Al-Mansour University College

قسم الهندسة المدنية
المرحلة الثالثة

Civil Eng. Dept
3rd. Stage

Engineering Economy

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الاقتصاد الهندسي

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Depreciation- Time Value Method

- ❑ To determine the purchase price equivalent annual cost, the uniform series capital recovery factor formula, Eq. [2.6], is used.
- ☞ The input parameters are the purchase price at time zero (*P*), expected service life (*n*), and the corporate cost of capital rate (*i*).

- ❑ To account for the salvage cash inflow, Eq. [2.4], the uniform series sinking fund factor formula is used.
- ☞ The input parameters are the estimated future salvage amount (*F*), the expected service life *(n)*, and the corporate cost of capital rate *(i)*.

Engineering Economy

Syllabus:

- Introduction
- Demand-Supply Relationship
- Costs
- Time-Value of Money
- Interests
- Depreciation
- Evaluation of Economic Alternatives

References:

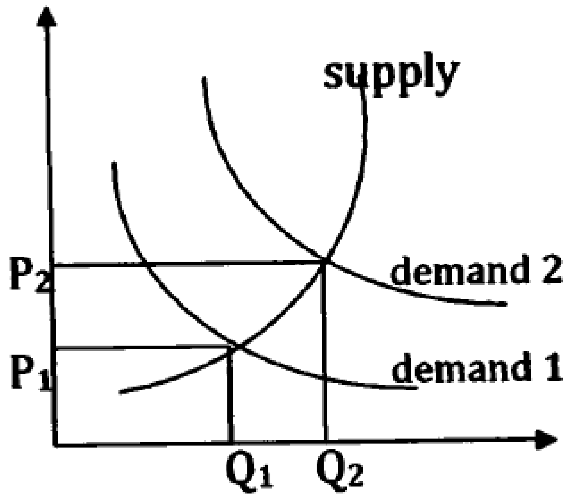
Engineering Economy	E. Paul DeGarmo
Engineering Economy	Leland Blank and Antony Tarquin
Engineering Economy and Project Management	Chan S. Park and Donald D. Tippett
Fundamentals of Engineering Economics	Kal Renganathan Sharma

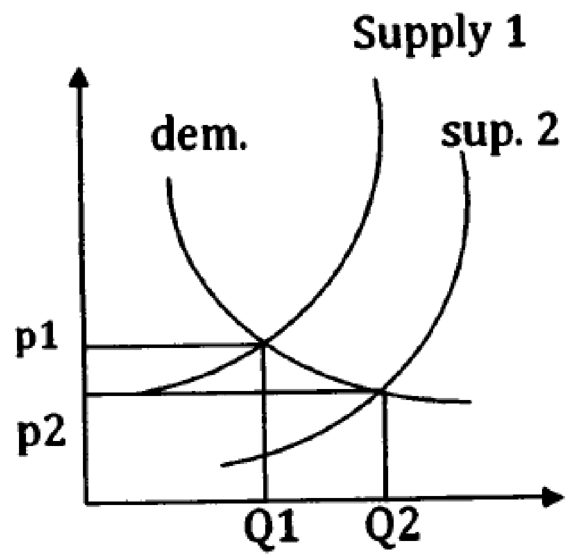
Demand and Supply

Demand: the desire to get Goods and services supported with the money that can the consumer give up on it and buy another one .

The factors depend on demand

1- Advertising.
2- Geographic Location.
3- Tastes of people.
4- Incomes.
5- Appearance a new goods.
6- Change of leveling life.
7- The cost of goods and the alternative.
Increasing in the demand causes increasing in the cost.





Introduction:

- ✪ The Accreditation Board for Engineering and Technology (ABET) states that **ENGINEERING** "*is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind*".

1.1. What is Engineering Economy?

- ❑ Engineering economy is a subset of economy for application to engineering projects.
- ❑ Engineers seek solutions to problems, and the economic <u>viability</u> of each potential <u>alternative</u> or design is normally considered along with the *technical* aspects.
- ❑ Engineering economy involves the <u>evaluation</u> of the *costs* and *benefits* of proposed projects.
- ➢ So, Engineering Economy study is necessary to <u>balance</u> the *unlimited desire* versus the *resource-constrained world*; to <u>maximize</u> *output* (worth) given *input* (cost) and to take the necessary for:

  Maximizing efficiency: (output / input) or (worth / cost)

1.2. Why Engineering Economy is Important?

There are lots of factors that are considered in making decisions. These factors are combinations of economic and non-economic ones. Engineers play a major role in investment by making decisions based on economic analysis and design considerations. Thus<u>, decisions often reflect the engineer's choice of how to best invest funds by housing the proper alternative out of a set of alternatives.</u>

1.3. Why do Engineering Need to Learn about Economics?

- ❑ Developing technological tools are the most challenge that always faces engineers.
- ❑ However, it is no longer possible, in most cases, to design and build things for the sake (purpose) of designing and building them.
- ❑ Natural <u>resources</u> (from which engineers build things) are becoming more <u>scarce</u> and <u>expensive</u>.
- ❑ Also, there are negative side-effects of engineering innovations (such as air pollution from automobiles) than ever before.
- ➢ <u>For these reasons:</u>

  Engineers must ask if a particular project will offer some net *benefit* to the people who will be affected by the project, after considering its inherent benefits, plus any negative *side-effects*, plus the cost of *consuming natural resources*, both in the price that must be paid for them and the realization that once they are used for that project, <u>they will no longer be available for any other project(s).</u>
- ✪ Engineers must decide if the benefits of a project exceed its costs, and must make this comparison in a unified framework.
- ✪ Accordingly, consideration of economic factors is as important as regard for the physical laws and science that determine what can be accomplished with engineering.

