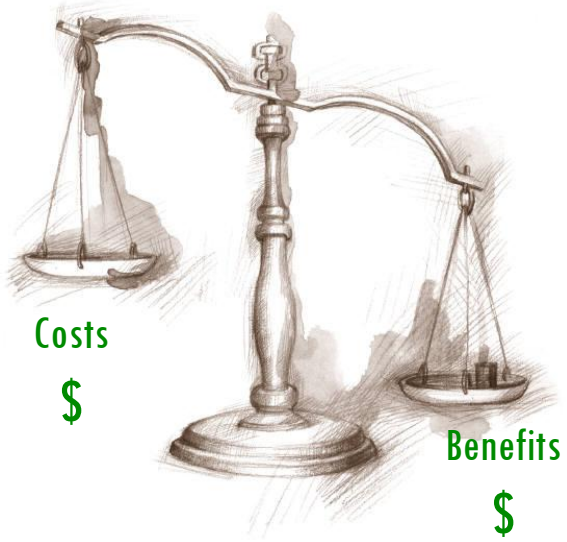
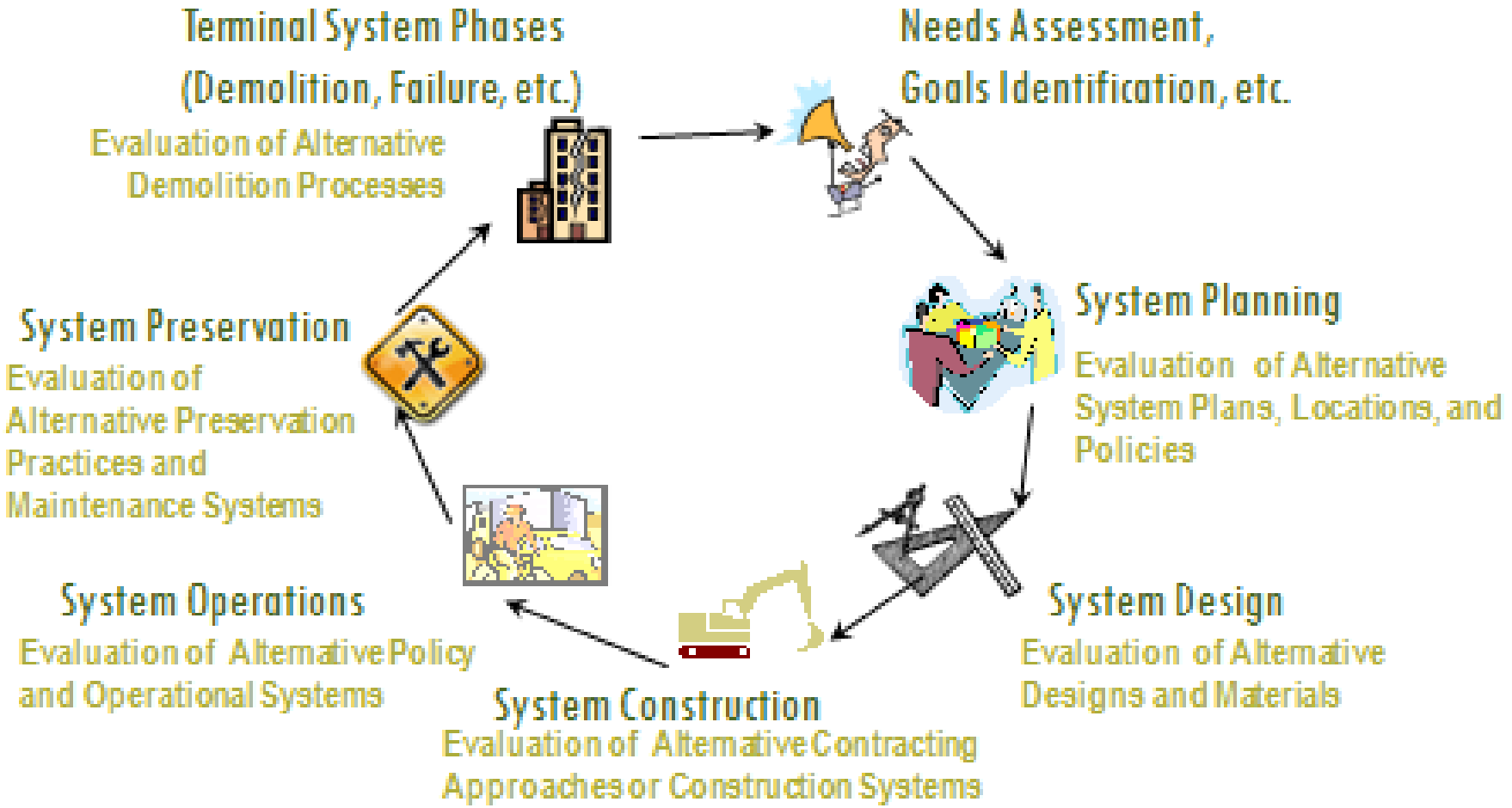
Engineering Economics II

