EM600 - Engineering Economics and Cost Analysis

Lecture 03: *Understanding the 3 Worths, Capitalized Cost and Capitalized Recovery*

STEVENS Institute of Technology

- References:
  – Park, Chan S. Contemporary Engineering Economics. New Jersey: Pearson Prentice Hall, 2006 (Chapter 5 & 6)
  – Ganguly, A. Engineering Economics Using Excel. New Jersey: SSE, 2008

After completing this module you should understand the following:

- Three Worths:
  - Present Worth, PW
  - Annual Equivalence, AE
  - Future Worth, FW
- Evaluation of Alternatives based on time value of money
- Capitalized Costs
- Capitalized Recovery
- Life Cycle Cost Analysis

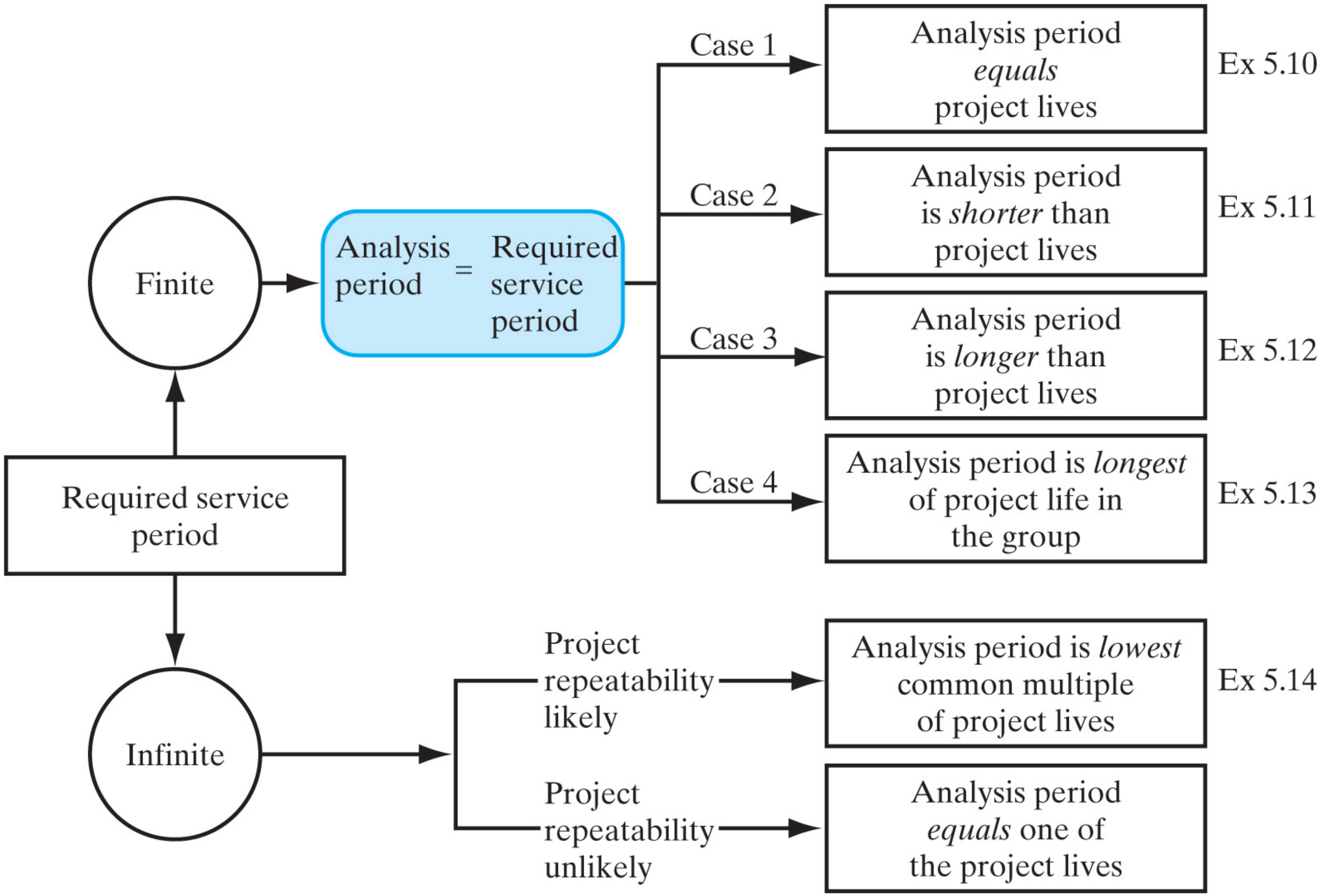
- Independent:
  - *. . . the decision regarding any one project has no effect on the decision to accept or reject another project.* (Chan S. Park)
- Mutually Exclusive:
  - *The acceptance of one project automatically leads to the rejection of all other projects under consideration.*

- Important considerations:
  - “Do Nothing” Approach
  - Project Class
    - Service project (Least Cost)
      - Revenue is independent of the option chosen
      - Each option must be capable of producing the same output
      - e.g. electricity supply
    - Revenue project (Max Benefit / Gain)
      - Revenue depends on the option chosen
      - Input and output not limited
      - Decision based on alternative with largest net gains

- Important considerations:
  - Total-Investment Approach
    - Calculate PW or FW for each option
    - Decision based on alternative with largest PW or FW
  - Scale of Investment
    - Projects may require different levels of investment.
    - Basic Assumption:
      - Funds not invested in the project will consider to earn interest at the MARR.
    - The disparity in scale of investment should not be of concern in comparing mutually exclusive alternatives.

Mutually Exclusive Projects

- Analysis Period
  - Definition: (Chan S. Park)
    - *The time span over which the economic effects of an investment will be evaluated.*
  - Also referred to as:
    - Study period
    - Planning horizon
  - Remember:
    - Projects with different useful lives must be compared over an equal time span.



Analysis period implied in comparing mutually exclusive alternatives (Chan S. Park, Figure 5.13)

- Payback Methods:
  - Definition: (Chan S. Park)
    - *The length of time required to recover the cost of an investment.*
  - Two types:
    - Conventional payback method
      - Does NOT consider the time value of money
    - Discounted payback method
      - Does consider the time value of money
  - Used for ***"initial project screening"***. A detailed economic analysis is then performed on the project if the payback period is within the desired timeframe.

- Conventional Payback Method
  - Calculation:
    - Uniform annual benefits / receipts:
      - $\text{Payback Period} = \dfrac{\text{Initial Cost}}{\text{Uniform Annual Benefit}}$
    - Varying annual benefits / receipts:
      - Sum the cash inflows expected for each year
      - **Project has reached payback point when**,
        - » Cash inflow ≥ Cash outflow (initial investment)
  - Issues:
    - Time Value of money not considered
    - Profitability is not measured
    - Does not consider receipts after the payback period

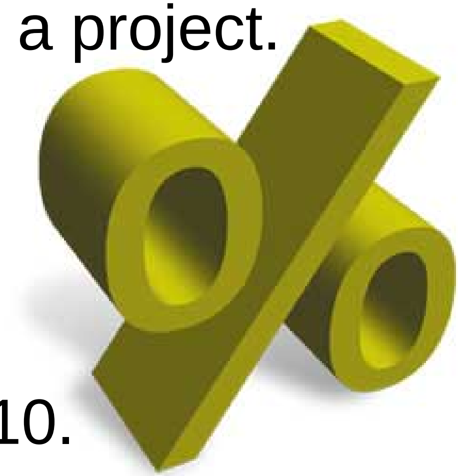
- Discounted Payback Method
  - Calculation (Chan S. Park, Table 5.2):

Period	Cash Flow	Cost of Funds (Interest Rate = 15%)	Cumulative Cash Flow
0	-\$85,000	0	-\$85,000
1	\$15,000	-\$85,000 × 0.15 = -\$12,750	-\$82,750
2	\$25,000	-\$82,750 × 0.15 = -\$12,413	-\$70,163
3	\$35,000	-\$70,163 × 0.15 = -\$10,524	-\$45,687
4	\$45,000	-\$45,687 × 0.15 = -\$6,853	-\$7,540
5	\$45,000	-\$7,540 × 0.15 = -\$1,131	\$36,329
6	\$35,000	\$36,329 × 0.15 = \$5,449	\$76,778

  - Benefits
    - Considers time value of money
  - Issues
    - Profitability is not measured
    - Does not consider receipts after the payback period

- Useful Definitions: (Chan S. Park)
  - **Discounted Cash Flow Analysis (DCF)**
    - *A method of evaluating an investment by estimating future cash flows and taking into consideration the time value of money.*
  - **Net Present Worth (NPW)**
    - *The difference between the present value of cash inflows and the present value of cash outflows.*
    - *NPW = NPV = PW = PV*

- MARR
  - **M**inimum **A**ttractive **R**ate of **R**eturn
    - The interest rate that the company wants to earn on its investments.
    - Selection is usually a policy decision made by top management.
    - MARR can change over the life of a project.
    - Based on:
      - Cost of Capital
      - Risk
    - Analytical process for determining MARR will be covered in Module 10.



- Present Worth Analysis (PW)
  - How is PW applied to a typical investment project?
    - Determine the MARR.
    - Estimate the service life of the project.
    - Estimate the cash inflow for each period over the service life.
    - Estimate the cash outflow for each period over the service life.
    - Determine the net cash flows for each period over the service life.