1.4. The Decision Making Process

1. Recognition of the Problem

The starting point of any attempt in a decision making process is the recognition that a problem exists.

Only when a problem is recognized can the work towards its solution begin in a logical manner.

2. Determination of Objectives

This step involves finding out what people need and want that can be supplied by engineering.

People's wants may arise from logical considerations, emotional drives, or a combination of the two.

The goal must specific not general or wide.

3. Assembly of Relevant Data

To make a good decision, one must first assemble good information.

From all data related to a given problem, it might be difficult to decide which data are important or relevant and which data are not.

In engineering decision making, an important source of data is a firm’s own accounting system.

4. Identification of Strategic Factors

The factors that stand in the way of attaining objectives are known as limiting factors.

Once the limiting factors have been identified, they are examined to locate strategic factors; those factors which can be altered to remove limitations restricting the success of an undertaking.

<u>Simple Example:</u>

A man who wants to empty the water from his swimming pool might be faced with the limiting factor that he only has a bucket to do the job with, and this would require far greater time and physical exertion than he has at his disposal.

A strategic factor developed in response to this limitation would be the procurement of some sort of pumping device which could do the job much more quickly.

1.5. Engineering Economic Studies

The four key steps in planning an economic study are:

1. Creative Step:

Research, exploration, and investigation of potential opportunities

2. Definition Step:

System alternatives are synthesized with economic requirements and physical requirements, and enumerated with respect to inputs/outputs.

3. Conversion Step:

The attributes of system alternatives are converted to a common measure so that systems can be compared.

Future cash flows are assigned to each alternative, consisting of the time-value of money.

4. Decision Step:

Qualitative and quantitative inputs and outputs to/from each system form the basis for system comparison and decision making.

Decisions among system alternatives should be made on the basis of their differences.

For example: infrastructure expenditure decision, replace versus repair decisions, and selection of a replacement for equipment.

So, briefly, performing an engineering economy study involves the following:

- Understand the problem.
- Define objectives.
- Collect relevant information.
- Define the set of feasible alternatives.
- Identify the criteria for decision making.
- Evaluate the alternatives and apply sensitivity analysis.

- Select the “best” alternative.
- Implement the alternative and monitor results.

1.6. Types of Strategic Engineering Economic Decisions

The following are samples of these strategic engineering economic decisions:

- Equipment and process selection.
- Equipment replacement.
- New Product and Product Expansion.
- Cost reduction.
- Service and quality improvement.

1.7. Costs

1.7.1 Fixed and Variable Costs

Fixed costs: Fixed costs are the costs that are not affected by the level of activity over a feasible range of operation. Examples for fixed costs are: depreciation, taxation, insurance and interest.

Variable costs: Variable costs are the costs that vary with the operation and level of activity. Examples for variable costs are; labor, energy and maintenance.

1.7.2 Recurring and Nonrecurring Costs

Recurring costs: are costs that are repeated when an organization produces similar goods or services on a continuing basis. Examples of recurring costs are variable costs, because they repeat with each unit of output.

Nonrecurring costs: Nonrecurring costs are those costs which are not repetitive with the production of a merchandise or service. Examples of recurring costs are purchase cost for real estate (land) upon which a plant will be built and construction costs.

1.7.3 Cash cost and Book Cost

Cash costs: are costs that involve cash payments and results in cash flow. They are the estimated costs and future expenses for the alternatives being analyzed.

Book costs: Book costs are costs that do not involve cash payments but it represent the recovery of past expenditures over a fixed period of time. Examples: depreciation charge is a book value for the use of plant and equipment. In engineering economy these costs should be considered as it affect the cash costs for example depreciation is not a cash cost and it is important in analysis because it affects income taxes which are a cash costs.

1.7.4 Other Cost Classifications

Opportunity Costs: Is the cost of forgoing the chance to earn profit on investment.

<u>Question</u>: "Is it in my best interest to keep my home because it is all paid for?

I have rented my former home, valued at about $185000, for $400 per month . "

<u>Answer</u>: There is little reason to continue owning your former home as a rental.

To see this, consider the opportunity cost, i.e., the return you are giving up, of ownership.

The same $185000 invested in secure bonds at 7% will provide almost $13000 in yearly income.

This is many times what is obtained from continual rental (4800 $/Year)

Sunk Costs: are the unrecoverable past costs and not relevant for decision making purposes. Suppose the heating, ventilating and air conditioning (HVAC) system in your home has just experienced a major failure. You immediately call the Air Condition Company for an estimate to replace your system. Their price is $4200 and you sign a contract and write a check for the required $1000 down payment. At this point the weather warms and the urgency for replacement of your system eases somewhat. You then get a second estimate for a new HVAC system. It is $3000. You call the company back and they inform you that the $1000 down payment is not refundable!

Time-Value of Money

Equation for Single Payments

To calculate the future value F of a single payment P after n periods at an interest rate i, these formulations are used:

At the end of the first period, $n = 1$: $F_1 = P + Pi$
At the end of the second period, $n = 2$: $F_2 = P + Pi + (P + Pi)i = P(1 + i)^2$
At the end of the nth period, $F = P(1 + i)^n$

Or the future single amount of a present single amount is

$$F = P(1 + i)^n \qquad \textbf{[2.1]}$$

Note that F is related to P by a factor that depends only on i and n. This factor is termed the *single payment compound amount factor (SPCAF)*; it makes F equivalent to P.

If a future amount F is given, the present amount P can be calculated by transposing the equation to

$$P = \frac{F}{(1 + i)^n} \qquad \textbf{[2.2]}$$

The factor $1/(1 + i)^n$ is known as the *present worth compound amount factor (PWCAF)*.

