Replacement Analysis

IE 201 – Chapter 7

Based on Dr. Darabi's and Dr. Haghighi's Notes

UIC ENGINEERING

Chapter 7: Replacement Analysis

7.1 Cash Flow and Opportunity Cost Approaches to Replacement Analysis

7.2 Optimum Replacement Interval

Fundamentals of Replacement Analysis

- **Replacement Analysis:** The comparison of investment alternatives that involve replacing an *asset* or *service provider*
- Possible motivations for replacement:

The **current asset** (the **defender**) has deficiencies:

High setup cost, excessive maintenance expense, declining productivity, high energy cost, limited capability, physical impairment

Potential replacement assets (the **challengers**) are available and have advantages over the defender:

Quicker to set up, easier to use, lower labor/maintenance/ energy cost, higher productivity, additional capabilities

An **external environment** is changing:

User preferences/expectations/ requirements, new ways of providing the service (including the availability of leased equipment and third-party suppliers), increased demand

Fundamentals of Replacement Analysis

- Types of obsolescence:

Functional Obsolescence

Results from physical deterioration of the defender, increased demand that exceeds the defender's capacity, or new requirements that the defender cannot meet

Technological Obsolescence

Occurs through the introduction of new technology, such that challengers possess capabilities not present in the defender

Economic Obsolescence

Occurs when the economic worth of a challenger exceeds that of the defender

- Replacement decisions might be difficult to make due to emotional attachment to the present asset and the cost already paid on the asset
  - **Sunk Cost:** Past costs that have no bearing on current decisions
- Replacement analyses are essentially just another type of alternative comparison

Sec. 7.1 – Cash Flow and Opportunity Cost Approaches to Replacement Analysis

- Two approaches to a replacement analysis:
  (1) Cash Flow and (2) Opportunity Cost approaches

✓**Salvage Value:** The estimated value of an asset at the end of its useful life. Also referred to as the **market value**

✓**Opportunity Cost:** The cost of a forgone alternative (or opportunity) that is incurred in order to pursue another alternative
  - Money that could have been earned if you had chosen the alternative (but you didn't, so it is lost)

✓**Equivalent Uniform Annual Cost:** The EUAC is the equivalent uniform annual cost to keep or operate an asset (similar to annual worth)

Cash Flow and Opportunity Cost Approaches

Cash Flow Approach

- The *insider's viewpoint* approach
- Cash flows are shown for each alternative for each year in the planning horizon
  - Purchasing costs
  - Operations & Maintenance costs
  - Lease payments (costs)
  - Sales/salvage values (negative costs)

Opportunity Cost Approach

- The *outsider's viewpoint* approach
- **Opportunity Cost:** the cost of a foregone alternative (or opportunity) that is incurred in order to pursue another alternative
  - By deciding to keep the asset, one gives up the opportunity to receive a monetary amount for it

Although both are equivalent, the **cash flow approach** is preferred

Cash Flow Approach: Example

A chemical mixer was purchased 8 years ago for $100,000.

- If retained, it will require an investment of $50,000 to upgrade; if upgraded, it will cost $35,000/year to operate and maintain (O&M) and will have a negligible salvage value after 5 years.
- A new mixer can be purchased for $120,000; it will have an annual O&M cost of $15,000 and a salvage value of $40,000 after 5 years.
- A mixer can be leased with 5 beginning-of-year lease payments of $20,000; O&M costs will be $18,000/year.

If the mixer is replaced, the old mixer can be sold on the used equipment market for $15,000. Using an *insider's approach*, what are (a) the EUAC of keeping the current mixer, (b) the EUAC of replacing with a new mixer, and (c) the EUAC of replacing with a leased mixer? The MARR is 10%. Which option is better?

Cash Flow Approach: Example

A chemical mixer was purchased 8 years ago for $100,000.