- # Present Worth Analysis:
  - Summary of Key Equations:

$$PW = -P + A(P/A,i,N) + F(P/F,i,N)$$

$$PW = -P + \sum_{n=0}^{N} A_n (P/F,i,n) + F(P/F,i,N)$$

$$PW = AE(P/A,i,N)$$

$$PW = FW(P/F,i,N)$$

where,

$P =$ initial investment (n = 0)

$A =$ annual cost / revenue (n = 1, 2, . . . , N)

$F =$ future costs, salvage value or expected income from sale of the item (n = N)

$PW =$ present worth of the investment taking A, F, i and N into account

$AE =$ annual equivalence / worth of the investment taking P, F, i and N into account

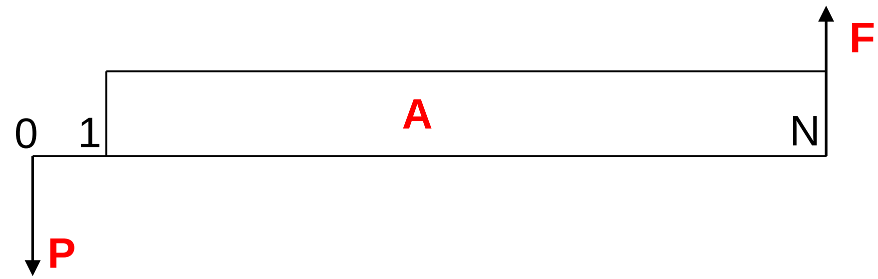
$FW =$ future worth of the investment taking P, A, i and N into account

$i =$ interest rate, MARR

$N =$ project life (n = 1, 2, . . . , N)

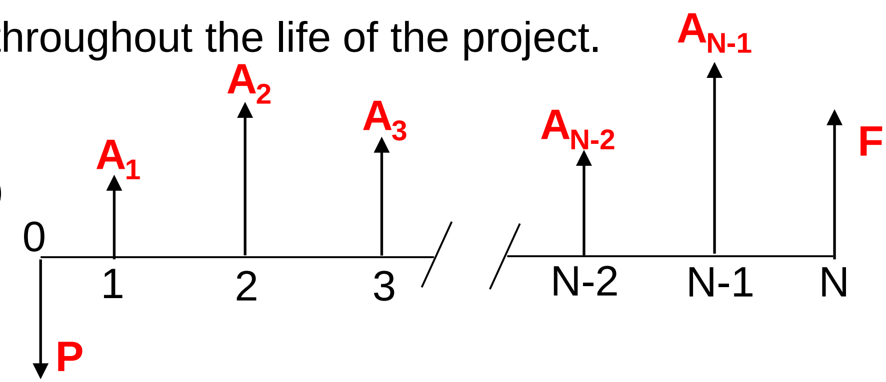
- Present Worth Analysis:
  - Using the Key Equations:

$$PW = -P + A(P/A,i,N) + F(P/F,i,N)$$



- Used to calculate the PW from first principles.
- Assumes the net annual costs / revenues / savings are constant throughout the life of the project.

$$PW = -P + \sum_{n=0}^{N} A_n(P/F,i,n) + F(P/F,i,N)$$



- Used to calculate the PW from first principles.
- Assumes the net annual costs / revenues are NOT constant throughout the life of the project. Each net annual cost / revenue value is treated individually as a “future” value and is discounted to a present worth value using the present worth factor for single payments (P/F, i, N).

- Present Worth Analysis:
  - Using the Key Equations:

$$PW = AE(P/A, i, N)$$

- Short cut method.
- The annual equivalence has been calculated.
- The PW can then be calculated (equivalence calculation) using the present worth factor for an equal payment series (P/A, i, N).

$$PW = FW(P/F, i, N)$$

- Short cut method.
- The future worth has been calculated.
- The PW can then be calculated (equivalence calculation) using the present worth factor for a single payment series (P/F, i, N).

- Single Project Evaluation
  - If PW > 0 ➔ ACCEPT
  - If PW = 0 ➔ INDIFFERENT
  - If PW < 0 ➔ REJECT
- Comparing Multiple Alternatives
  - Revenue Projects:
    - Calculate PW for each alternative
    - Select the option with the largest PW
  - Service Projects:
    - Service projects (equal revenues) are compared on a cost only basis
    - Select the option with the *least negative* PW

- Example 1:
  - Given:
    - P = $650,000
    - A = $162,500 (uniform)
    - MARR = i = 15%
    - N = 8
  - Solution:
    - Back to basics

$$PW = -P + A(P/A, i, N)$$

$$PW = -\$650{,}000 + \$162{,}500(P/A, 15\%, 8)$$

$$PW = -\$650{,}000 + \$162{,}500(4.4873)$$

$$PW = \$79{,}186$$

The result is negative because it represents money that you would have to pay now, an outgoing cash flow, to earn A each year. Therefore you must include a "-" before the value

- Solution:
  - Excel

	A	B	C
1	P	$650,000	
2	A	$162,500	
3	i	15%	
4	N	8	
5			
6	PW	=-B1+PV(B3,B4,-B2,,0)	

6	PW	$79,190

Example 5.4 (Chan S. Park)

- Example 2:
  - Given:
    - P = $75,000
    - A_1 = $24,400; A_2 = $27,340; A_3 = $55760
    - MARR = i = 15%
    - N = 3
  - Solution:
    - Back to basics

For varying future benefits, treat each benefit as a future cash flow, FV in excel

$$PW = -P + \sum_{n=1}^{N} A_n(P/F,i,n)$$

$$PW = -\$75{,}000 + \$24{,}400(P/F,15\%,1) + \$27{,}340(P/F,15\%,2) + \$55{,}760(P/F,15\%,3)$$

$$PW = -\$75{,}000 + \$24{,}400(0.8696) + \$27{,}340(0.7561) + \$55{,}760(0.6575)$$

$$PW = \$3552$$

The result is negative because it represents money that you would have to pay now, an outgoing cash flow, to earn A each year. Therefore you must include a "-" before the value

- Solution:
  - Excel

	A	B	C
1	P	$75,000	
2	A_1	$24,400	
3	A_2	$27,340	
4	A_3	$55,760	
5	i	15%	
6	N_1	1	
7	N_2	2	
8	N_3	3	
9			
10	PW	=-B1-(PV(B5,B6,,B2,0)+PV(B5,B7,,B3,0)+PV(B5,B8,,B4,0))	
11			

10	PW	$3,553

Example 5.5 (Chan S. Park)

- Capitalized Equivalent Method
  - Uses
    - Perpetual project service life
      - N ➔ ∞
    - Extremely long project service life
      - N ≥ 50 years
  - Capitalized Cost Equation:
    - $CE = \dfrac{A}{i}$
    - e.g.
      A = $120K,
      i = 8%,
      N = 50 years

$$CE = \frac{A}{i} = A(P/A,i,N)$$

$$CE = \frac{\$120K}{8\%} = \$120K\overset{12.2335}{(P/A,8\%,50)}$$

$$CE = \$1500K = \$1468K \text{ . . . } \textit{Minimal difference}$$

- Useful Definitions: (Chan S. Park)
  - **Net Future Worth (NFW)**
    - *The value of an asset or cash at a specified date in the future that is equivalent in value to a specified sum today.*
    - *NFW = NFV = FW = FV*

- # Future Worth Analysis:
  - Summary of Key Equations:

$$FW = -P(F/P,i,N) + A(F/A,i,N) + F$$

$$FW = -P(F/P,i,N) + \sum_{n=0}^{N} A_n (F/P,i,N-n) + F$$

$$FW = AE(F/A,i,N)$$

$$FW = PW(F/P,i,N)$$

where,

$P =$ initial investment (n = 0)

$A =$ annual cost / revenue (n = 1, 2, . . . , N)

$F =$ future costs, salvage value or expected income from sale of the item (n = N)

$PW =$ present worth of the investment taking A, F, i and N into account

$AE =$ annual equivalence / worth of the investment taking P, F, i and N into account

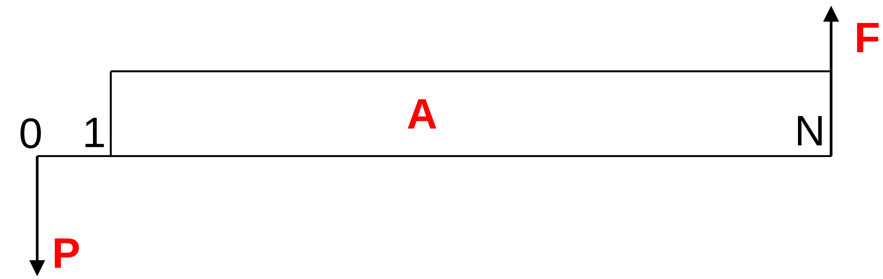
$FW =$ future worth of the investment taking P, A, i and N into account

$i =$ interest rate, MARR

$N =$ project life (n = 1, 2, . . . , N)

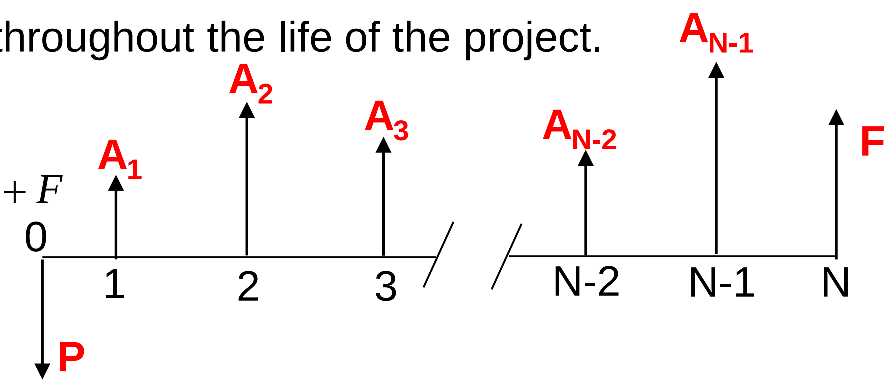
- Future Worth Analysis:
  - Using the Key Equations:

$$FW = -P(F/P,i,N) + A(F/A,i,N) + F$$



- Used to calculate the FW from first principles.
- Assumes the net annual costs / revenues / savings are constant throughout the life of the project.

$$FW = -P(F/P,i,N) + \sum_{n=0}^{N} A_n (F/P,i,N-n) + F$$



- Used to calculate the FW from first principles.
- Assumes the net annual costs / revenues are NOT constant throughout the life of the project. Each net annual cost / revenue value is treated individually as a "present" value and is compounded to a future value (over "N-n" years) using the compound amount factor for single payments (F/P, i, N).

- # Future Worth Analysis:
  - Using the Key Equations:

$$FW = AE(F/A,i,N)$$

- Short cut method.
- The annual equivalence has been calculated.
- The FW can then be calculated (equivalence calculation) using the compound amount factor for an equal payment series (F/A, i, N).

$$FW = PW(F/P,i,N)$$

- Short cut method.
- The present worth has been calculated.
- The FW can then be calculated (equivalence calculation) using the compound amount factor for a single payment series (F/P, i, N).