P = a present single amount of money
F = a future single amount of money, after n periods of time
i = the rate of interest per period of time (usually one year)
n = the number of time periods

Formulas for a uniform series of pavemnt

Let A = uniform end-of-peroid payment or reciepts contiuing for a duration of n peroids

$$F = A\left[\frac{(1+i)^n - 1}{i}\right] \qquad \textbf{[2.3]}$$

The relationship $[(1+i)^n - 1]/i$ is known as the *uniform series compound amount factor (USCAF)*. The relationship can be rearranged to yield

$$A = F\left[\frac{i}{(1+i)^n - 1}\right] \qquad \textbf{[2.4]}$$

The relationship $i/[(1+i)^n - 1]$ is known as the *uniform series sinking fund factor (USSFF)*, because it determines the uniform end-of-period investment A that must be made to provide an amount F at the end of n periods.

To determine the equivalent uniform period series required to replace a present value of P, simply substitute Eq. [2.1] for F into Eq. [2.4] and rearrange. The resulting equation is

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \qquad \textbf{[2.5]}$$

This relationship is known as the *uniform series present worth factor (USPWF)*.

By inverting Eq. [2.5], the equivalent uniform series end-of-period value A can be obtained from a present value P. The equation is

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \qquad \textbf{[2.6]}$$

This relationship is known as the *uniform series capital recovery factor (USCRF)*.

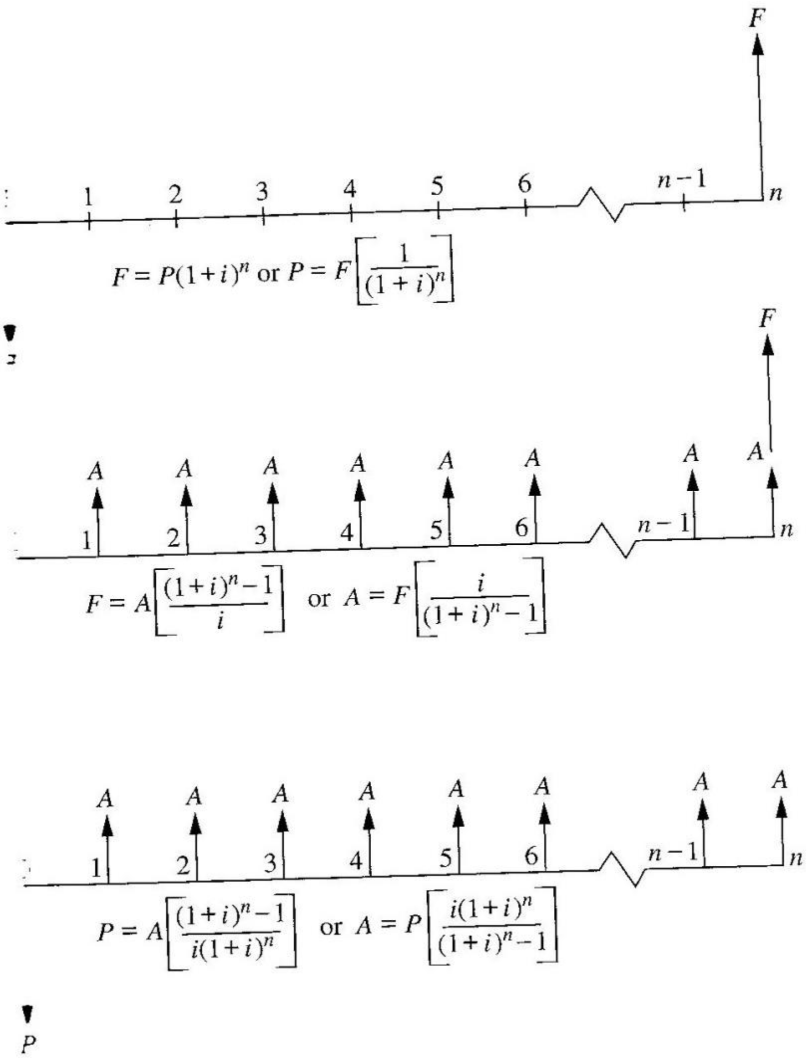


FIGURE 2.1 Cash flow diagrams

TABLE 2.1 Economic analysis relationships

Name	Symbol	Converts	Icon	Formula
Single payment compound amount factor	SPCAF	given P to F	$(F/P, i\%, n)$	$(1 + i)^n$
Present worth compound amount factor	PWCAF	given F to P	$(P/F, i\%, n)$	$1/(1 + i)^n$
Uniform series compound amount factor	USCAF	given A to F	$(F/A, i\%, n)$	$\frac{(1 + i)^n - 1}{i}$
Uniform series sinking fund factor	USSFF	given F to A	$(A/F, i\%, n)$	$\frac{i}{(1 + i)^n - 1}$
Uniform series present worth factor	USPWF	given A to P	$(P/A, i\%, n)$	$\frac{(1 + i)^n - 1}{i(1 + i)^n}$
Uniform series capital recovery factor	USCRF	given P to A	$(A/P, i\%, n)$	$\frac{i(1 + i)^n}{(1 + i)^n - 1}$

Depreciation: Decrease in value with the passage of time

- **Market depreciation:**

  The asset's loss in value over time as determined by **<u>market</u>** forces (Example: demand for used equipment)

- **Book depreciation:**

  An **<u>accounting</u>** method used to describe an asset's loss in value

- **Tax depreciation:**

  The loss in value of an asset over time as specified by the **<u>government</u>**

Classes of Depreciation:

1. Normal depreciation :
   a. Physical
   b. Functional
2. Depreciation due to changes in price level
3. Depletion

SALVAGE VALUE

- Salvage value is the cash *inflow* a firm receives if a machine still has value at the time of its disposal.
- This is a cash inflow that will occur at a future date.
- Used equipment prices are difficult to predict.