- If retained, it will require an investment of $50,000 to upgrade it; if upgraded, it will cost $35,000/year to operate and maintain (O&M) and will have a negligible salvage value after 5 years.
- A new mixer can be purchased for $120,000; it will have an annual O&M cost of $15,000 and a salvage value of $40,000 after 5 years.
- A mixer can be leased with 5 beginning-of-year lease payments of $20,000; O&M costs will be $18,000/year.

If the mixer is replaced, the old mixer can be sold on the used equipment market for $15,000. Using an *insider's approach*, what are (a) the EUAC of keeping the current mixer, (b) the EUAC of replacing with a new mixer, and (c) the EUAC of replacing with a leased mixer? The MARR is 10%. Which option is better?

1) Identify the cash flows for each option:

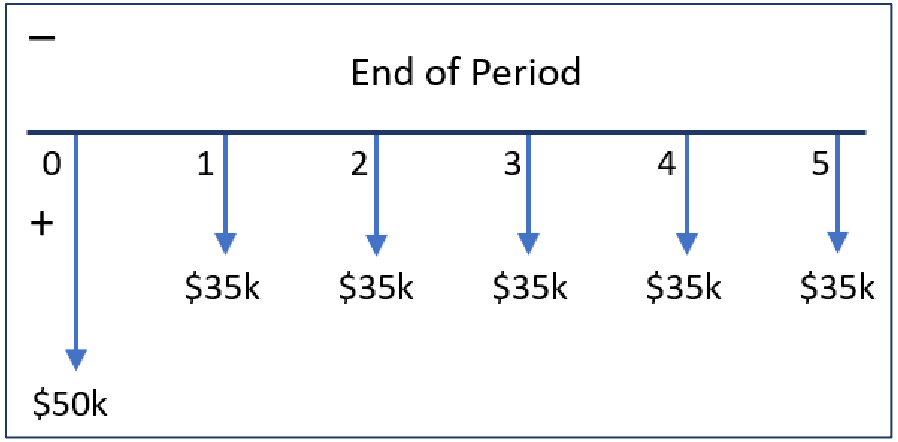
EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

Note: the $100K purchase price for the mixer is a **sunk cost** and does not factor in to the analysis

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

$$\text{EUAC(Keep)} = 50\text{k}(A|P\ 10\%, 5) + 35\text{k} = 48{,}190$$

Keep:



Cash Flow Approach: Example

A chemical mixer was purchased 8 years ago for $100,000.

- If retained, it will require an investment of $50,000 to upgrade it; if upgraded, it will cost $35,000/year to operate and maintain (O&M) and will have a negligible salvage value after 5 years.
- A new mixer can be purchased for $120,000; it will have an annual O&M cost of $15,000 and a salvage value of $40,000 after 5 years.
- A mixer can be leased with 5 beginning-of-year lease payments of $20,000; O&M costs will be $18,000/year.

If the mixer is replaced, the old mixer can be sold on the used equipment market for $15,000. Using an *insider's approach*, what are (a) the EUAC of keeping the current mixer, (b) the EUAC of replacing with a new mixer, and (c) the EUAC of replacing with a leased mixer? The MARR is 10%. Which option is better?

1) Identify the cash flows for each option:

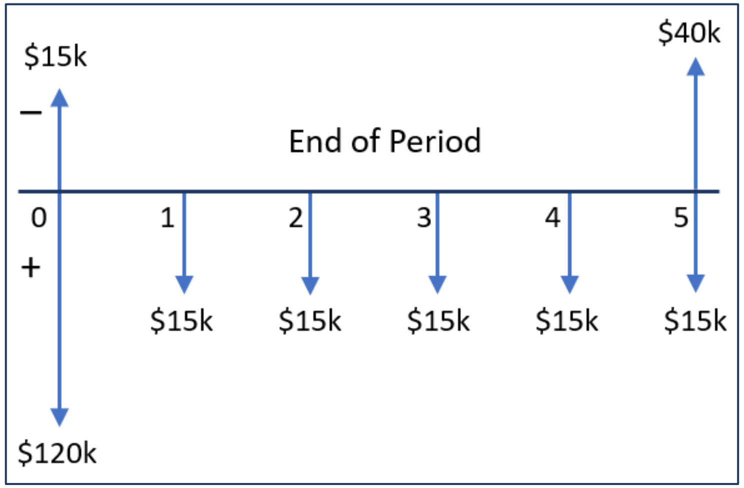
EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