(Evaluation of Alternatives using Life-cycle Cost Analysis)



SAMUEL LABI

Recall the Phases of CE Systems Development ...



From economic perspective only, on what basis do we choose one alternative over another?

- "Alternative" …
  means "mutually exclusive".

In other words, if 2 projects are described as "alternative", the occurrence of one project completely precludes the occurrence of another

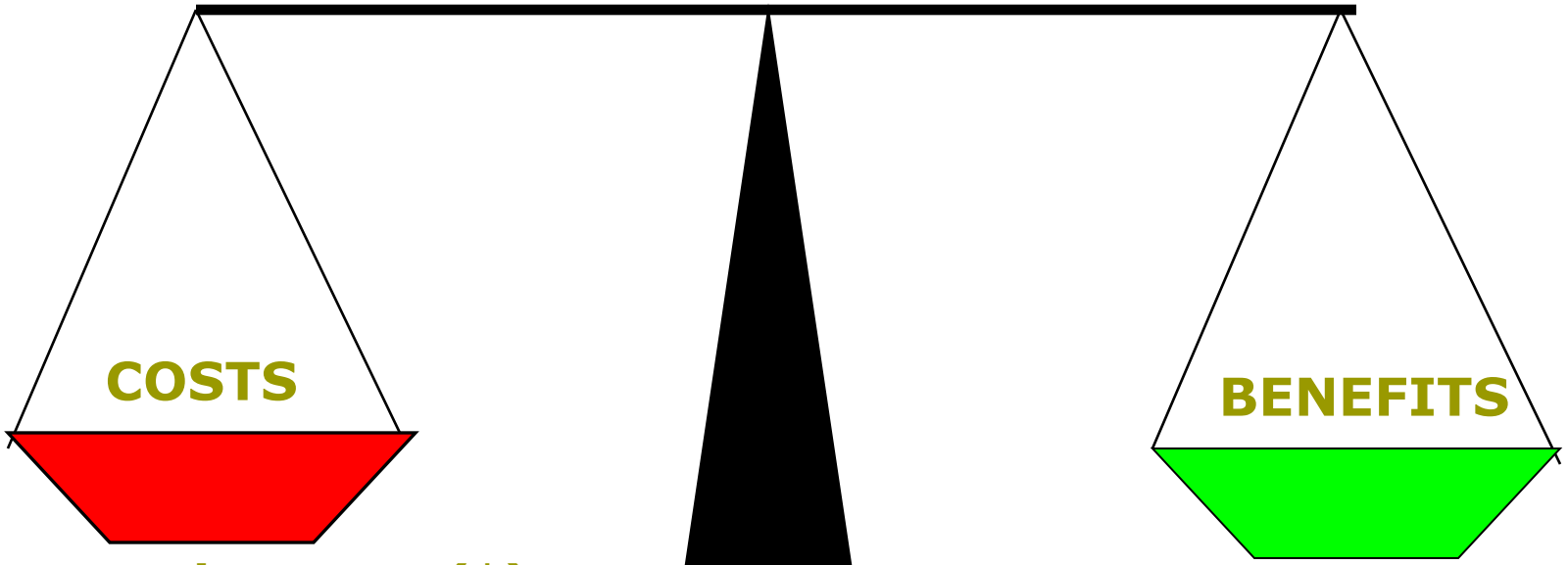
Either you do one project or you do the other

You cannot do both.