~~Tax Savings from Depreciation~~

Straight-Line Depreciation Straight-line depreciation is easy to calculate. The annual amount of depreciation D_n, for any year n, is a constant value, and thus the book value (BV_n) decreases at a uniform rate over the useful life of the machine. Here are the equations:

$$\text{Depreciation rate, } R_n = \frac{1}{N} \qquad [2.7]$$

where N = number of years.

$$\text{Annual depreciation amount, } D_n = \text{Unadjusted basis} \times R_n$$

Substituting Eq. [2.7] yields

$$D_n = \frac{\text{Unadjusted basis}}{N} \qquad [2.8]$$

$$\text{Book value year } m\text{, } BV_n = \text{Unadjusted basis} - (n \times D_n) \qquad [2.9]$$

Example:

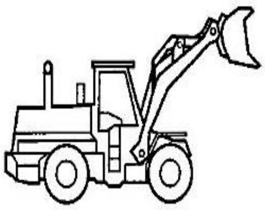
A new tractor is purchased with ($ 350000). Assume it has an estimated useful life of 5 years. Determine the depreciation and the book value for each of the 5 years using the straight-line method.

Depreciation rate, R_n =1/5 = 0.2

Annual depreciation amount, D_n = $350,000 x 0.2 = $70,000

m	BV_{n-1}	D_n	BV_n
0	$ 0	$ 0	$350,000
1	350,000	70,000	280,000
2	280,000	70,000	210,000
3	210,000	70,000	140,000
4	140,000	70,000	70,000
5	70,000	70,000	0

EXAMPLE 2.8



A company having a cost of capital rate of 8% purchases a \$300,000 loader. This machine has an expected service life of four years and will be used 2,500 hr per year. The tires on this machine cost \$45,000. The estimated salvage value at the end of four years is \$50,000. Calculate the depreciation portion of the ownership cost for this machine using the time value method:

Initial cost	\$300,000
Cost of tires	−45,000
Purchase price less tires	\$225,000

Calculate the equivalent uniform period series required to replace a present value of \$255,000. Using Eq. [2.6],

$$A = \$255{,}000\left[\frac{0.08(1 + 0.08)^4}{(1 + 0.08)^4 - 1}\right]$$

$$= \$255{,}000 \times 0.3019208 = \$76{,}990 \text{ per year}$$

Calculate the equivalent uniform end-of-period investments that equal the future salvage value. Using Eq. [2.4],

$$A_{\text{salvage}} = \$50{,}000\left[\frac{0.08}{(1 + 0.08)^4 - 1}\right]$$

$$= \$50{,}000 \times 0.02219208 = \$11{,}096 \text{ per year}$$

Therefore, using the time value method the hourly depreciation portion of the machine's ownership cost is

$$\frac{\$76{,}990/\text{yr} - \$11{,}096/\text{yr}}{2{,}500 \text{ hr/yr}} = \$26.358/\text{hr}$$

Depreciation—Average Annual Investment Method Since equipment value decreases with machine life, all components of ownership cost that vary in value (usually thought of in terms of book value) also decrease. These include depreciation, taxes, insurance, and storage. It is convenient to use an average machine value and therefore have a constant charge to use over the life. This average value is referred to as the *average annual investment (AAI)*.

Hence a second approach to calculating the depreciation portion of ownership cost is referred to as the average annual investment (AAI) method.

$$\text{AAI} = \frac{P(n+1) + S(n-1)}{2n} \qquad \textbf{[2.13]}$$

where

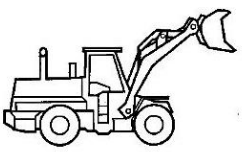
P = purchase price less the cost of the tires

S = the estimated salvage value

n = expected service life in years

The AAI is multiplied by the corporate cost of capital rate to determine the cost of money portion of depreciation. The straight-line depreciation of the cost of the machine less the salvage and less the cost of tires, if it is a pneumatic-tired machine, is then added to the cost of money portion (interest) to arrive at the total amount of ownership depreciation.

EXAMPLE 2.9



Using the same machine and company information as in Example 2.8, calculate the ownership depreciation using the AAI method:

$$\text{AAI} = \frac{\$255{,}000(4+1) + \$50{,}000(4-1)}{2 \times 4}$$

$$= \$178{,}125/\text{yr}$$

$$\text{Cost of money portion} = \frac{\$178{,}125/\text{yr} \times 8\%}{2{,}500\ \text{hr/yr}} = \$5.700/\text{hr}$$

Straight-line depreciation portion

Initial cost	\$300,000
Cost of tires	−45,000
Salvage	−50,000
	\$205,000

$$\frac{\$205{,}000}{4\ \text{yr} \times 2{,}500\ \text{hr/yr}} = \$20.500/\text{hr}$$

Total ownership depreciation using the AAI method:

$$\$5.700/\text{hr} + \$20.500 = \$26.200/\text{hr}$$

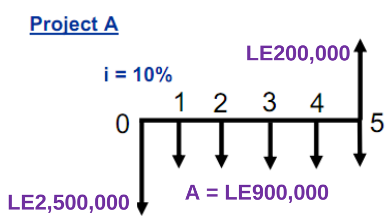
ECONOMIC EVALAUTION OF ALTERNATIVES

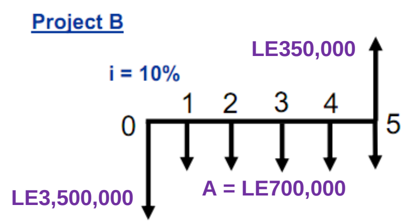
Present Worth Analysis

3.4.1 Present Worth Comparison of Equal-Lived Alternatives

Example 3.1: Make a present-worth comparison of the equal-service life projects for which costs are shown below, if i = 10%. Which project would you select?