Note: the $100K purchase price for the mixer is a **sunk cost** and does not factor in to the analysis

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

$$\mathrm{EUAC(Replace)} = 105\mathrm{k}(A|P\ 10\%, 5) + 15\mathrm{k} - 40\mathrm{k}(A|F\ 10\%, 5) = 36{,}147$$

Replace:



Cash Flow Approach: Example

A chemical mixer was purchased 8 years ago for $100,000.

- If retained, it will require an investment of $50,000 to upgrade it; if upgraded, it will cost $35,000/year to operate and maintain (O&M) and will have a negligible salvage value after 5 years.
- A new mixer can be purchased for $120,000; it will have an annual O&M cost of $15,000 and a salvage value of $40,000 after 5 years.
- A mixer can be leased with 5 beginning-of-year lease payments of $20,000; O&M costs will be $18,000/year.

If the mixer is replaced, the old mixer can be sold on the used equipment market for $15,000. Using an *insider's approach*, what are (a) the EUAC of keeping the current mixer, (b) the EUAC of replacing with a new mixer, and (c) the EUAC of replacing with a leased mixer? The MARR is 10%. Which option is better?

1) Identify the cash flows for each option:

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

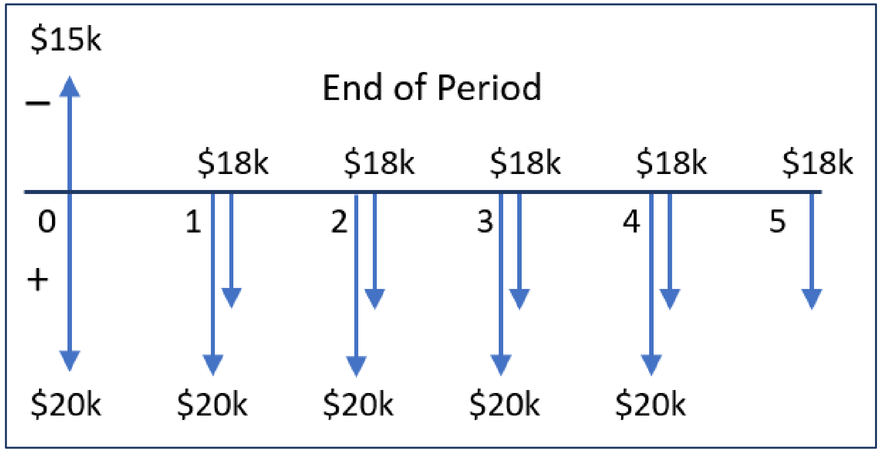
Note: the $100K purchase price for the mixer is a **sunk cost** and does not factor in to the analysis

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

$$\text{EUAC(Lease)} = \underbrace{20\text{k}(F|P\ 10\%, 1)} + 18\text{k} - 15\text{k}(A|P\ 10\%, 5) = 36{,}043$$

(each arrow has the same value, so you only need to shift one forward – not all 5)

Lease:



Cash Flow Approach: Example

A chemical mixer was purchased 8 years ago for $100,000.

- If retained, it will require an investment of $50,000 to upgrade it; if upgraded, it will cost $35,000/year to operate and maintain (O&M) and will have a negligible salvage value after 5 years.
- A new mixer can be purchased for $120,000; it will have an annual O&M cost of $15,000 and a salvage value of $40,000 after 5 years.
- A mixer can be leased with 5 beginning-of-year lease payments of $20,000; O&M costs will be $18,000/year.