- "Evaluation" means …

  … comparing the positive impacts (**benefits**) with the negative impacts (**costs**) as a basis of deciding whether or not to undertake the project.

Economic Evaluation of Investments-The General Picture



-Construction costs ($)

-Maint./Ops Costs ($)

-Air/Noise Pollution ($)?

-Environ. Degradation (4)

-Increased Energy Use, etc. (4)

-Income/Revenue ($)

-Increased Safety ($)

-Decreased Congestion ($)

-Public Wellbeing ($)

Single Project Evaluation

Assessing the benefits and costs of only 1 project, and deciding whether or not to undertake that project.

- Examples:
  - **Should a traffic light be installed at a certain intersection?**
  - **Should a new treatment plant be built to replace an existing one?**

Multi Project Evaluation

- Assessing the benefits and costs of several alternative projects, and deciding which one to undertake.

- Note that all alternatives in a given problem address the same objective.

- ***Examples:***

- What type of traffic light should be installed at a certain intersection?

- Which design should be selected for a new treatment plant?

- Which location should a new bridge be sited?

- What size of bus should a transit company purchase?

What do we seek in economic evaluation?

… "most economically feasible"

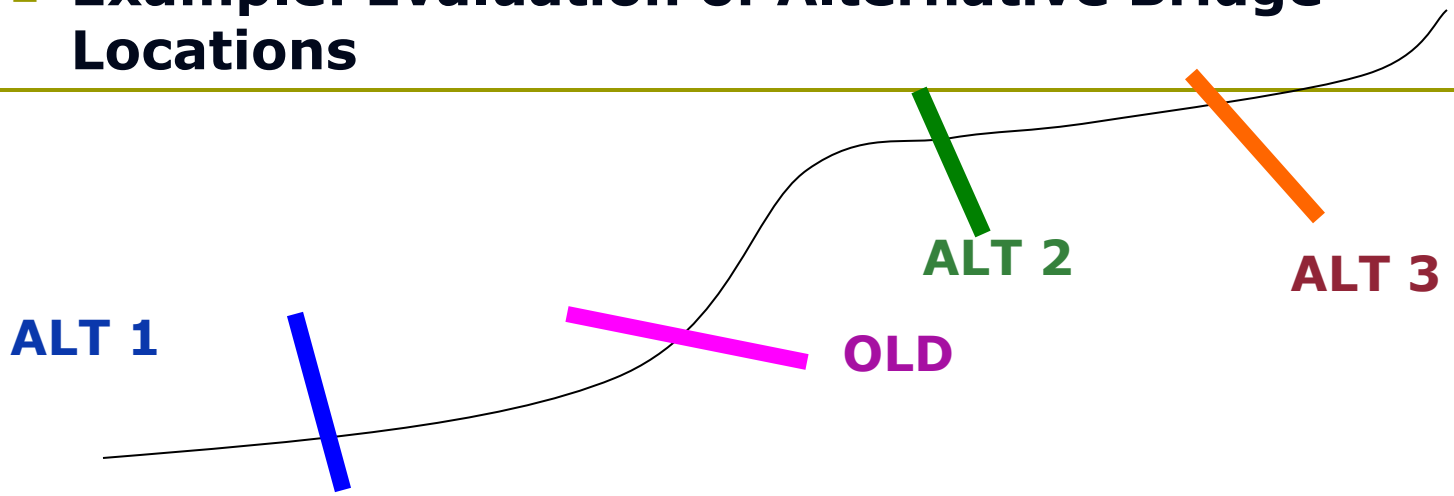
… "economically optimal"

… "most economically viable"

… "most preferred, economically",

etc

- **Example: Evaluation of Alternative Bridge Locations**



	Performance Criteria		Evaluation Criteria	
	B'fits	Costs	B/C	B-C
Alt 1				
Alt 2				
Alt 3				

The best alternative is the one with the best value of the selected evaluation criterion.