	Project A	Project B
First cost, P	LE 2,500,000	LE3,500,000
Annual operating cost, A	LE 900,000	LE 700,000
Salvage value, F	LE 200,000	LE 350,000
Project service life (years)	5	5





Solution:

P_A = LE2,500,000 + LE900,000 (P/A, 10%, 5) - LE200,000 (P/F, 10%, 5)

= LE5,788,000

P_B = LE3,500,000 + LE700,000 (P/A, 10%, 5) - LE350,000 (P/F, 10%, 5)

= LE5,936,000

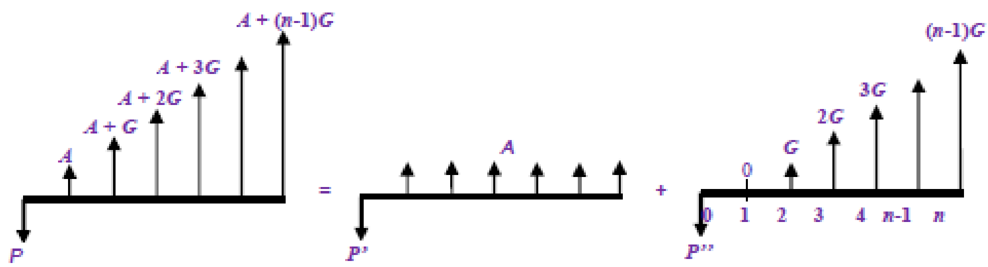
Project A should be selected since $P_A < P_B$

Example 3.2: Two machines are under consideration for a carpentry workshop. Machine A will have a first cost of LE5,000, an annual operation and maintenance cost of LE300, and a LE1,200 salvage value. Machine B will have a first cost of LE7,000, an annual operation and maintenance cost of LE200, and a LE1,300 salvage value. If both machines are expected to last for ten years, determine which machine should be selected on the basis of their present-worth values using an interest rate of 10%.

Solution:

2.8 Arithmetic Gradient Uniform Series Payments

In case of the cash flow or payments is not of constant amount A, there is a uniformly increasing series. The uniformly increased payments may be resolved into two components as shown below.



$$F = \frac{G}{i}\left[\frac{(1+i)^n - 1}{i} - n\right] \tag{2.25}$$

Accordingly, the present worth of F could be determined by dividing Eq. 2.25 by $(1+i)^n$.

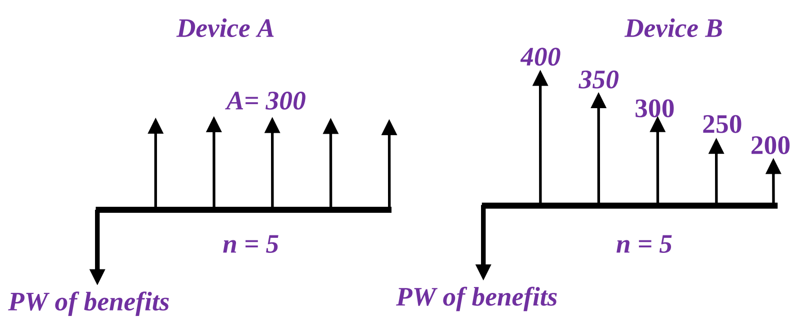
$$P = G\left[\frac{(1+i)^n - in - 1}{i^2(1+i)^n}\right] \tag{2.26}$$

$$A = G\left[\frac{(1+i)^n - in - 1}{i\,(1+i)^n - i}\right] = G\left[\frac{1}{i} - \frac{n}{(1+i)^n - 1}\right] \tag{2.27}$$

result in LE300 savings annually. Device *B* will provide savings for LE400 the first year but will decline LE50 annually. With interest rate 7%, which device should the firm purchase?

Solution:

Both devices have the same useful lives and both costs LE1000. The appropriate decision criterion is to choose the alternative that maximizes the present worth of benefits. The cash flow diagram is shown below.



PW_A = 300(P/A, 7%, 5) = 300(4.100) = LE1230

PW_B = 400(P/A, 7%, 5) – 50(P/G, 7%, 5)

= 400(4.100) – 50(7.647) = LE1257.65

Device *B* has the largest present worth of benefits, therefore, it the preferred alternative. It is worth noting that, if we ignored the time value of money, both alternatives provide LE1500 benefits over the five years. Device *B* provides more benefits in the first two years and smaller in the last two years, this more rapid flow of money from *B*, although the total value equal that of *A*, results in greater present worth of benefits.

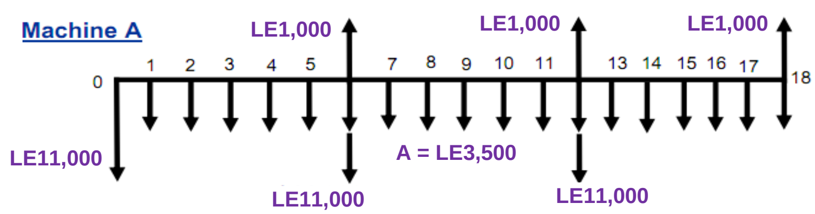
3.4.2 Present Worth Comparison of Different-Lived Alternatives

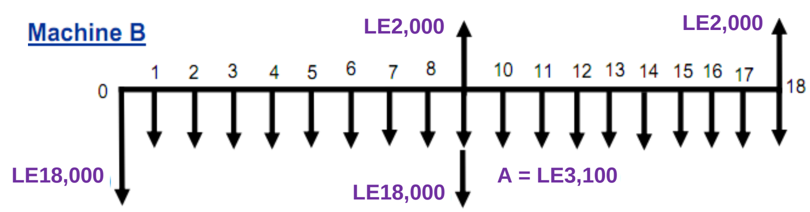
In the previous examples, the useful life of each alternative was equal to the analysis period. But, there will be many situations where the alternatives have useful lives different from the analysis period. This situation will be examined in this section.