If the mixer is replaced, the old mixer can be sold on the used equipment market for $15,000. Using an *insider's approach*, what are (a) the EUAC of keeping the current mixer, (b) the EUAC of replacing with a new mixer, and (c) the EUAC of replacing with a leased mixer? The MARR is 10%. Which option is better?

1) Identify the cash flows for each option:

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

Note: the $100K purchase price for the mixer is a **sunk cost** and does not factor in to the analysis

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

$$\text{EUAC(Keep)} = 50\text{k}(A|P\ 10\%, 5) + 35\text{k} = 48{,}190$$

$$\text{EUAC(Purchase)} = 15\text{k} + 105\text{k}(A|P\ 10\%, 5) - 40\text{k}(A|F\ 10\%, 5) = 36{,}147$$

$$\text{EUAC}(\textbf{Lease}) = 18\text{k} + 20\text{k}(F|P\ 10\%, 1) - 15\text{k}(A|P\ 10\%, 5) = \mathbf{36{,}043}$$

We select the option with the lowest EUAC as the replacement

Thus, the **leasing option** is the best option

Opportunity Cost Approach: Example

Find the best replacement alternative for the chemical mixer using the Opportunity Cost approach (MARR = 10%).

1) Identify the cash flows for each option:

Treat the *market value* of the current asset as an investment cost if it is retained:

- If the mixer is replaced, the old mixer can be sold for $15,000
- This salvage value is lost if the current mixer is kept
  (an **opportunity cost** that is "paid")

Opportunity Cost Approach

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$65,000.00	−$120,000.00	−$20,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

The $15k earned from selling the current mixer is **not** considered as revenue under the Opportunity Cost approach

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

50,000 (upgrade) + **15,000** (**opportunity cost** for not selling the current mixer)

$$\text{EUAC(Keep)} = 65\text{k}(A|P\ 10\%, 5) + 35\text{k} = 52{,}146$$

$$\text{EUAC(Purchase)} = 40{,}103.80$$

$$\text{EUAC(Lease)} = 40{,}000$$

Which alternative will you choose?

A) Keep

B) Purchase

C) Lease

Cash Flow Approach

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

Remember: The $15k can only be accounted for once –

- Cash Flow Approach: A revenue for Alternatives 2 and 3
- Opportunity Cost Approach: A cost for Alternative 1

Opportunity Cost Approach: Example

Find the best replacement alternative for the chemical mixer using the Opportunity Cost approach (MARR = 10%).

1) Identify the cash flows for each option:

Treat the *market value* of the current asset as an investment cost if it is retained:

- If the mixer is replaced, the old mixer can be sold for $15,000
- This salvage value is lost if the current mixer is kept (an **opportunity cost** that is "paid")

Opportunity Cost Approach

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$65,000.00	−$120,000.00	−$20,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

The $15k earned from selling the current mixer is **not** considered as revenue under the Opportunity Cost approach

2) Calculate the EUAC (Equivalent Uniform Annual Cost) for each option:

50,000 (upgrade) + **15,000** (**opportunity cost** for not selling the current mixer)

$$\mathrm{EUAC(Keep)} = 65\mathrm{k}(A|P\ 10\%, 5) + 35\mathrm{k} = 52{,}146$$

$$\mathrm{EUAC(Replace)} = 40{,}103.80$$

$$\mathrm{EUAC(Lease)} = 40{,}000$$

Select the option with the lowest EUAC: **leasing** is the best option

Cash Flow Approach

EOY	CF(Keep)	CF(Replace)	CF(Lease)
0	−$50,000.00	−$105,000.00	−$5,000.00
1–4	−$35,000.00	−$15,000.00	−$38,000.00
5	−$35,000.00	$25,000.00	−$18,000.00