Do we always use both benefits and costs in evaluation?

No!

(1) If all alternative projects have the same cost, then evaluation can be done on the basis of their benefits only

Also:

If all alternative projects have the same benefit,

then

evaluation can be done on the basis of their costs only

And:

If all alternative projects have different benefits and different costs,

then

evaluation can be done on the basis of both benefits and costs.

Criteria for Economic Evaluation

- Present Worth of Costs (PWC)
- Equivalent Uniform Annual Cost (EUAC)
- Equivalent Uniform Annual Return (EUAR)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Benefit-cost Ratio (BCR)

1. Present Worth of Costs

- Is used when benefits of all alternatives are equal, so cost is the only criterion to consider in choosing the best alternative
- Alternatives have the same service life or analysis period
- Converts all costs into an equivalent single cost assumed to occur at the beginning of the analysis period (time = zero).

Present Worth of Costs - Example

- An airplane purchase is proposed.
- For airplane type A
  - initial cost = $50 million,
  - average annual maintenance cost = $0.25 million,
  - salvage value = $8 million.
- For airplane type B
  - initial cost = $30 million,
  - average annual maintenance cost = $0.75 million,
  - salvage value = $2 million.
- Both types have a useful life of 15 years. Which alternative should be selected? Assume 7% interest rate.

Solution

- PWC_A (in millions)

$$= 50 + 0.25*USPWF(7\%, 15) - 8*SPPWF(7\%, 15) = \$49.38M$$

- PWC_B (in millions)

$$= 30 + 0.75*USPWF(7\%, 15) - 2*SPPWF(7\%, 15) = \$36.11M$$

- Alternative B has a lower PWC
- Thus Alt B. is more desirable.

2. Equivalent Uniform Annual Costs (EUAC)

- Is used when benefits of all alternatives are equal, so cost is the only criterion to consider in choosing the best alternative
- Alternatives have the different service lives or analysis periods
- Converts all costs into an equivalent cost assumed to occur at each year of the analysis period.

Example

- Bus transit services in MetroCity can be performed satisfactorily using any one of two alternative bus types, A or B.

- Bus type A: initial cost = $100,000
  estimated life = 6 yrs
  annual maintenance & operating costs = $8,000
  salvage value = $20,000.

- Bus type B: initial cost = $75,000
  estimated life = 5 yrs
  annual maintenance & operating costs = $8,000 for the first 2yrs and $12,000 for the remaining 4 yrs
  salvage value = $10,000.

- Find the equivalent annual cost of each alternative, and decide which option is more desirable. Assume a 6% interest rate.

Solution

- $EUAC_A$ (in thousands) = $100CRF(6\%, 6) + 8USPWF(6\%, 6)$ $CRF(6\%, 6) - 20SFDF(6\%, 6) = \$25.47$

- $EUAC_B$ (in thousands) = $75CRF(6\%, 5) + 8USPWF(6\%, 2)$ $CRF(6\%, 6) + (12USPWF(6\%, 4)\ SPPWF(6\%, 2)CRF(6\%, 6) - 40SFDF(6\%, 6) = \$22.57$

- Alternative B is more desirable.

Equivalent Uniform Annual Return

- Used when costs are different and benefits are also different across alternatives
- Combines all costs and benefits or returns associated into a single annual value of return (benefits less costs) over the analysis period.
- This method can be used when the alternatives have different service lives.