Example 3.6: Make a present-worth comparison of the different-life machines for which costs are shown below, if i = 15%. Which machine would you select?

	Machine A	Machine B
First cost, P	LE11,000	LE18,000
Operation and Maintenance cost, A	LE3,500	LE3,100
Salvage value, F	LE1,000	LE2,000
Service life (years), n	6	9

Solution: The cash flow for one cycle of an alternative must be duplicated for the least common multiple of years, so that service life is compared over the total life for each alternative. Since the machines have different lives, they must be compared over the least common multiple of years, 18 years.





P_A = LE11,000 + LE11,000 (P/F, 15%, 6) + LE11,000 (P/F, 15%, 12) + LE3,500 (P/A, 15%, 18) - LE1,000 (P/F, 15%, 6) - LE1,000 (P/F, 15%, 12) - LE1,000 (P/F, 15%, 18) = LE38,559

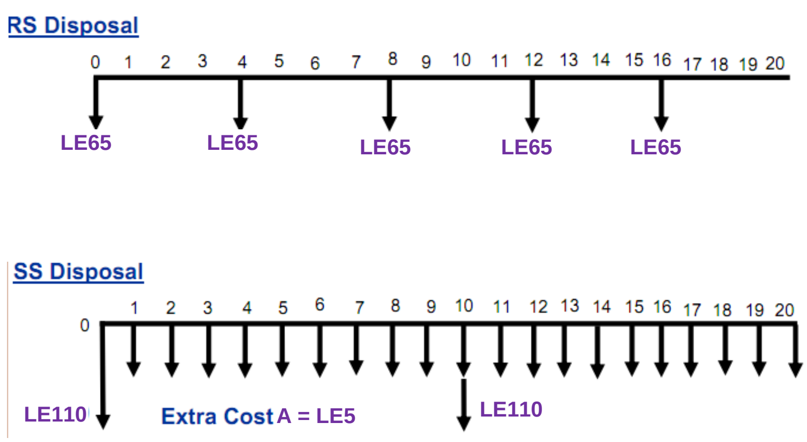
P_B = LE18,000 + EL18,000 (P/F, 15%, 9) + LE3,100 (P/A, 15%, 18) - LE2,000 (P/F, 15%, 9) - LE2,000 (P/F, 15%, 18) = LE41,384

Machine A should be selected since $P_A < P_B$

Example 3.7: A company is trying to decide between two different garbage disposals. A regular (RS) disposal has an initial cost of LE65 and a life of 4 years. The alternative is a corrosion-resistant disposal constructed of stainless steel (SS). The initial cost of the SS disposal is LE110, but it is expected to last 10 years. The SS disposal is expected to cost LE5 per year more than the RS disposal. If the interest rate is 6%, which disposal should be selected, assuming both have no salvage value?

Solution: Since the disposals have different lives, they must be compared over the least common multiple of years, which is 20 years.

	RS	SS
Initial cost	LE65	LE110
Additional cost per year	-	LE5
Salvage value, F	-	-
Service life (years), n	4	10



P_{RS} = LE65 + LE65 (P/F, 6%, 4) + LE65 (P/F, 6%, 8) + LE65 (P/F, 6%, 12) + LE65 (P/F, 6%, 16) = LE215

P_{SS} = LE110 + LE110 (P/F, 6%, 10) + LE5 (P/A, 6%, 20) = LE229

Disposal RS should be selected since $P_{RS} < P_{SS}$

Example 3.14: Solve the problem presented in example 3.13 using the *EUAW*.

Solution: Using the equation: $0 = \pm P\ (A/P,\ i\%,\ n) \pm A$

$0 = -\ 5{,}000\ (A/P,\ i\%,\ 10) + 7{,}000\ (A/F,\ i\%,\ 10) + 100$

Try $i = 5\%$: $0 = -\ 5{,}000\ (A/P,\ 5\%,\ 10) + 7{,}000\ (A/F,\ 5\%,\ 10) + 100$

= + LE9.02

Try $i = 6\%$: $0 = -\ 5{,}000\ (A/P,\ 6\%,\ 10) + 7{,}000\ (A/F,\ 6\%,\ 10) + 100$

= - LE48.26

By interpolation: $i = 5.16\%$

3.6.2 Comparing Two Alternative Using the IRR Method

When two alternatives are compared, the *IRR* for each one is calculate and the alternative with the highest *IRR* will be chosen given that it satisfies the *MARR*. If the cash flows for one or all alternatives contain expenditures only, in this case we couldn't compute the *IRR* and accordingly we couldn't compare these alternatives using the *IRR*. Do not simply pick the project with the highest rate of return value. In this case the rate of return analysis is performed by computing the incremental rate of return (ΔIRR) on the difference between the alternatives. The cash flow for the difference between the alternatives is computed by taking the higher initial cost alternative minus the lower initial cost alternative. If the ΔIRR is ≥ the *MARR* then choose the higher cost alternative. If the ΔIRR is ≤ the *MARR* then choose the lower cost alternative.

Example 3.15: You are given the choice of selecting one of two alternatives. The cash flows of the alternatives as shown in the following table. If the *MARR* is 6%, which one you select?