Remember: The $15k can only be accounted for once –

- Cash Flow Approach: A revenue for Alternatives 2 and 3
- Opportunity Cost Approach: A cost for Alternative 1

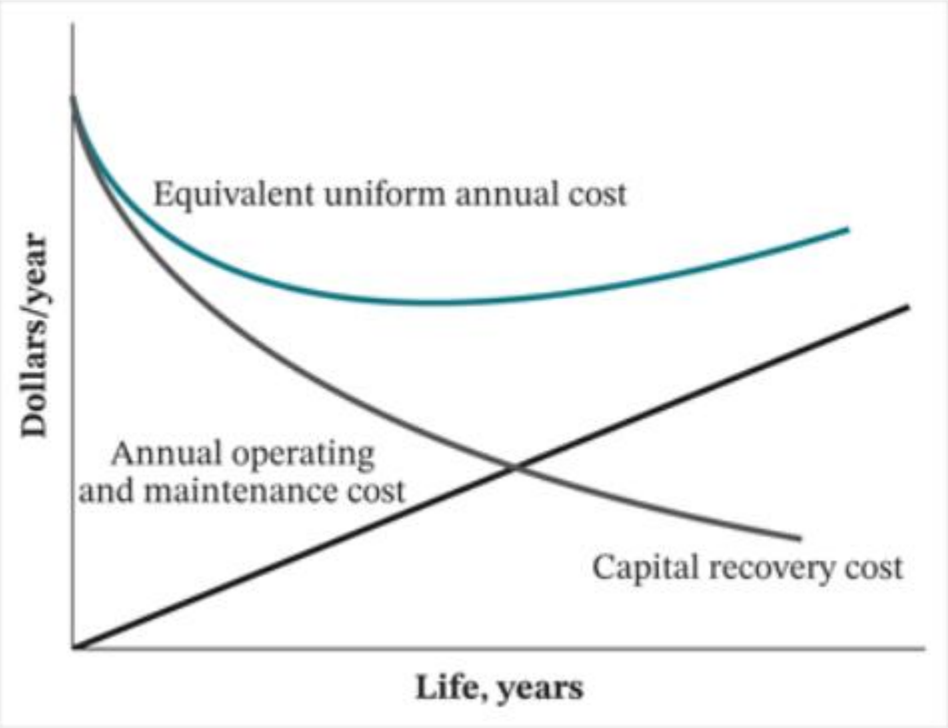
Sec. 7.2 – Optimum Replacement Interval

Optimum Replacement Interval (ORI): The interval at which an asset should be replaced to minimize cost (or maximize worth)

- Goal: Determine the optimum replacement interval in cases where an asset will be needed for an indefinite period of time
- Assumptions:
  - A particular asset is needed for an **indefinite** period of time
  - When it wears out, it will be replaced by an **identical asset**, as many times as necessary