- Single Project Evaluation
  - If FW > 0 ➔ ACCEPT
  - If FW = 0 ➔ INDIFFERENT
  - If FW < 0 ➔ REJECT
- Comparing Multiple Alternatives
  - Revenue Projects:
    - Calculate FW for each alternative
    - Select the option with the largest FW
  - Service Projects:
    - Service projects (equal revenues) are compared on a cost only basis
    - Select the option with the *least negative* FW

- # Example 3:
  - Given:
    - F = $55,760
    - A_0 = $75,000, A_1 = $24,400; A_2 = $27,340
    - MARR = i = 15%
    - N = 3
  - Solution:
    - Back to basics

For varying past benefits, treat each benefit as a present cash flow, PV, in excel

$$FW = \sum_{n=1}^{N} A_n(F/P,i,N-n)+F$$

$$FW = -\$75{,}000(F/P{,}15\%{,}3)+\$24{,}400(F/P{,}15\%{,}2)$$
$$+\$27{,}340(F/P{,}15\%{,}1)+\$55{,}760$$

$$FW = -\$75{,}000(1.5209)+\$24{,}400(1.3225)$$
$$+\$27{,}340(1.1500)+\$55{,}760$$

$$FW = \$5{,}403$$

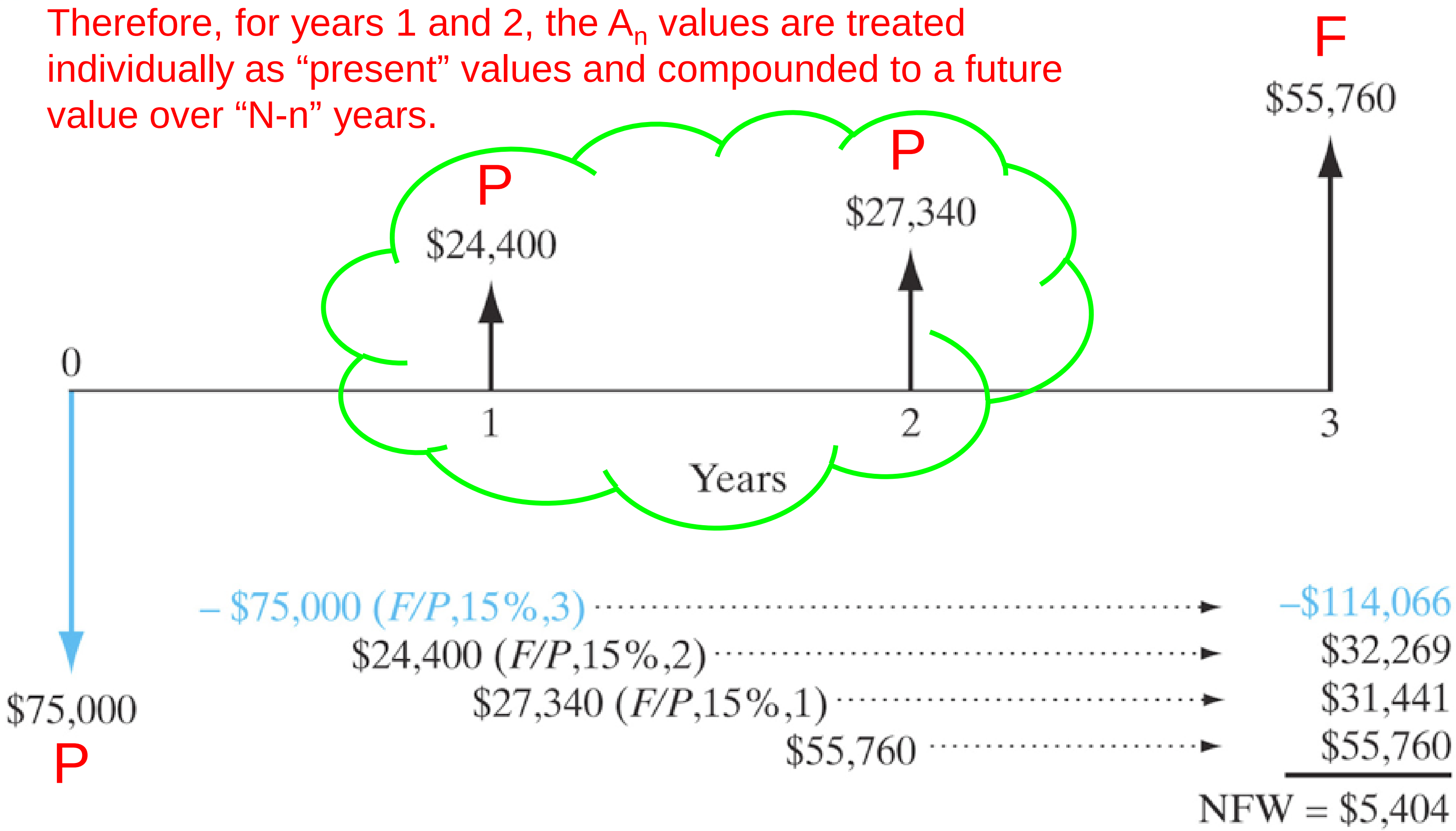
- Solution:
  - Excel

	A	B	C
1	F	$55,760	
2	A_0	$75,000	
3	A_1	$24,400	
4	A_2	$27,340	
5	i	15%	
6	N_1	0	
7	N_2	1	
8	N_3	2	
9	N	3	
10			
11	FW	=FV(B5,B9-B6,,B2,0)+FV(B5,B9-B7,,-B3,0)+FV(B5,B9-B8,,-B4,0)+B1	
12			
13			

11	FW	$5,404

Example 5.6 (Chan S. Park)

A_n is not constant throughout the life cycle of the project. Therefore, for years 1 and 2, the A_n values are treated individually as “present” values and compounded to a future value over “N-n” years.



Example 5.6 (Chan S. Park, Figure 5.8)

- Useful Definitions: (Chan S. Park)
  - **Annual Equivalent Worth (AE)**
    - *The annual equivalent worth measures the worth of an investment by determining equal payments on an annual basis.*
    - *AE = AW = AV = -AC*

- Annual Equivalent Worth Analysis:
  - Summary of Key Equations:

$$AE = -P(A/P,i,N) + A + F(A/F,i,N)$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (P/F,i,N)(A/P,i,N) + F(A/F,i,N)$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (F/P,i,N-n)(A/F,i,N) + F(A/F,i,N)$$

$$AE = PW(A/P,i,N)$$

$$AE = FW(A/F,i,N)$$

where,

$P =$ initial investment (n = 0)

$A =$ annual cost / revenue (n = 1, 2, . . . , N)

$F =$ future costs, salvage value or expected income from sale of the item (n = N)

$PW =$ present worth of the investment taking A, F, i and N into account

$AE =$ annual equivalence / worth of the investment taking P, F, i and N into account

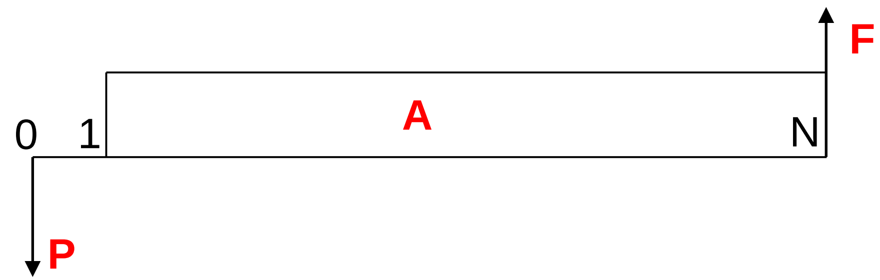
$FW =$ future worth of the investment taking P, A, i and N into account

$i =$ interest rate, MARR

$N =$ project life (n = 1, 2, . . . , N)

- Annual Equivalent Worth Analysis:
  - Using the Key Equations:

$$AE = -P(A/P,i,N) + A + F(A/F,i,N)$$



- Used to calculate the AE from first principles.
- Assumes the net annual costs / revenues / savings are constant throughout the life of the project.

$$AE = PW(A/P,i,N)$$

- Short cut method.
- The present worth has been calculated.
- The AE can then be calculated (equivalence calculation) using the capital recovery factor for an equal payment series (A/P, i, N).

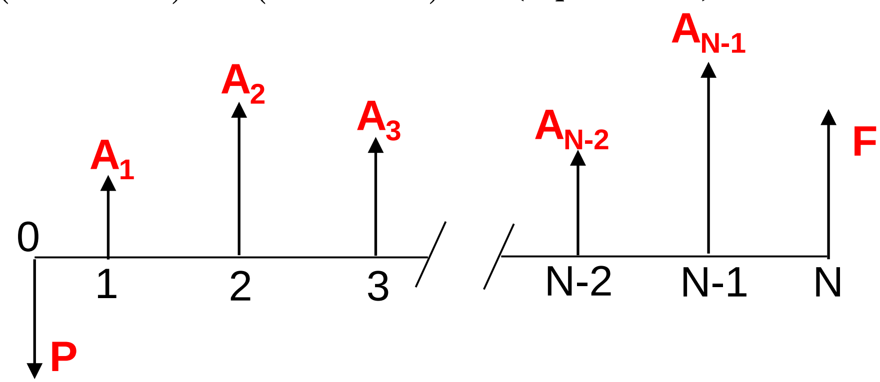
$$AE = FW(A/F,i,N)$$

- Short cut method.
- The future worth has been calculated.
- The AE can then be calculated (equivalence calculation) using the sinking fund factor for a single payment series (A/F, i, N).

