140
4		0.3503	$1,000	0.2003	$1,972
5		0.2983	$0	0.1483	$1,849

$$\boxed{CR(i) = I(A/P,i,N) - S(A/F,i,N)}$$

- Example 2: (Chan S. Park, example 14.4)
  - **DEFENDER:**
    - Step 3: Calculate OC(i) for each year (n = 1, . . . , 5)

Year	Annual OC	(A/P, i, N)	(P/F, i, N)	OC(i)
0	-	-	-	-
1	$2,000	1.1500	0.8696	$2,000
2	$3,500	0.6151	0.7561	$2,698
3	$5,000	0.4380	0.6575	$3,361
4	$6,500	0.3503	0.5718	$3,990
5	$8,000	0.2983	0.4972	$4,584

Remember Slide 22?

$$\boxed{OC(i) = \left(\sum_{n=1}^{N} OC_n (P/F, i, n)\right)(A/P, i, N)}$$

- Example 2: (Chan S. Park, example 14.4)
  - **DEFENDER:**
    - Step 4: Calculate EUAC(i) for each year (n = 1, . . . , 5)

Year	CR(i)	OC(i)	EUAC(i)
0	-	-	-
1	\$3,130	\$2,000	\$5,130
2	\$2,418	\$2,698	**\$5,116**
3	\$2,140	\$3,361	\$5,500
4	\$1,972	\$3,990	\$5,961
5	\$1,849	\$4,584	\$6,434

- Economic Life of the Defender = N_D^* = 2
- EUAC at N_D^* = $EUAC_D^*$ = \$5,116

- Example 2: (Chan S. Park, example 14.4)
  - **CHALLENGER:**
    - Step 1: Calculate I (n = 0) and OC_n & S_n for each year (n = 1, . . . , 5)

Year	I	Annual OC	Annual S
0	$10,000	$0	$0
1	$0	$2,000	$6,000
2	$0	$2,800	$5,100
3	$0	$3,600	$4,335
4	$0	$4,400	$3,685
5	$0	$5,200	$3,132

- Example 2: (Chan S. Park, example 14.4)
  - **CHALLENGER:**
    - Step 2: Calculate CR(i) for each year (n = 1, . . . , 5)

Year	I	(A/P, i, N)	Annual S	(A/F, i, N)	CR(i)
0	$10,000	-	-	-	-
1		1.1500	$6,000	1.0000	$5,500
2		0.6151	$5,100	0.4651	$3,779
3		0.4380	$4,335	0.2880	$3,132
4		0.3503	$3,685	0.2003	$2,765
5		0.2983	$3,132	0.1483	$2,519

$$\boxed{CR(i) = I(A/P,i,N) - S(A/F,i,N)}$$

- Example 2: (Chan S. Park, example 14.4)
  - **CHALLENGER:**
    - Step 3: Calculate OC(i) for each year (n = 1, . . . , 5)

Year	Annual OC	(A/P, i, N)	(P/F, i, N)	OC(i)
0	-	-	-	-
1	$2,000	1.1500	0.8696	$2,000
2	$2,800	0.6151	0.7561	$2,372
3	$3,600	0.4380	0.6575	$2,726
4	$4,400	0.3503	0.5718	$3,061
5	$5,200	0.2983	0.4972	$3,378

Remember Slide 22?

$$\boxed{OC(i) = \left(\sum_{n=1}^{N} OC_n (P/F, i, n) \right) (A/P, i, N)}$$

- Example 2: (Chan S. Park, example 14.4)
  - **CHALLENGER:**
    - Step 4: Calculate EUAC(i) for each year (n = 1, . . . , 5)

Year	CR(i)	OC(i)	EUAC(i)
0	-	-	-
1	\$5,500	\$2,000	\$7,500
2	\$3,779	\$2,372	\$6,151
3	\$3,132	\$2,726	\$5,857
4	\$2,765	\$3,061	**\$5,826**
5	\$2,519	\$3,378	\$5,897

- Economic Life of the Challenger = N_C^* = 4
- EUAC at N_C^* = $EUAC_C^*$ = \$5,826