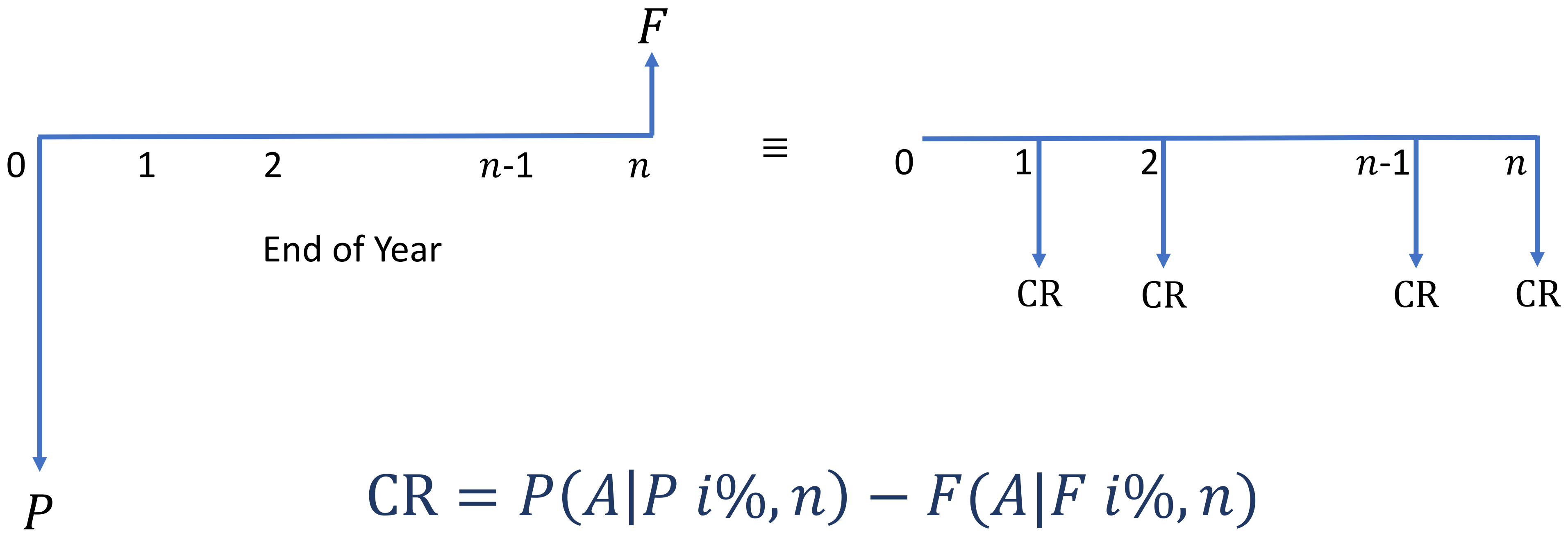
Parameters for Determining ORI

- **Capital Recovery Cost:** The cost of ownership, a value that typically decreases with increased usage
- As equipment ages, **operating and maintenance (O&M) costs** tend to increase
- The equivalent uniform annual cost (EUAC) (combining both above) is a convex function of the life of the equipment



EUAC Components Used to Determine the Optimum Replacement Interval

Capital Recovery Cost



$$\text{CR} = P(A|P\ i\%, n) - F(A|F\ i\%, n)$$

Capital Recovery Cost: The **uniform annual cost equivalent** of the initial investment (P) and the salvage value of an asset (F) after n years of use (where the TVOM is i%)

Capital Recovery Cost: Example

The initial investment cost of a machine is \$500,000 and its salvage value after 10 years is \$50,000. If TVOM is 10%, calculate the capital recovery cost.

$$\mathrm{CR} = P(A|P\ i\%, n) - F(A|F\ i\%, n)$$

$$\mathrm{CR} = 500{,}000(A|P\ 10\%, 10) - 50{,}000(A|F\ 10\%, 10)$$

$$= 500{,}000(0.16275) - 50{,}000(0.06275) = 78{,}237.5$$

Optimum Replacement Interval (ORI) Calculations

1. Convert the acquisition and disposal costs (salvage values) to a uniform annual series (i.e. find the capital recovery cost)
2. Convert the O&M costs to a uniform annual series
3. Obtain the EUAC for a given value of n (compute the sum of CR and O&M)
4. The ORI occurs where EUAC is minimized: search over n to find the minimum EUAC – the associated n is the ORI

Optimum Replacement Interval: Example

\$500,000 is invested in a surface-mount placement (SMP) machine. Experience shows that the salvage value for the SMP machine decreases by 25% per year.