Example

- Two alternative designs proposed for renovating Water Port.
- Annual benefits Aare in terms of monetized savings in inventory delay, safety and security, and vessel operations.
- Alternative A: initial project cost = $200 million, life = 25 yrs,

  salvage value = $22 million, annual maintenance/operating costs = $80 million, annual benefits = $75 million.
- Alternative B: initial project cost = $175 million, life = 20 yrs,

  salvage value = $15 million, annual maintenance/operating costs = $90 million, annual benefits = $55 million.
- Find the equivalent uniform annual return of each alternative and identify the better alternative. Assume that both alternatives will yield similar levels of performance and have no salvage value. Assume a 4% interest rate.

- $EUAR_A$ (in millions)

  $= 75 - 200CRF(4\%,25) - 80 + 22SFDF(4\%,25) = -\$17.27\text{M}$

- $EUAR_B$ (in millions)

  $= 55 - 175CRF(4\%,25) - 90 + 15SFDF(4\%,25) = -\$45.84\text{M}$

- Alternative A is more desirable.

- The NPV of an investment is the difference between the present worth of benefits and the present worth of costs.
- NPV reflects the value of the project at the time of the base year of the analysis which may be considered the year of decision making.
- NPV is often considered as the best economic efficiency indicator as it provides a magnitude of net benefits in monetary terms.
- Among competing transportation projects or policies, the alternative with the highest NPV is considered the most "economically efficient."

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- Alternative B: initial project cost = $175 million, life = 20 yrs,

  salvage value = $15 annual maintenance/operating costs = $90 million, annual benefits = $55 million.
- Find the equivalent uniform annual return of each alternative and identify the better alternative. Assume that both alternatives will yield similar levels of performance and have no salvage value. Assume a 4% interest rate.

- NPV_A (in millions)

$$= 75 * USPWF(4\%, 25) - 200 - 80 * USPWF(4\%, 25) + 22 * SPPWF(4\%,25) = -\$269.86\text{M}$$

- NPV_B (in millions)

$$= 55 * USPWF(4\%, 25) - 175 - 90 * USPWF(4\%, 25) + 15 * SPPWF(4\%,25) = -\$716.15\text{M}$$

- Alternative A is more desirable.

The Internal Rate of Return (IRR)

- IRR found by equating PW_{benefits} to PW_{costs}, or by equating $EUAC_{\text{benefits}}$ to $EUAC_{\text{costs}}$.
- Minimum attractive rate of return (MARR)
  - is the lowest rate of return that investors will accept before they invest considering the likely investment risks or the opportunity to invest elsewhere for possibly greater returns.
- Then the IRR is compared to the Minimum Attractive Rate of Return (MARR).
  - If the IRR › MARR, then the investment is considered worthwhile.
  - If the IRR ‹ MARR, then investment is considered NOT worthwhile.

Solution

- Equating the net cash flow on both sides yields:

$$5{,}000\text{USPWF}(i\%,10) + 15{,}000\text{SPPWF}(i\%,10) = 30{,}000 + 2000\text{USPWF}(i\%,10)$$

- Solving this equation by trial and error yields: $i = 6.25\%$ This value exceeds the MARR value of 5%.
- So it is economically more efficient to undertake the project than to do nothing.

Benefit Cost Ratio

- The benefit-cost ratio (BCR) is a ratio of benefits to costs.
- That is:
  - $NPV_{\text{Benefits}}/NPB_{\text{Costs}}$
  - $EUA_{\text{Benefits}}/EUA_{\text{Costs}}$
- An investment with a BCR exceeding 1 is considered to be economically feasible
- The alternative (investment) with the highest BCR value is considered the best.

Example

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  salvage value = $15 annual maintenance/operating costs = $90 million, annual benefits = $55 million.
- Find the equivalent uniform annual return of each alternative and identify the better alternative. Assume that both alternatives will yield similar levels of performance and have no salvage value. Assume a 4% interest rate.