- Annual Equivalent Worth Analysis:
  - Using the Key Equations:

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (P/F,i,N)(A/P,i,N) + F(A/F,i,N) \qquad \text{(equation 1)}$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (F/P,i,N-n)(A/F,i,N) + F(A/F,i,N) \qquad \text{(equation 2)}$$

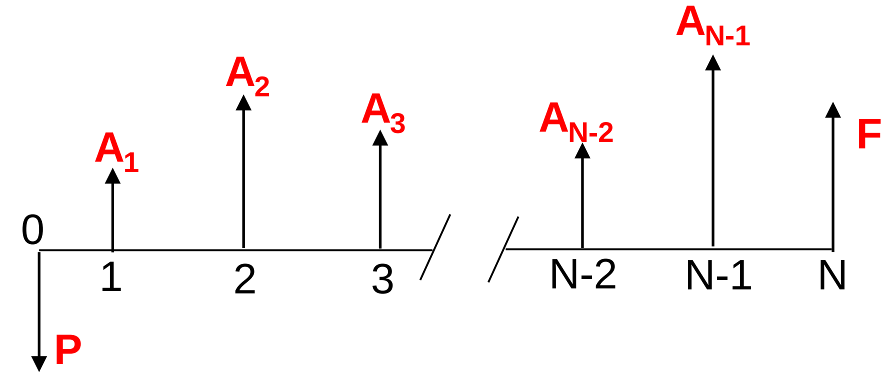


- Used to calculate the AE from first principles.
- Assumes the net annual costs / revenues are NOT constant throughout the life of the project.
- **Equation 1:** Each net annual cost / revenue value is treated individually as a “future” value and is discounted to a present value using the present worth factor for single payments (P/F, i, N). This is then equated to an annual equivalence (AE) using the capital recovery factor (A/P,I,N).

- Annual Equivalent Worth Analysis:
  - Using the Key Equations:

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (P/F,i,N)(A/P,i,N) + F(A/F,i,N) \qquad \text{(equation 1)}$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (F/P,i,N-n)(A/F,i,N) + F(A/F,i,N) \qquad \text{(equation 2)}$$



- Used to calculate the AE from first principles.
- Assumes the net annual costs / revenues are NOT constant throughout the life of the project.
- **Equation 2:** Each net annual cost / revenue value is treated individually as a "present" value and is and is compounded to a future value (over "N-n" years) using the compound amount factor for single payments (F/P, i, N). This is then equated to an annual equivalence (AE) using the sinking fund factor (A/F,I,N).

- Single Project Evaluation
  - If AE > 0 ➔ ACCEPT
  - If AE = 0 ➔ INDIFFERENT
  - If AE < 0 ➔ REJECT
- Comparing Multiple Alternatives
  - Revenue Projects:
    - Calculate AE for each alternative
    - Select the option with the largest AE
  - Service Projects:
    - Service projects (equal revenues) are compared on a cost only basis
    - Select the option with the *least negative* AE

- Example 4:
  - Install a 150MW feedwater heater, given:
    - Initial cost, P = $1,650,000
    - Service life, N = 25 years
    - Salvage value, S = 0
    - Expected improvement in fuel efficiency = 1%
      - Pre installation: 55%
      - Post installation: 56%
    - Fuel cost = $0.05kWh
    - Load factor = 85%
  - a. Determine the annual worth for installing the unit at i = 12% ➔ constant fuel price, uniform A
  - b. If the fuel cost increases at the annual rate of 4%, what is AE at i = 12%? ➔ varying fuel price (%), varying A, treat as Geometric Gradient Series

Example 6.1 (Chan S. Park)

- Example 4: part (a)
  - Reduction in energy consumption = **4,870kW**
    - Before adding the second unit, $\frac{150MW}{55\%} = 272,727kW$
      After adding the second unit, $\frac{150MW}{56\%} = 267,857kW$
      $272,727kW - 267,857kW = 4,870kW$
  - Annual operating hours @ 85% = **7,446 hours/year**
    - $(365)(24)(85\%) = 7,446$ hours/year
  - Assuming constant fuel cost over the service life of the second heater,
    - $A_{\text{fuel savings}} = (\text{reduction in energy consumption}) \times (\text{fuel cost}) \times (\text{operating hours per year})$

$$A_{\text{fuel savings}} = (4,870kW) \times (\$0.05/kWh) \times (7,446\,hours/year)$$

$$A_{\text{fuel savings}} = \$1,813,149 \text{ per year}$$

$$\text{AE} = \text{-P}(\text{A/P,i,N}) + \text{A}$$

$$AE = -\$1,650,000(\text{A/P},12\%,25) + \$1,813,149$$

$$AE = -\$1,650,000(0.1275) + \$1,813,149$$

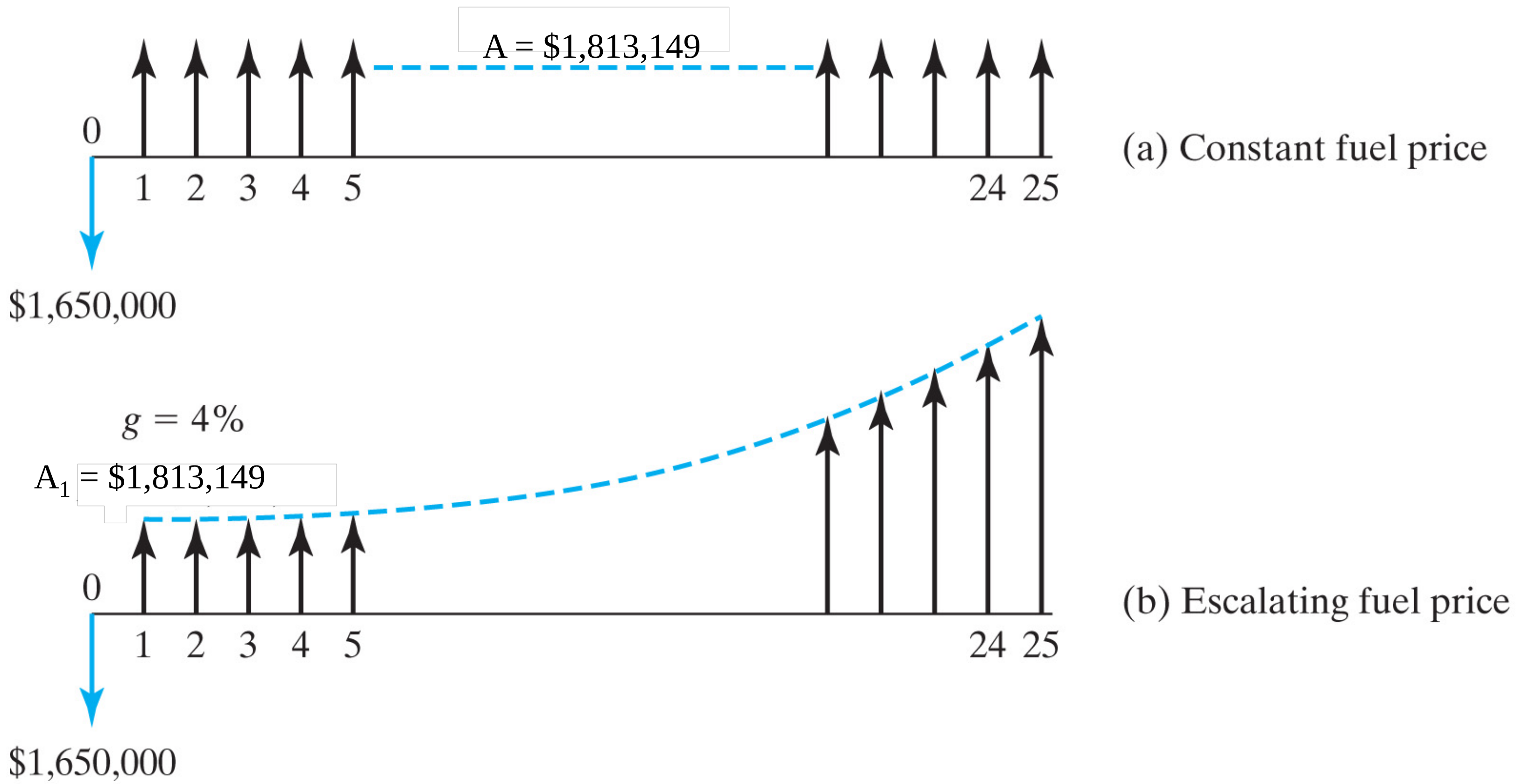
$$\boxed{AE = \$1,602,774}$$

Excel:

32	**AE**	
33	P	$1,650,000
34	(A/P,12%,25)	0.1275
35	A	$1,813,149
36	AE	=PMT(12%,25,B33,,)+B35

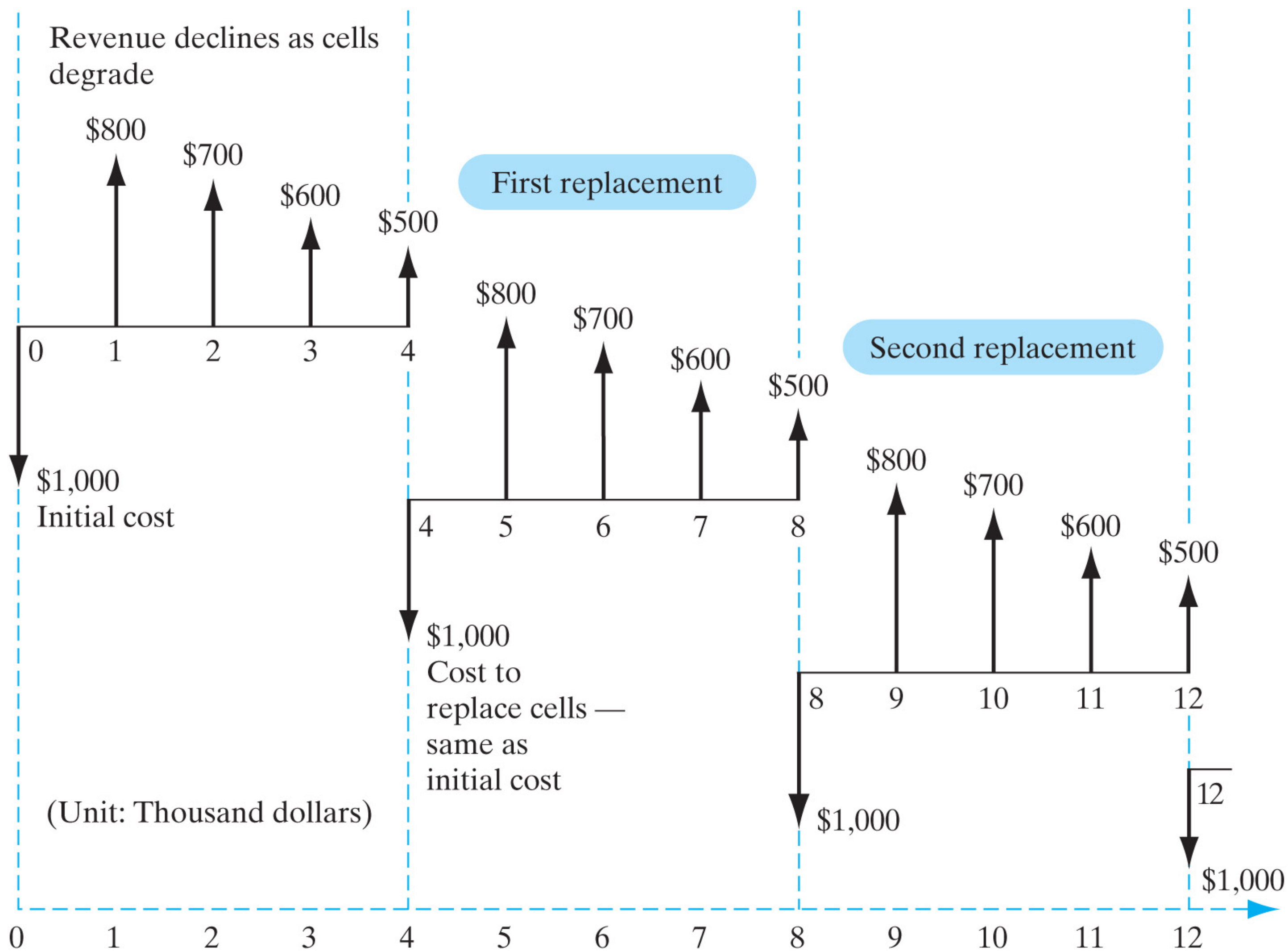
Example 6.1 (Chan S. Park)