- Example 2: (Chan S. Park, example 14.4)
  - **SUMMARY:**
    - Defender:
      - Economic Life of the Defender = $N_D^* = 2$
      - EUAC at N_D^* = $EUAC_D^*$ = $5,116
    - Challenger
      - Economic Life of the Challenger = $N_C^* = 4$
      - EUAC at N_C^* = $EUAC_C^*$ = $5,826
    - Comparison
      - $EUAC_D^* < EUAC_C^*$

    - ***What does this mean?***

- Example 2: (Chan S. Park, example 14.4)
  - **CONCLUSION:**
    - ***The defender will have an equivalent annual cost of $5,116 per year for the next 2 years,***

      whereas,

      The challenger would have an equivalent annual cost of $5,826 per year for the next 2 years (assuming it is going to be kept for a total of 4 years).

    - ***Therefore, as the EUAC of the defender (if kept for 2 additional years) is lower than that of the challenger (if kept for 4 years), the defender should be kept for 2 more years.***

    - ***KEEP THE DEFENDER FOR 2 ADDITIONAL YEARS.***

- Example 2: (Chan S. Park, example 14.4)
  - **When should the defender be replaced?:**
    - Economic life of defender, N_D^*, is 2 years.
    - Calculate how much it would cost if the defender is kept for a 3rd year.
      - Opportunity cost of keeping the defender for a 3rd year = Salvage value at end of 2nd year, **I = $3,000**
      - Operating cost for the 3rd year, **OC = $5,000**
      - Salvage value at end of 3rd year, **S = $2,000**
      - Therefore, where i = 15% and N = 1

Marginal Analysis

(A/P, i, N)	=	1.1500
(A/F, i, N)	=	1.0000
CR(i)	=	$1,450
(P/F, i, N)	=	0.8696
OC(i)	=	$5,000
EUAC(i)	=	$6,450

$$CR(i) = I(A/P,i,N) - S(A/F,i,N)$$
$$CR(i) = \$3{,}000(1.1500) - \$2{,}000(1.0000)$$

$$OC(i) = \left(\sum_{n=1}^{N} OC_n(P/F,i,n)\right)(A/P,i,N)$$
$$OC(i) = (\$5{,}000)(0.8696)(1.15000)$$

- Example 2: (Chan S. Park, example 14.4)
  - **When should the defender be replaced?:**
    - It costs $6,450 to keep the defender for 1 additional year after its economic service life.
    - This value is greater than the EUAC of the challenger (kept for 4 years), $EUAC_C^* = \$5,826$ at $N_C^* = 4$.
    - ***Conclusion:***

      Keep the defender for 2 years.