Solution

Taking the ratio of all benefits to all costs yields:

For Alternative A:

$$BCR_A = \frac{PWB_A}{PWC_A} = \frac{75 \times USPWF(4\%, 25) + 22 \times SPPWF(4\%, 25)}{200 + 80 \times USPWF(4\%, 25)} = 0.8139$$

For Alternative B:

$$BCR_B = \frac{PWB_B}{PWC_B} = \frac{55 \times USPWF(4\%, 25) + 15 \times SPPWF(4\%, 25)}{175 + 90 \times USPWF(4\%, 25)} = 0.5470$$

$BCR_A > BCR_B$, hence, A is a better alternative.

Example Question

- John is considering buying an old used car for a part-time pizza delivery business. He expects the following costs and benefits over a 5-year period:

  Initial Cost (car purchase)= $5,000

  Car maintenance cost = $1,000 in year 2
  and $1,800 in Year 4

  Annual Income from Pizza deliveries = $10,000

  Salvage value of the car after Year 5 = $2,000

Example Question (continued)

- Jeff (John's friend) tries to convince John to buy a fast new small car for the pizza delivery business. With this new car, the following costs and benefits over a 5-year period, are expected:

  Initial Cost (car purchase)= $13,000

  Car maintenance cost = $500 in Year 3

  Annual Income from Pizza deliveries = $12,000

  Salvage value of the car after Year 5 = $7,000

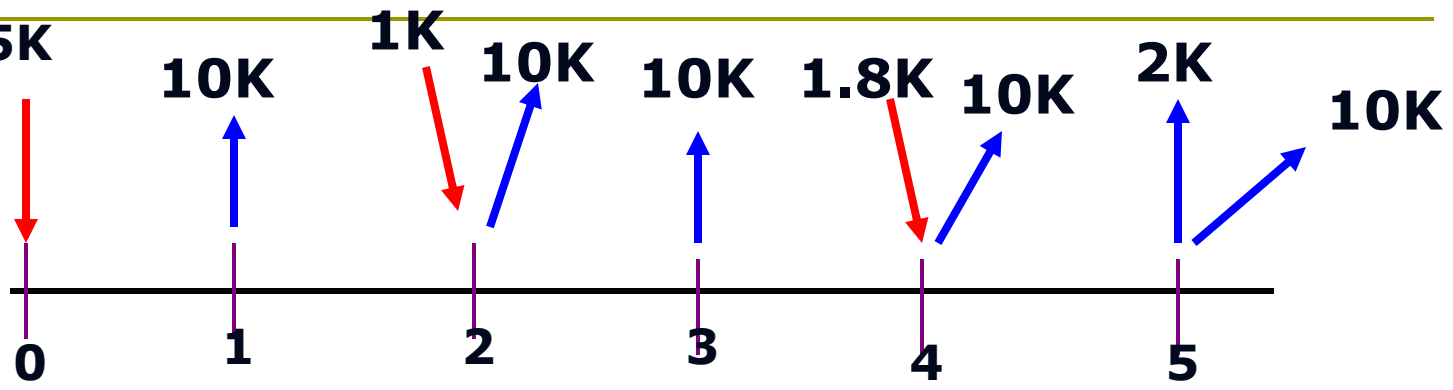
Example Question (continued)

- Which alternative investment is better? Use each of the following 4 methods of economic evaluation:
  - Net Present Value
  - Equivalent Uniform Annual Revenue
  - Benefit Cost Ratio
  - Internal Rate of Return Method