- Example 4: part (b)
  - From part (a), A_1 = \$1,813,149
  - Calculate present worth (PW)
    - $$PW = -P + A_1\left[\frac{1-(1+g)^N(1+i)^{-N}}{i-g}\right]$$
      $$PW = -\$1{,}650{,}000 + \$1{,}813{,}149\left[\frac{1-(1+4\%)^{25}(1+12\%)^{-25}}{12\% - 4\%}\right]$$
      $$PW = \$17{,}460{,}293$$
  - Calculate annual worth (AW)
    - $$AE = PW(A/P, i, N)$$
      $$AE = \$17{,}460{,}293(A/P, 12\%, 25)$$
      $$AE = \$17{,}460{,}293(0.1275)$$
      $$AE = \$2{,}226{,}187$$



Example 6.1 (Chan S. Park, Figure 6.1)

- Repeating Cash Flow Cycles:
  - e.g. equipment, solar cells for example, may need to be replaced periodically as they will degrade over time compromising efficiency.
  - AE is calculated by examining the first cash flow cycle -
    - Calculate PW for the first cash flow cycle
    - Calculate AE for the first cash flow cycle
  - This yields the same solution as when the entire project is examined.



Conversion of repeating cash flow cycles into an equivalent annual payment. (Chan S. Park, Figure 6.2)

- Mutually Exclusive Alternatives
  - Two main considerations:
    - The analysis period equals the project life
      - Calculate as before.
    - The analysis period does not equal the project life
      - Lowest common multiple approach
      - Lowest common multiple approach can be avoided if:
        - » The service of the selected alternative is required on a continuous basis.
        - » Each alternative will be replaced by an identical asset that has the same costs and performance
        - » Treat as a repeating cash flow in this case

Figures of Merit Summary

- **Present Worth**

$$PW = -P + A(P/A,i,N) + F(P/F,i,N)$$

$$PW = -P + \sum_{n=0}^{N} A_n (P/F,i,n) + F(P/F,i,N)$$

$$PW = AE(P/A,i,N)$$

$$PW = FW(P/F,i,N)$$

- **Future Worth:**

$$FW = -P(F/P,i,N) + A(F/A,i,N) + F$$

$$FW = -P(F/P,i,N) + \sum_{n=0}^{N} A_n (F/P,i,N-n) + F$$

$$FW = AE(F/A,i,N)$$

$$FW = PW(F/P,i,N)$$

- **Annual Equivalence:**

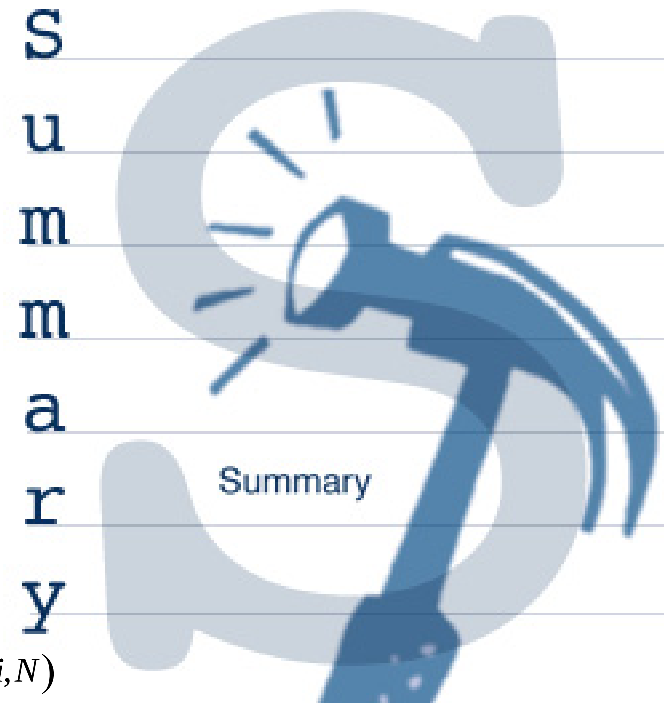
$$AE = -P(A/P,i,N) + A + F(A/F,i,N)$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (P/F,i,N)(A/P,i,N) + F(A/F,i,N)$$

$$AE = -P(A/P,i,N) + \sum_{n=1}^{N} A_n (F/P,i,N-n)(A/F,i,N) + F(A/F,i,N)$$

$$AE = PW(A/P,i,N)$$

$$AE = FW(A/F,i,N)$$



- Example 5:
  - Given:

n	Model A	Model B
0	-$12,500	-$15,000
1	-$5,000	-$4,000
2	-$5,000	-$4,000
3	-$5,000 + $2,000	-$4,000
4		-$4,000 + $1,500

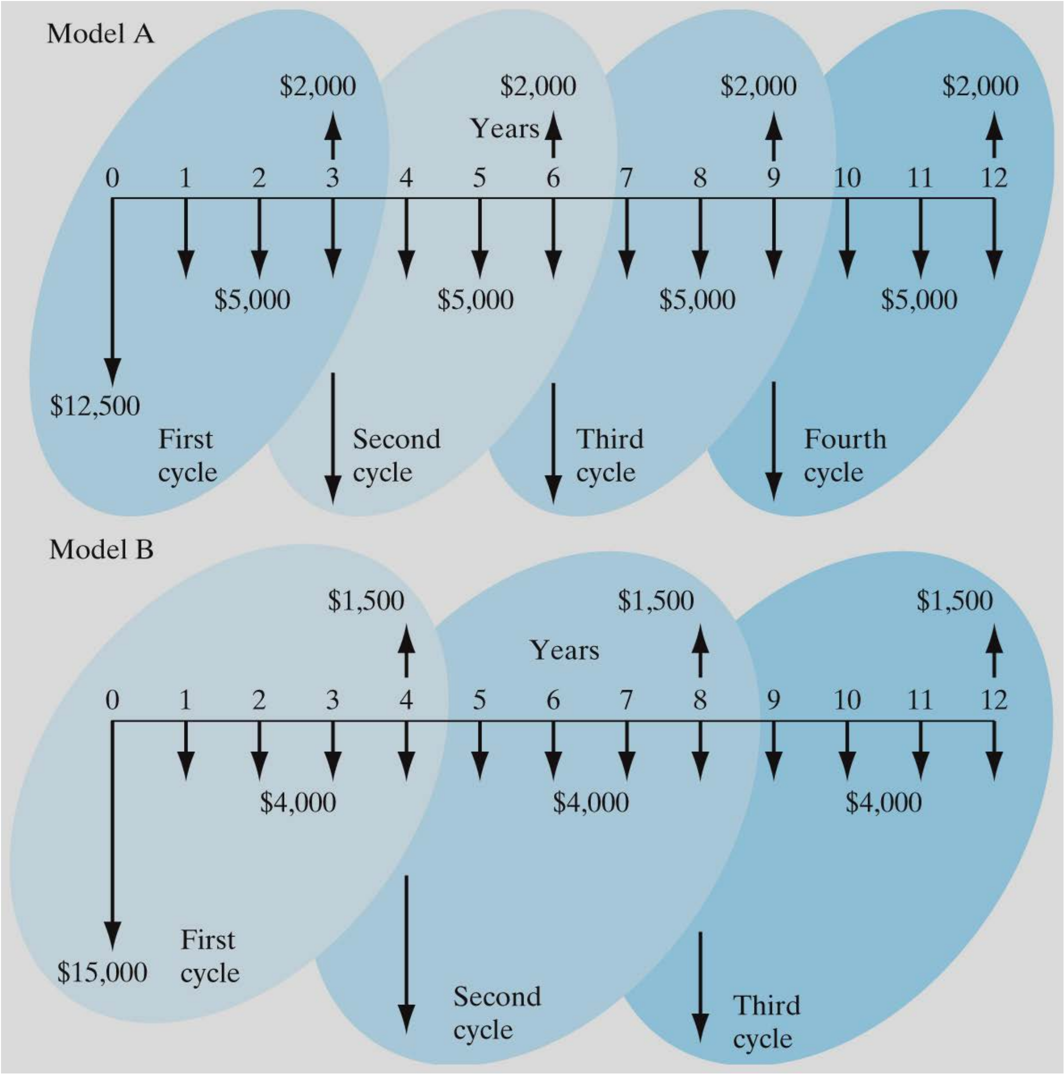
i = 15%

  - Find:
    - NPW of each alternative
    - AE of each alternative
  - Select the best alternative

Example 5.14 and Example 6.3 (Chan S. Park)

- Example 5:
  - Approach:
    - The projects must be comparable in terms of TIME.
    - Identify the lowest common multiple or LCM (LCM = 12 years)
    - Any cash flow difference between the alternatives will be revealed during the first 12 years
    - The same cash flow patterns will then repeat within each 12 year cycle for an indefinite period.