Year	Alternative 1	Alternative 2
0	-LE10	-LE20
1	+15	+28

3.4.3 Present Worth Comparison of Infinite Analysis Periods

In the present worth analysis, sometimes an infinite analysis period ($n = \infty$) is encountered. Alternatives such as roads, dams, bridges or whatever is sometimes considered permanent. In these situations a present worth analysis would have an infinite analysis period. This analysis is called *capitalized cost*. A capitalized cost is the present sum of money that would need to be set aside now, at some interest rate, to yield the funds required to provide the service indefinitely.

Example 3.8: A city plans a pipeline to transport water from a distant watershed area to the city. The pipeline will cost LE8 million and have an expected life of seventy years. The city anticipates it will need to keep the water line in service indefinitely. Compute the capitalized cost assuming 7% interest.

Solution: We have the capitalized cost equation $P = A/i$, which is simple to apply when there are end-of-period disbursements A. in this case, the LE8 million repeats every 70 years. We can find A first based on a present LE8 million disbursement.

$A = P(A/P, i, n)$ = LE8,000,000(0.0706) = LE565,000

Now, the infinite series payment formula could be applied for $n = \infty$:

Capitalized cost $P = A / i$ = 565,000 / 0.07 = LE8,071,000

3.5 Equivalent Uniform Annual Worth Analysis

Instead of computing equivalent present sum, in this section alternatives could be compared based on their equivalent annual costs (cash flows). Based on particular situation, the equivalent uniform annual cost (*EUAC*), the equivalent uniform annual benefits (*EUAB*), or their difference could be calculated.

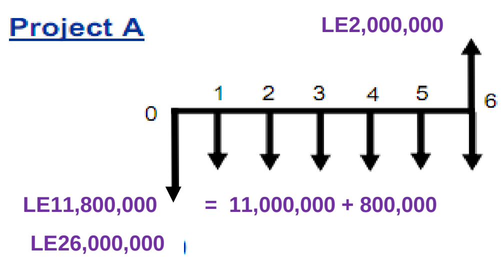
In chapter two, techniques to convert money, at one point in a time, to sum equivalent sum or series were presented. In this section, the goal is to convert money into an equivalent uniform annual cost or benefits. The major advantage of this method is that it is not necessary to make the comparison over the same number of years when the alternatives have different lives. The reason for that, it is an equivalent annual cost over the life of the project.

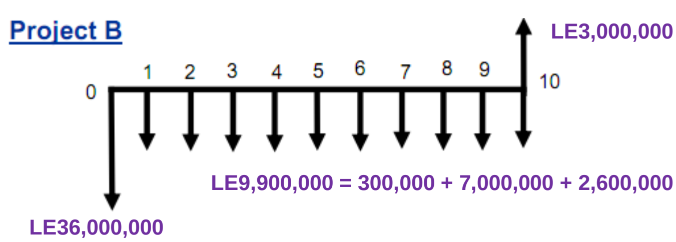
Example 3.9: If the minimum required rate of return is 15% which project should be selected?

	Project A	Project B
First cost	LE26,000,000	LE36,000,000
Annual maintenance cost	LE800,000	LE300,000
Annual labor cost	LE11,000,000	LE7,000,000
Extra income taxes		LE2,600,000
Salvage value	LE2,000,000	LE3,000,000
Project service life (years)	6	10

Solution:

In this case, all costs or savings (cash flows) which occur during the life time of an investment are discounted to a uniform annual series of cash flows over the life time of the investment.





$EUAC_A$ = LE26,000,000(A/P, 15%, 6) - LE2,000,000(A/F, 15%, 6) + LE11,800,000 = LE18,442,000

$EUAC_B$ = LE36,000,000(A/P, 15%, 10) - LE3,000,000 (A/F, 15%, 10) + EL9,900,000= LE16,925,000

Project B should be selected since $EUAC_B < EUAC_A$

Example 3.10: An asset depreciates uniformly from a first cost of LE50,000 to zero over a 20-year time frame. If operating costs are initially LE1,500 but increase by LE2,000 per year and revenues are LE20,000 per year but decrease by LE1,000 per year what is the EAW if the machine is replaced every 10 years and the interest rate is 5%.

Solution:

$EAUC$ = -(50,000 – 25,000)(A/P, 5, 10) – 1,500 – 2,000(A/G, 5, 10)
+ 20,000 – 1,000(A/G, 5, 10)
= -25,000(0.1295) – 1,500 – 2,000(4.09909) + 20,000
– 1,000(4.09909) = LE2,965

Example 3.11: In the construction of an aqueduct to expand the water supply of a city, there are two alternatives. Either a tunnel through a mountain or a pipeline can be laid on the ground. Given the following information which alternative should be adopted? Assume a 6% interest rate.

	Tunnel	Pipeline
Initial cost	LE5,500,000	LE5,000,000
Annual maintenance	0	0
Salvage value	0	0
Project service life (years)	Permanent	50

Solution: For the tunnel with its permanent useful life, n considered to be infinity.

$EAUC_{tunnel} = Pi$ = 5,500,000 (0.06) = LE330,000

For the pipeline,

$EAUC_{pipeline}$ = 5,000,000(A/P, 6, 50) = LE317,000

Then, select the pipeline option.

3.6 The Rate of Return Method

Currently we use three different methods of determining whether an economic proposal is valid. Present worth comparisons, Future worth comparisons and Equivalent annual worth comparisons. While these methods will tell us which alternative is the best, and whether we are gaining a greater return than our minimum attractive rate of return (*MARR*), we don't know the rate of return that we are actually receiving. The objective of the rate of return method is to find the rate of return (*i*% percentage) for an investment over a specific service life. The rate of return method considers all the cash follows that occur during the life cycle of an investment. There are two methods to find the rate of return for an investment. These are: the present worth Method and the equivalent uniform annual cost (*EUAC*) method.