Hence, its salvage value equals \$500,000(0.75^n) after n years of use. O&M costs increase at a rate of 15% per year; the O&M cost equals \$125,000 the first year of use. Based on a MARR of 10%, what is the ORI and what is the minimum EUAC?

$$\mathrm{CR} = P(A|P\ i\%, n) - F(A|F\ i\%, n)$$

Acquisition cost: $P = 500{,}000$, Salvage value: $F = 500{,}000(0.75^n)$

$$\textbf{EUAC} = \underbrace{125{,}000(P|A_1\ \overset{i}{10\%}, \overset{j}{15\%}, n)(A|P\ 10\%, n)}_{\text{Convert O\&M costs to a uniform annual series}} + \underbrace{500{,}000(A|P\ 10\%, n) - 500{,}000(0.75^n)(A|F\ 10\%, n)}_{\text{Convert Capital Recovery Cost (acquisition and disposal) to a uniform annual series}}$$

geometric series:

Make a table and find EUAC for different values of n

Locate the smallest EUAC: the associated n is the ORI

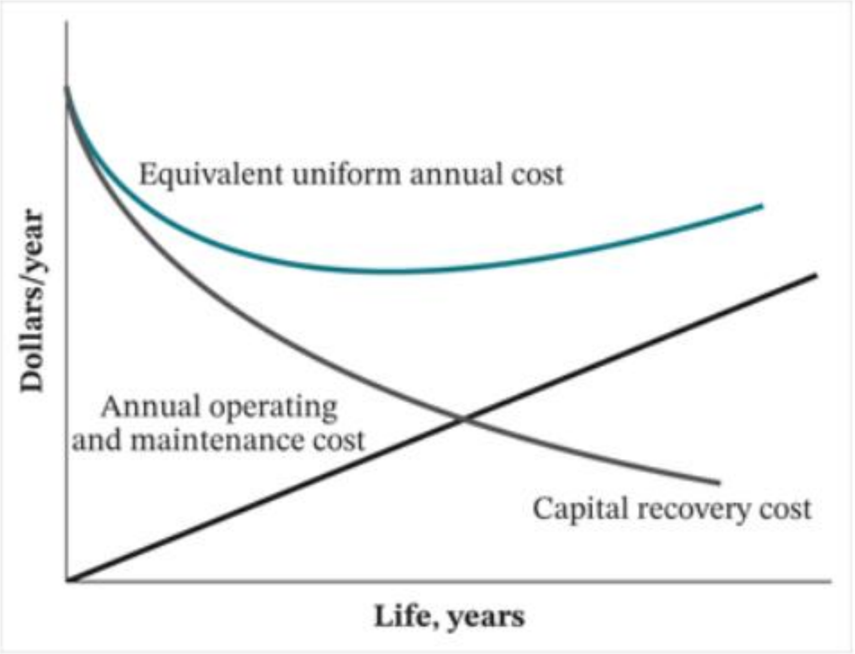
What is the ORI for the SMP machine?

ORI = **5 years**; EUAC = \$276,611

n	$(A\|P\ 10\%,n)$	$(P\|A_1\ 10\%,15\%,n)$	$(A\|F\ 10\%,n)$	EUAC
4	0.31547	3.89190	0.21547	\$277,119
5	0.26380	4.97789	0.16380	\$276,611
6	0.22961	6.11325	0.12691	\$278,729

Behavior of the ORI as Parameters Change

↑ slope of O&M	→	↓ ORI
↑ initial cost (investment)	→	↑ ORI
↑ MARR	→	↑ ORI
↑ rate of decrease in salvage value	→	↑ ORI



Important Observations

1. Implicit in the solution procedure we used to obtain the ORI is an assumption that the planning horizon equals an **integer multiple** of the ORI value obtained
    - For the previous example: 5, 10, 15,…; i.e. assuming an infinite planning horizon
2. Subsequent replacements must have cash flow profiles that are **identical** to their predecessors
3. For the ORI to be truly optimal, it must **minimize present worth of costs** over the planning horizon
4. If the planning horizon is fixed and is greater than the ORI, the optimal replacement sequence will use the ORI for an infinite planning horizon
    - For the previous example: Assume n = 27. Then ORI = {5,5,5,5,5,2}