Example 5.14 and Example 6.3 (Chan S. Park)



Example 5.14 and Example 6.3 (Chan S. Park, Figure 5.17)

Example 5: Model A

- N = 3, therefore 4 replacements occur in a 12 year period.
- PW for 1st investment cycle, PW_1:
  - $$PW = -P + A(P/A,i,N) + F(P/F,i,N)$$
    $$PW = -\$12{,}500 - \$5{,}000(P/A,15\%,3) + \$2{,}000(P/F,15\%,3)$$
    $$PW = -\$12{,}500 - \$5{,}000(2.2832) + \$2{,}000(0.6575)$$
    $$\boxed{\begin{array}{l} PW_1 = -\$22{,}601 \\ AE_1 = PW_1(A/P,i,N) = -\$22{,}601(A/P,15\%,3) = -\$22{,}601(0.4380) = -\$9{,}899 \end{array}}$$
- Total PW for 4 replacement cycles:
  - $$PW = -PW_1[1 + (P/F,i,N) + (P/F,i,2N) + (P/F,i,3N)]$$
    $$PW = -\$22{,}601[1 + (P/F,15\%,3) + (P/F,15\%,6) + (P/F,15\%,9)]$$
    $$PW = -\$22{,}601[1 + 0.6575 + 0.4323 + 0.2843]$$
    $$\boxed{\begin{array}{l} PW = -\$53{,}657 \\ AE = PW(A/P,i,N) = -\$53{,}657(A/P,15\%,12) = -\$53{,}657(0.1845) = -\$9{,}900 \end{array}}$$

Example 5: Model B

- N = 4, therefore 3 replacements occur in a 12 year period.
- PW for 1st investment cycle, PW_1:
  - $PW = -P + A(P/A,i,N) + F(P/F,i,N)$

    $PW = -\$15{,}000 - \$4{,}000(P/A,15\%,4) + \$1{,}500(P/F,15\%,4)$

    $PW = -\$15{,}000 - \$4{,}000(2.8550) + \$1{,}500(0.5718)$

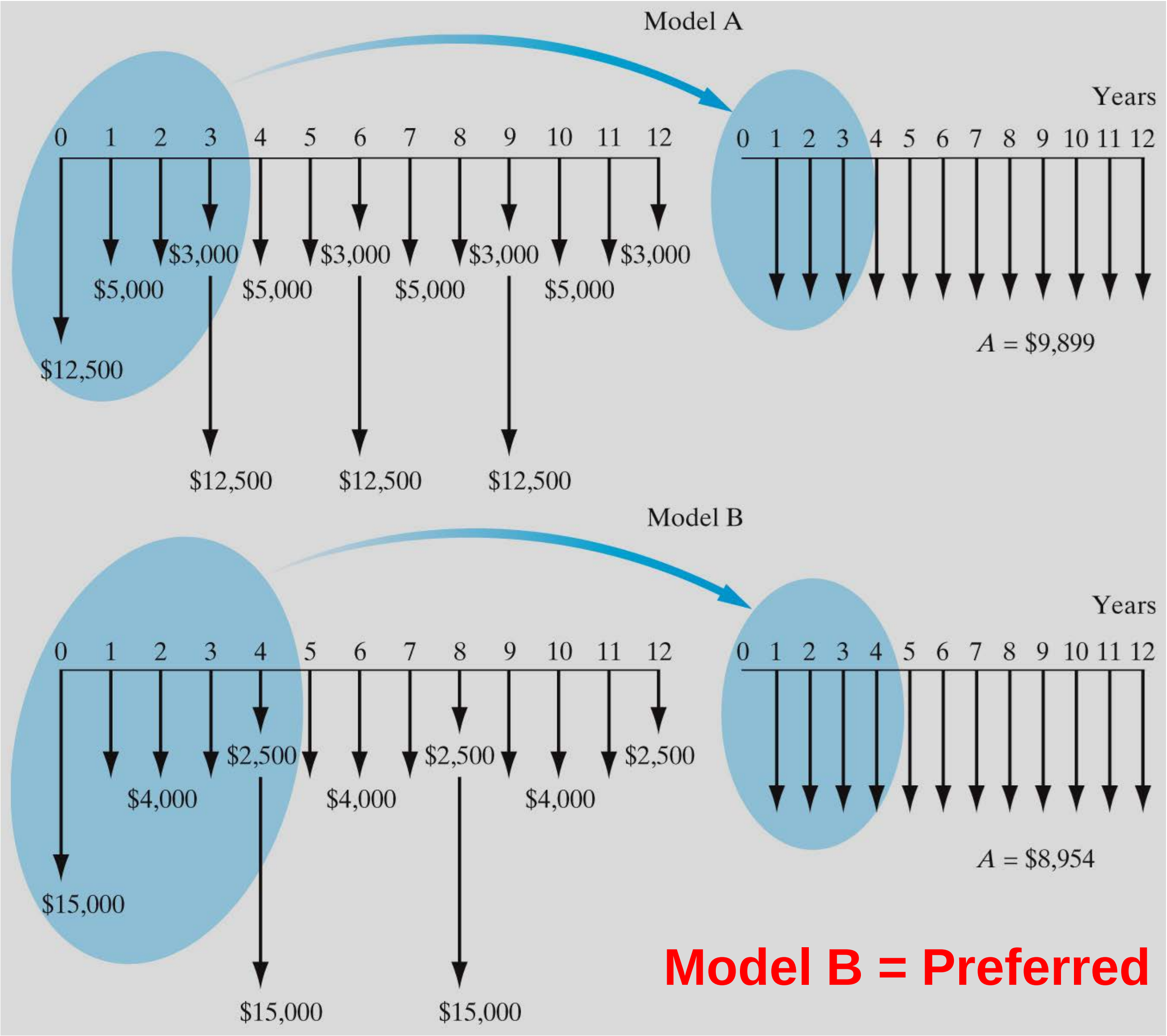
    $\boxed{\begin{aligned} &PW_1 = -\$25{,}562 \\ &AE_1 = PW_1(A/P,i,N) = -\$25{,}562(A/P,15\%,4) = -\$25{,}562(0.3503) = -\$8{,}954 \end{aligned}}$

- Total PW for 3 replacement cycles:
  - $PW = -PW_1[1 + (P/F,i,N) + (P/F,i,2N)]$

    $PW = -\$25{,}562[1 + (P/F,15\%,4) + (P/F,15\%,8)]$

    $PW = -\$25{,}562[1 + 0.5718 + 0.3269]$

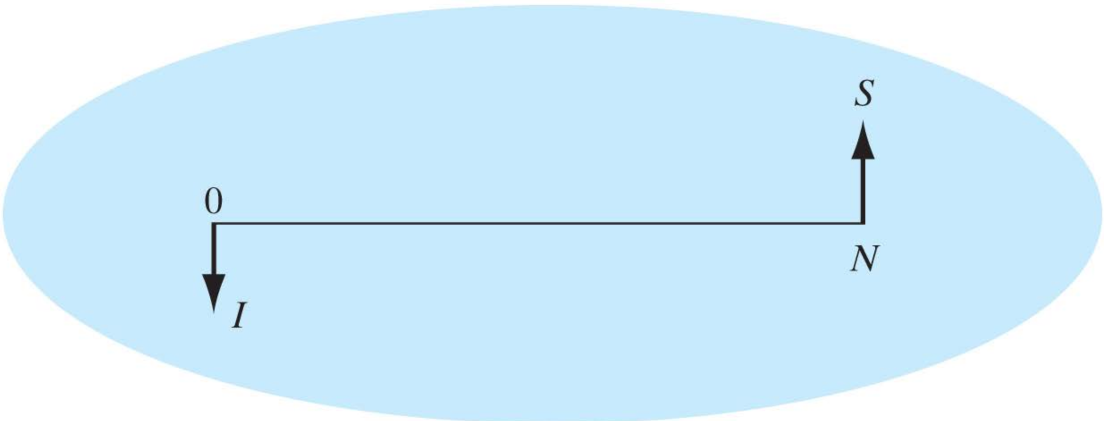
    $\boxed{\begin{aligned} &PW = -\$48{,}535 \\ &AE = PW(A/P,i,N) = -\$48{,}535(A/P,15\%,12) = -\$48{,}535(0.1845) = -\$8{,}955 \end{aligned}}$



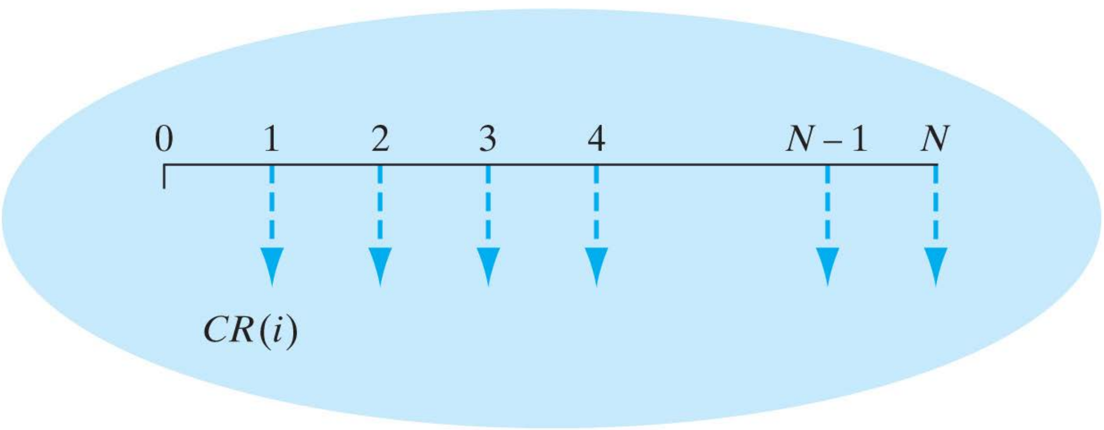
Example 5.14 and Example 6.3 (Chan S. Park, Figure 6.3)

- Useful Definitions:
  - Capital Cost
    - *The amount of net investment.* (Chan S. Park)
  - Operating and Maintenance Cost: *[O+M](i)*
    - *Costs incurred through the operation and maintenance of physical plant or equipment needed to provide service.*
  - Capital Recovery Cost: *CR(i)*
    - *The annual payment that will repay the cost of a fixed asset over the useful life of the asset and will provide an economic rate of return on the investment.* (Chan S. Park)
  - Equivalent Uniform Annual Cost: *EUAC(i)**
    - EUAC(i) = CR(i) + [O+M](i)
    - Refer to lecture 9 (retirements and replacements) also.