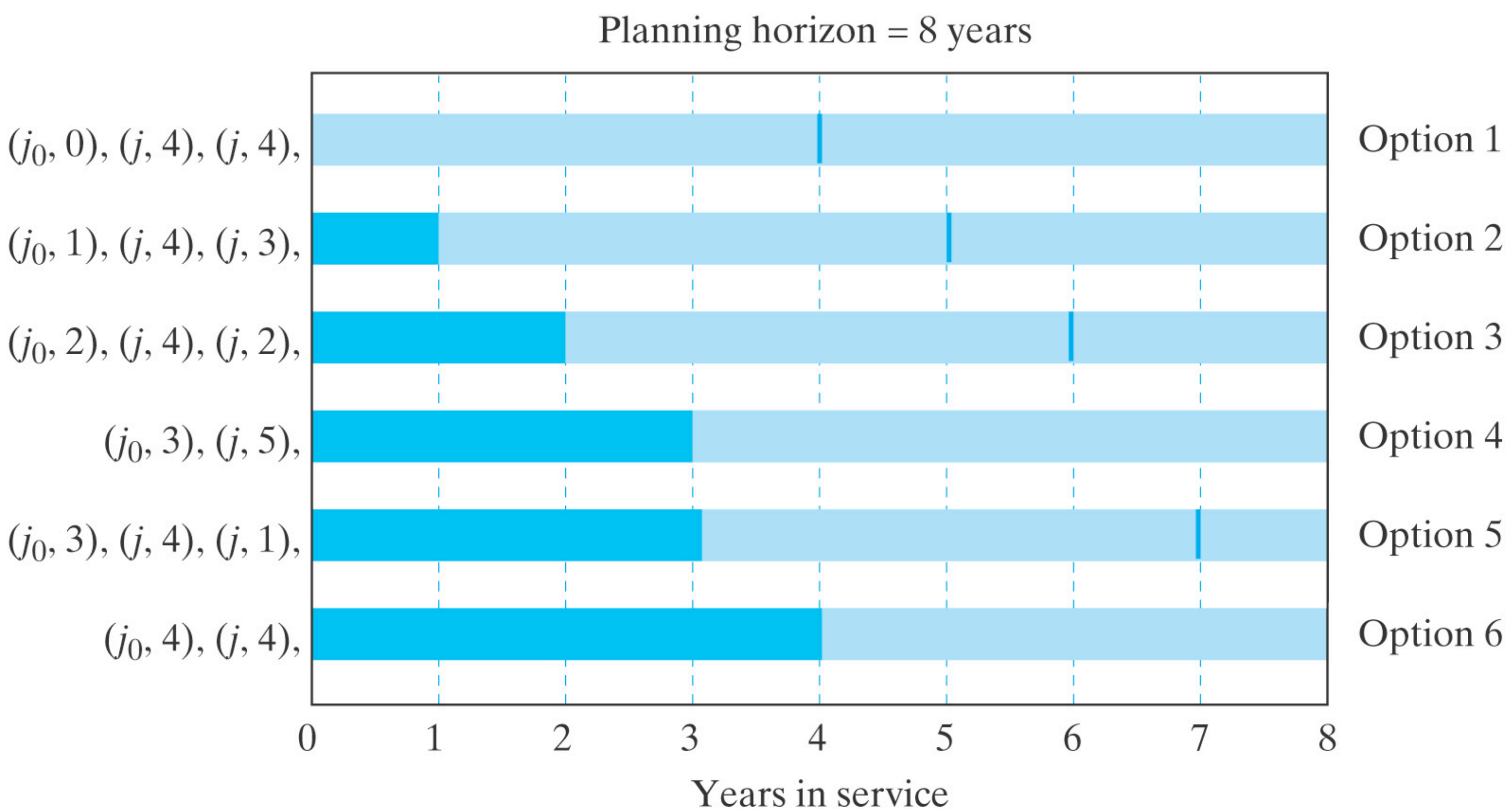
      Then, replace the defender with the challenger at the end of the 2nd year.

      Keep the challenger for 4 years.

- Replacement Strategies:
  - Finite Planning Horizon
    - Consider a firm with a contract to perform a particular service using the current defender or the challenger for the next 8 years.
    - What is the best replacement strategy?

- Replacement Strategies:
  - Finite Planning Horizon
    - Step 1: Identify the likely replacement patterns for the finite planning horizon.
      - As the planning horizon grows a computer program may be required to identify the different options.
    - Step 2: Calculate the annual equivalent costs for both the defender and the challenger.
    - Step 3: For each likely option identified, calculate the PW for the option.
    - Step 4: Identify the option with the minimum cost (PW) from step 3.
    - Refer to Chan S. Park example 14.5.

- Replacement Strategies:
  - Finite Planning Horizon



Some likely replacement patterns under a finite planning horizon of eight years (Chan S. Park, Figure 14.9)

- Replacement Analysis with Tax Considerations:
  - Guidelines:
    - Incorporate the tax effects (gains / losses) whenever an asset is disposed of.
    - Incorporate the tax effects of depreciation allowances.
    - When calculating the net proceeds from sale of the old asset, any gains or losses must be identified to determine the correct amount of the opportunity cost.
    - Whenever possible, replacement decisions should be based on the cash flows after taxes.
    - All basic replacement decision rules including the way of computing economic service life remain unchanged.

Questions?