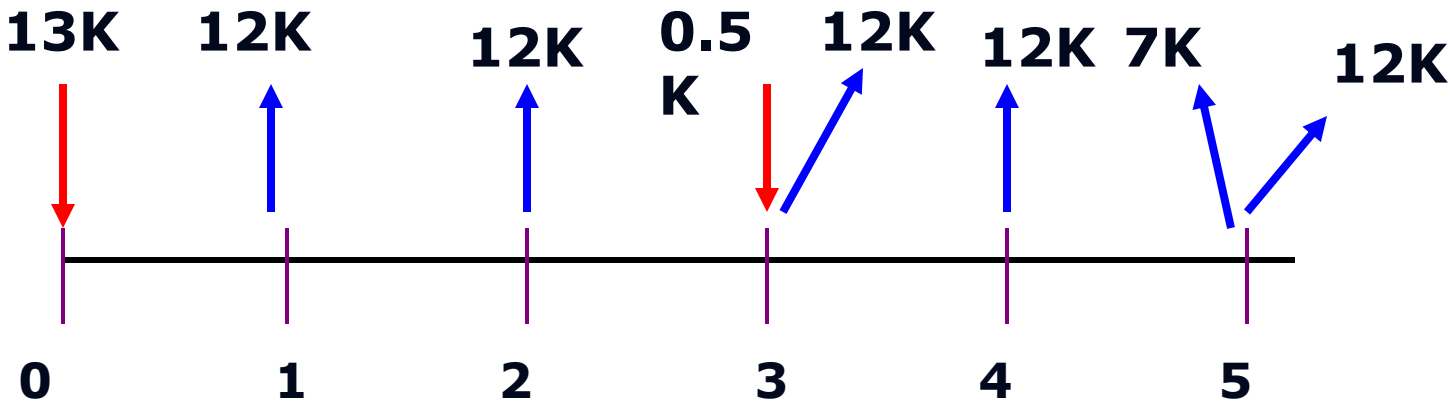
- Assume 5% interest rate.

SOLUTION

Alt 1:



Alt 2:



The Net Present Value (NPV) Method

	Alternative 1	Alternative 2
Present Worth of Benefits (PWB)	10K*USPWF(5%, 5Yrs) + 2K*SPPWF(5%, 5 Yrs) = $44,856	12K*USPWF(5%,5Yrs) + 7K*SPPWF(5%,5 Yrs) = $57,429
Present Worth of Costs (PWC)	5K*SPPWF(5%, 0 Yrs) + 1K*SPPWF(5%, 2Yrs) + 1.8K*SPPWF(5%, 4 Yrs) = $7387	13K*SPPWF(5%, 0Yrs) + 0.5K*SPPWF(5%, 3Yrs) = $13,431
Net Present Value, NPV = PWB-PWC	**$37,469**	**$43,998**
Evaluation and Decision	**Alternative 2 is better!**	

- The Equivalent Uniform Annual Return (EUAR) Method

	Alternative 1	Alternative 2
Present Worth of Benefits	10K*USPWF(5%, 5Yrs) + 2K*SPPWF(5%, 5 Yrs) = $44,856	12K*USPWF(5%,5Yrs) + 7K*SPPWF(5%,5 Yrs) = $57,429
Equiv. Uniform Annual Benefit =PWB*USCRF	$10,387	$13,209
Present Worth of Costs	5K+ 1K*SPPWF(5%, 2Yrs) + 1.8K*SPPWF(5%, 4 Yrs) = $7387	13K+ 0.5K*SPPWF(5%, 3Yrs) = $13,431
Equiv. Uniform Annual Cost =PWC*USCRF	$1,699	$3,089
Eq. Unif An. Return =EUAB-EUAC	$8,688	$10,120
Evaluation and Decision	Alternative 2 is better	

The Benefit/Cost Ratio Method

	Alternative 1	Alternative 2
Present Worth of Benefits (PWB)	10K*USPWF(5%, 5Yrs) + 2K*SPPWF(5%, 5 Yrs) = $44,856	12K*USPWF(5%,5Yrs) + 7K*SPPWF(5%,5 Yrs) = $57,429
Present Worth of Costs (PWC)	5K + 1K*SPPWF(5%, 2Yrs) + 1.8K*SPPWF(5%, 4 Yrs) = $7387	13K + 0.5K*SPPWF(5%, 3Yrs) = $13,431
Benefit Cost Ration, BCR **= PWB/PWC**	**6.07**	**4.28**
Evaluation and Decision	**Alternative 1 is more attractive**	