*** Also referred to as: "annual equivalent cost" (AEC), OR "annual cost" (AC)**



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



Capital recovery cost calculation (Chan S. Park, Figure 6.4)

- Example 6:
  - A local pharmaceutical manufacturing company is considering purchasing some purification machines for their factory. Each machine will cost $55,000 and have an operating and maintenance cost that starts at $18,000/machine the first year and increases by $3,000 per year. Assume the salvage value of each machine is $12,000 at the end of 5 years and the interest rate is 10%.
  - Calculate the EUAC of one truck.

- Example 6:
  - Given:
    - I = $55,000
    - S = $12,000
    - N = 5 years
    - i = 10%
    - O + M costs ➔ Gradient Series

      A_1 = $18,000

      G = $3,000
  - Steps:
    - Calculate CR(i)
    - Calculate [O+M](i)
    - Calculate EUAC

- Example 6:

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

$$CR(i) = (\$55{,}000 - \$12{,}000)(A/P,10\%,5) + (10\%)(\$12{,}000)$$

$$CR(i) = (\$43{,}000)(0.2638) + \$1{,}200$$

$$CR(i) = \$12{,}543$$

$$[O+M](i) = A_1 + G(A/G,i,N)$$

$$[O+M](i) = \$18{,}000 + \$3{,}000(A/G,10\%,5)$$

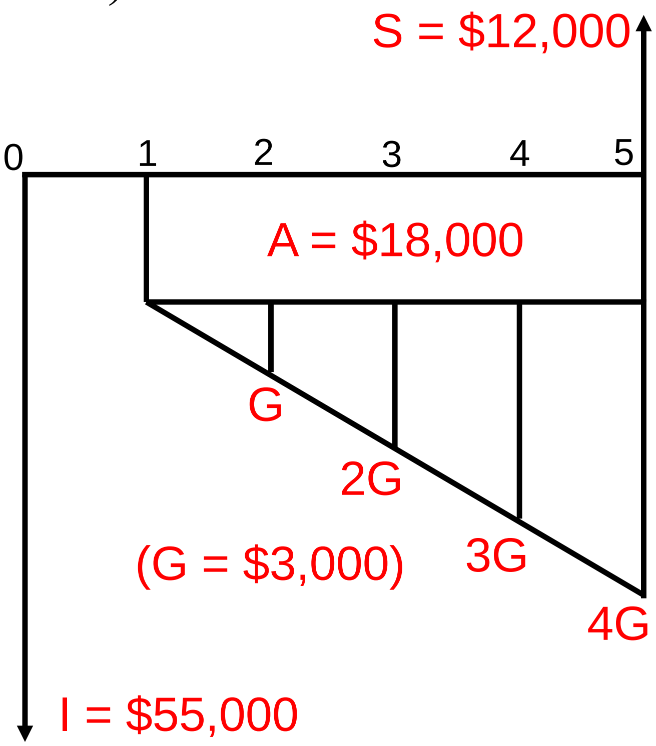
$$[O+M](i) = \$18{,}000 + \$3{,}000(1.8101)$$

$$[O+M](i) = \$23{,}430$$

$$EUAC(i) = CR(i) + [O+M](i)$$

$$EUAC(i) = \$12{,}543 + \$23{,}430$$

$$EUAC(i) = \$35{,}974$$



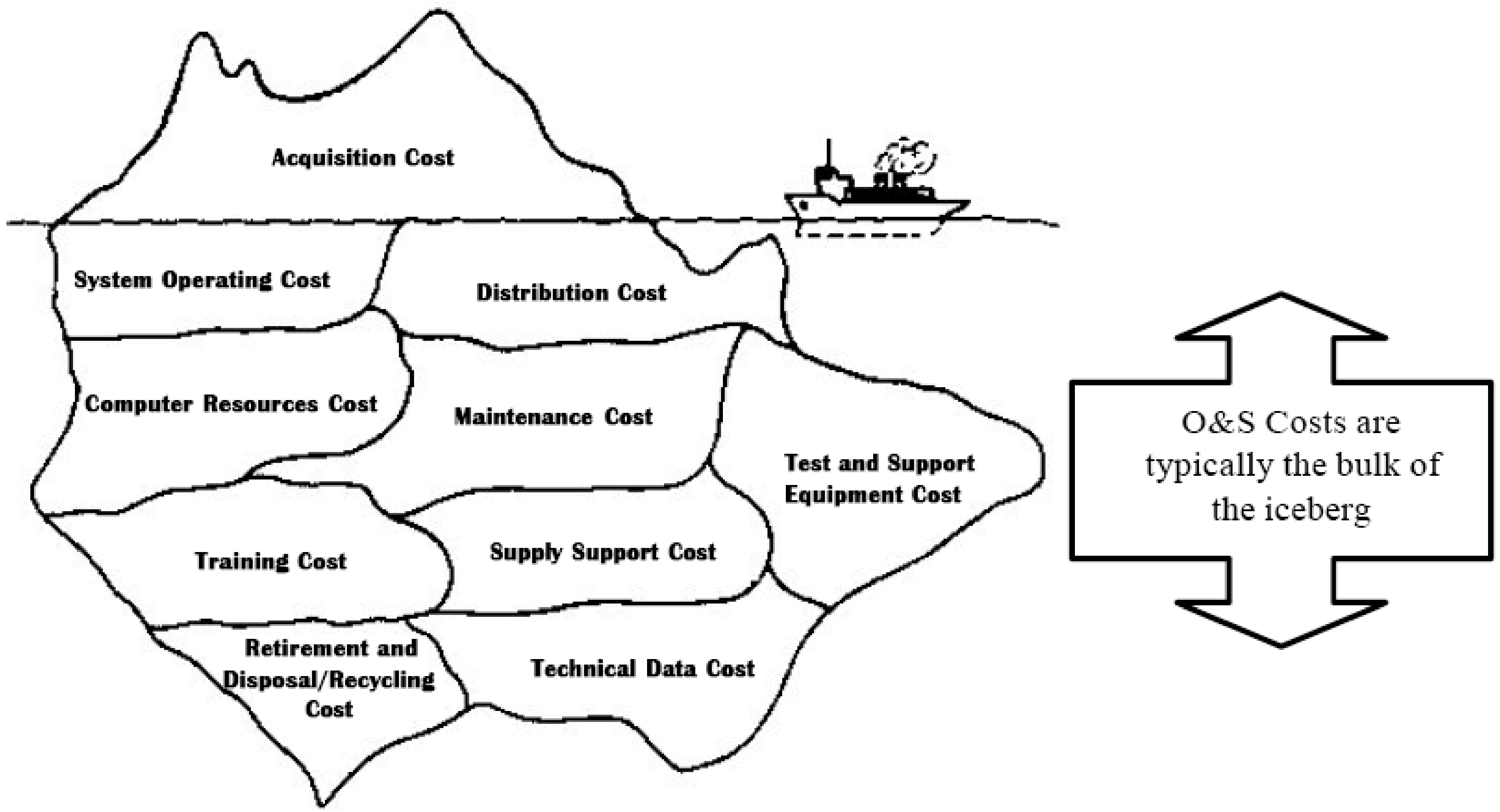
- Make-or-Buy Decisions:
  - Among the most common of business decisions.
  - Method of comparing the make or buy options in dollars per unit.
  - Requires the use of annual worth analysis.

- Recommended Procedure: (Chan S. Park)
  - **Step 1:**
    Determine the time span (planning horizon) for which the part (or product) will be needed.
  - **Step 2:**
    Determine the annual quantity of the part (or product).
  - **Step 3:**
    Obtain the unit cost of purchasing the part (or product) from the outside firm.
  - **Step 4:**
    Determine the equipment, manpower, and all other resources required to make the part (or product).
  - **Step 5:**
    Estimate the net cash flows associated with the “make’’ option over the planning horizon.
  - **Step 6:**
    Compute the annual equivalent cost of producing the part (or product).
  - **Step 7:**
    Compute the unit cost of making the part (or product) by dividing the annual equivalent cost by the required annual volume.
  - **Step 8:**
    Choose the option with the minimum unit cost.

- Life Cycle Cost Analysis:
  - Formal Definition:
    - A general method of economic evaluation which takes into account all relevant costs over a given period of time adjusting for differences in the timing and the true value of those costs.
  - What is Life Cycle Cost?
    - Life-cycle cost (LCC) is the total cost of ownership of a product, structure, or system over its useful life.

	R &D	Investment	O&S
F-16 Fighter	2%	20%	78%
M-2 Bradley Fighting Vehicle	2%	14%	84%

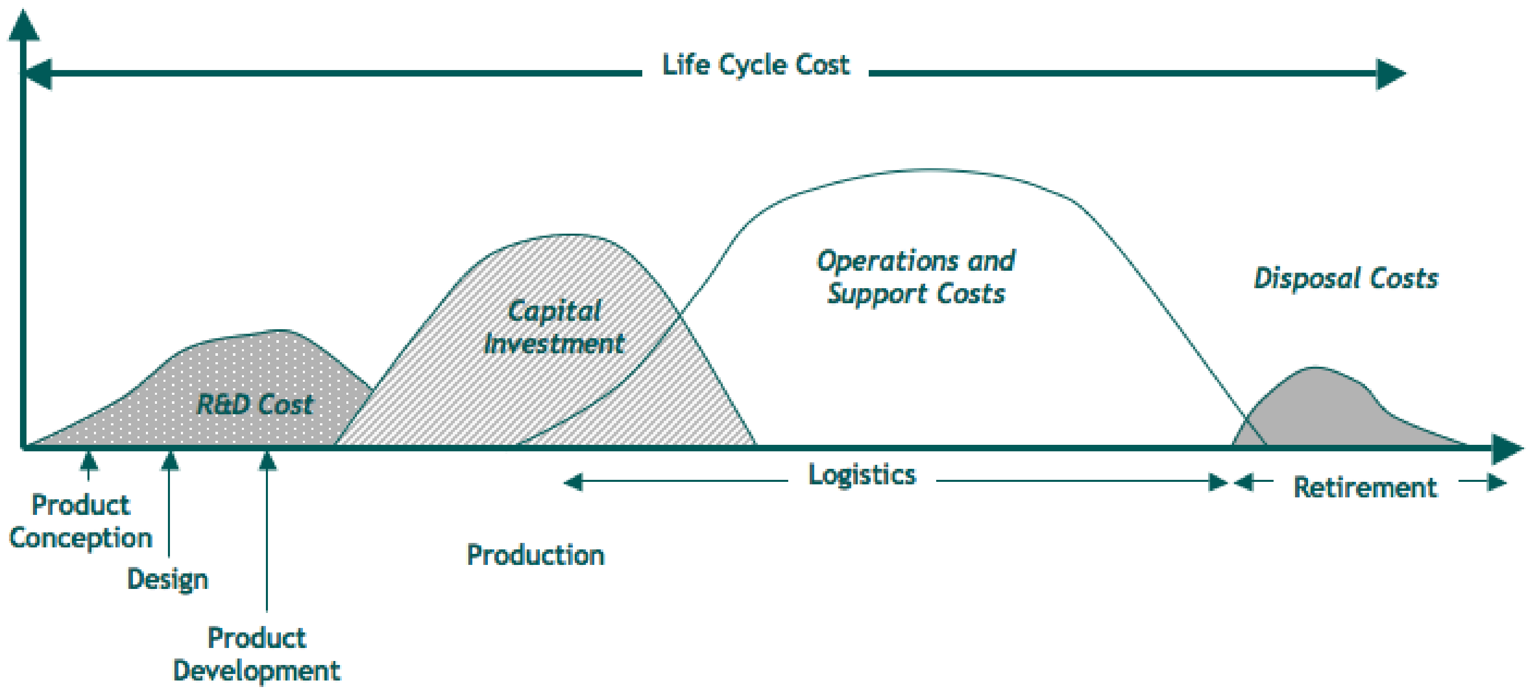
PERCENTAGE OF LIFE-CYCLE COSTS INCURRED IN VARIOUS PROGRAM PHASES



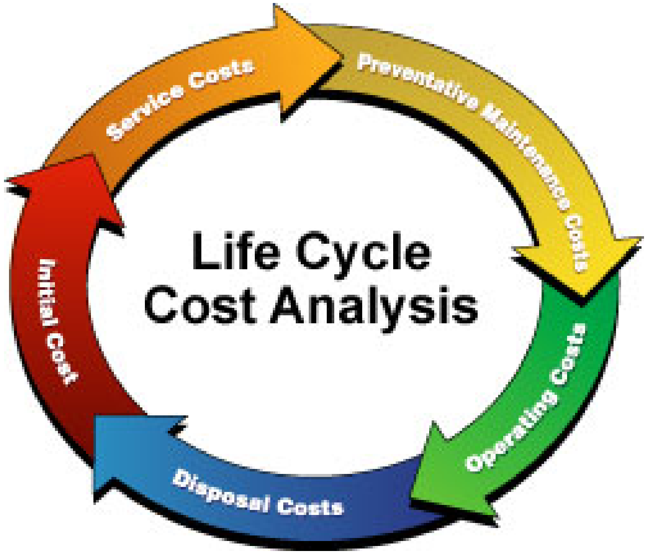
The Life Cycle Cost Iceberg
("Life cycle Cost and Economics Analysis" by Fabrycky & Blanchard)
http://www.rmspartnership.org/briefings/LOG203-1.pdf

- Purposes of Life Cycle Costing in acquisition management, product development, etc. are:
  - Estimate the total costs to the stakeholder
  - Reduce/capture total ownership cost (TOC) through using LCC tradeoffs in the systems engineering/product development process
  - Control cost through using LCC contractual provisions in procurements
  - Assist in day-to-day acquisition management actions by providing timely, consistent, and relevant cost information, and,
  - By understanding TOC, determine whether to proceed to next development phase

- Major Cost Factors:
  - For products purchased off the shelf, the major factors are the cost of acquisition, operation, service, and disposal.
  - For products or systems that are not available for immediate purchase, it may be necessary to include the costs associated with conceptual analysis, feasibility studies, development and design, logistics support analysis, manufacturing, and testing.



- When is the development of a LCC model particularly useful?
  - When a number of alternatives exist in the early stages of a project's life cycle and the selection of an alternative has a noticeable influence on the total life-cycle cost.
  - At the outset of a project, they provide a means of evaluating alternative designs; as work progresses, they may be called on to evaluate proposed engineering changes.
  - At a higher level, model results support decisions regarding logistic and configuration issues, the selection of manufacturing processes, and the formulation of maintenance procedures.
  - By proper use, engineers and managers can choose alternatives so that the life-cycle cost is minimized while the required system effectiveness is maintained.

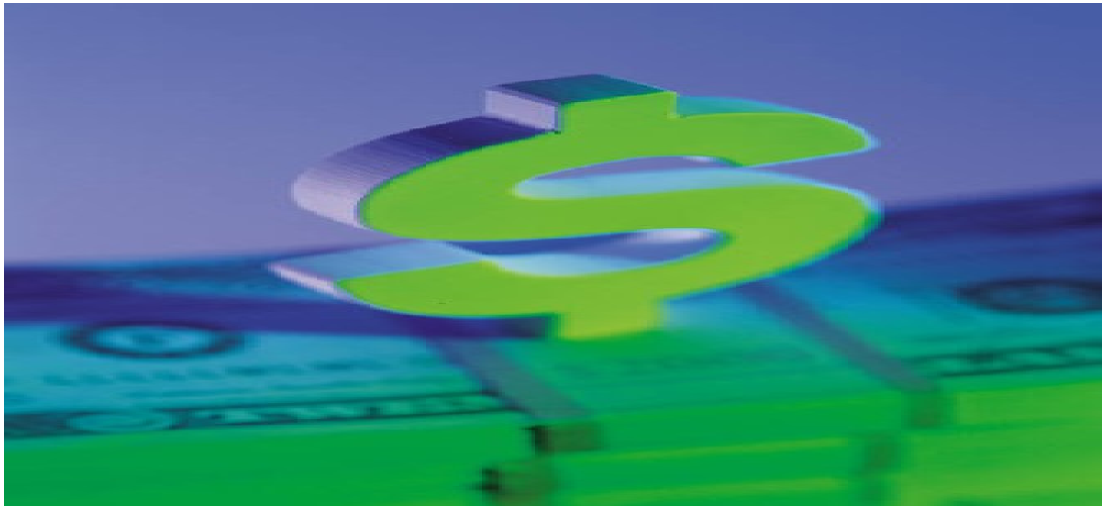


- What are the two principal types of uncertainty that LCC model builders are advised to consider?
  - **Type 1:**

    Uncertainty regarding the cost-generating activities during the system's life cycle
  - **Type 2:**

    Uncertainty regarding the expected cost of each of these activities

- Applications for LCC models:
  - Strategic or long-range budgeting
  - Strategic or long-range technical decisions
  - Data analysis and processing
  - Logistic support analysis



- Applications for LCC models:
  - Strategic or long-range budgeting
    - LCC can be used to coordinate investment expenditures over the system's useful life.
    - LCC can be used to adjust the requirement for capital for one system or project with capital needed or generated by other systems or projects.
    - Long-range budget planning is important for strategic investment decisions.

- Applications for LCC models:
  - Strategic or long-range technical decisions
    - Strategic decision making as it relates to such issues as the redesign of a system or the early termination of an R&D project is difficult to support.
    - The LCC model can be used to monitor changes in cost estimates as the project evolves.
    - LCC estimates improve over time, therefore, rough projections made in the early phases of a project's life cycle may be updated later and provide managers with more accurate data to support the technical decision-making process.

- Applications for LCC models contd:
  - Data analysis and processing
    - LCC models routinely serve as a framework for the collection, storage, and retrieval of cost data.
    - By using an appropriate data structure (e.g., life-cycle cost breakdown structure), the cost components of current or retired systems can be analyzed simultaneously to yield better estimates for future systems.

- Applications for LCC models contd:
  - Logistic support analysis
    - Logistics is generally concerned with transportation, inventory and spare parts management, database systems, maintenance, and training.
    - Questions such as what maintenance operations should be performed and at what frequency, how much to invest in spare parts, how to package and ship systems and parts, what training facilities are required, and what type of courses should be offered to the operators and maintenance personnel are examples of decisions supported by LCC analyses.

- Problem 1:

Case Study 3-1 Nuclear Powered Carriers (Federation of American Scientists, 2007)
A nuclear-powered carrier costs about $8.1 billion, or about 58 percent, more than a conventionally powered carrier to acquire, operate and support for 50 years, and then to inactivate. The investment cost for a nuclear-powered carrier is more than $6.4 billion, which we estimate is more than double that for a conventionally powered carrier. Annually, the costs to operate and support a nuclear carrier are almost 34 percent higher than those to operate and support a conventional carrier. In addition, it will cost the Navy considerably more to inactivate and dispose of a nuclear carrier (CVN) than a conventional carrier (CV) primarily because the extensive work necessary to remove spent nuclear fuel from the reactor plant and remove and dispose of the radiological contaminated reactor plant and other system components.

- Problem 1:

Life-Cycle Costs for Conventional and Nuclear Aircraft Carriers
(Based on a 50-year service life)
(Fiscal year 1997 dollars in millions)

Cost Category	CV	CVN
Investment Costs		
Ship acquisition cost	\$2,050	\$4,059
Midlife modernization cost	\$866	\$2,382
Total investment cost	\$2,916	\$6,441
Average annual investment cost	\$58	\$129
Operating and Support Cost		
Direct operating and support cost	\$10,43	\$11,677
Indirect operating and support cost	\$688	\$3,205
Total operating and support cost	\$11,125	\$14,882
Average annual operating and support cost	\$222	\$298
Inactivation/Disposal Cost		
Inactivation/disposal cost	\$53	\$887
Spent nuclear fuel storage cost	n/a	\$13
Total inactivation/disposal cost	\$53	\$899
Average annual inactivation/disposal cost	\$1	\$18
Total life-cycle cost	\$14,094	\$22,222
Average annual life-cycle cost	\$282	\$444

Questions?