Internal rate of return (*IRR*) calculations (*i*) tell us the exact rate of return we are receiving on an individual investment. These calculations must be done through trial and error, or by using commercially available software. If projects being assessed are independent of each other then any project with an *IRR* greater than the *MARR* should be accepted. *IRR* is defined as the interest rate paid on the unpaid balance of a loan such that the payment schedule makes the unpaid loan balance equal to zero when the final payment is made.

For example, we might invest LE5000 in a machine with a five-year useful life and a *EUAB* of LE1252. Now, a question is raised: what rate of return would we receive on this investment? The least *IRR* is the one that makes the *NPV* of all payments equal to zero. The five payments of LE1252 are equivalent to a present sum of LE5000 when interest rate is 8%. Therefore, the *IRR* on this investment is 8% as shown in the following table.

IRR is also defined as the investment rate that makes the *PV* of all expenditures equals the *PV* of all income; i.e., the *NPV* equals zero. To calculate the *IRR*, the *NPV* of all values are calculated as a function of the interest rate (*i*). Then, we calculate (*i*) that makes the *NPV* equals zero.

Year	Cash flow	Unrecovered investment at beginning of year	8% return on unrecovered investment	Investment repayment at end of year	Unrecovered investment at end of year
0	-LE5000				
1	+1252	LE5000	EL400	LE852	LE4148
2	+1252	4148	331	921	3227
3	+1252	3227	258	994	2233
4	+1252	2233	178	1074	1159
5	+1252	1159	93	1159	0
			LE1260	LE5000	

In present worth and equivalent uniform annual worth analysis, one must select an interest rate for use in the calculations and this may be difficult. In rate of return analysis, no interest rate is introduced into the calculations. Instead we compute an internal rate of return from the cash flow. To decide proceeding or not, the calculated rate of return is compared with a preselected minimum attractive rate of return.

3.6.1 IRR for One Alternative

When deciding on one alternative, then the alternative is acceptable if it brings a positive *IRR* or an *IRR* greater than the *MARR*.

Rate of return calculation by the present worth method:

The calculations are done in three steps:

- Draw a cash flow diagram.
- Set up the rate of return equation in the form:

$$0 = \pm P + \Sigma^{n}_{j=1} F\,(P/F, i\%, n) \pm A\,(P/A, i\%, n) \quad (3.2)$$

- Select values of *i* by trial and error until the equation is balanced.

Rate of Return Calculation by the EUAC Method:

The calculations are done in three steps:

- Draw a cash flow diagram.
- Set up the rate of return equation in the form:

$$0 = \pm P\,(A/P, i\%, n) \pm A \quad (3.3)$$

- Select values of *i* by trial and error until the equation is balanced.

Example 3.12: An investment resulted in the following cash flow. Compute the rate of return.

Year	0	1	2	3	4
Cash flow	-LE700	+LE100	+LE175	+LE250	+LE325

Solution: $EUAB - EUAC = 0$

$100 + 75(A/G, i, 4) - 700(A/P, i, 4) = 0$

This equation is solved using trial and error. Try $i = 5\%$

$100 + 75(A/G, 5, 4) - 700(A/P, 5, 4) = +\text{LE}11$

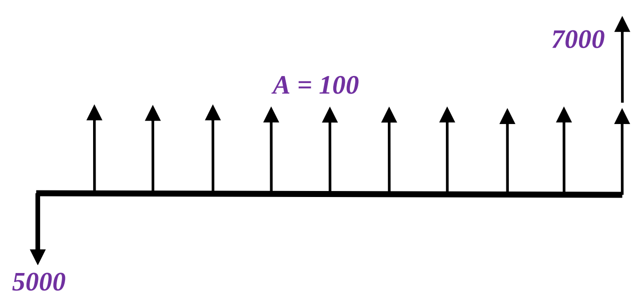
Try $i = 8\%$

$100 + 75(A/G, 8, 4) - 700(A/P, 8, 4) = -\text{LE}6$

i is between 5 and 8%. Then try another value for i or find i by interpolation, then $i = 7\%$.

Example 3.13: If LE5,000 is invested now, this is expected to yield LE100 per year for 10 years and LE7,000 at the end of 10 years, what is the rate of return?

Solution:



Using the equation: $0 = \pm P + \Sigma^{n}_{j=1} F\ (P/F, i\%, n) \pm\ A\ (P/A, i\%, n)$

$0 = -5{,}000 + 100\ (P/A, i\%, 10) + 7{,}000\ (P/F, i\%, 10)$

Try $i = 5\%$: $0 = -5{,}000 + 100\ (P/A, 5\%, 10) + 7{,}000\ (P/F, 5\%, 10)$

$= +\ \text{LE}69.46$

Try $i = 6\%$: $0 = -5{,}000 + 100\ (P/A, 6\%, 10) + 7{,}000\ (P/F, 6\%, 10)$

$= -\ \text{LE}355.19$

By interpolation $i = 5.16\%$

Solution: Normally, we select the lesser-cost alternatives (alternative 1), unless we find the additional cost of alternative 2 produces sufficient additional benefits that we would prefer. So, we will evaluate the difference project.

Year	Alternative 1	Alternative 2	Alt. 2 – Alt. 1
0	-LE10	-LE20	-20 – (-10) = -10
1	+15	+28	28 – 15 = +13

$PW_{cost} = PW_{benefit}$

$10 = 13(P/F, i\%, 1)$

$(P/F, i\%, 1) = 10/13 = 0.7692$; then $i = 30$

Then, choose alternative 2.

Thus means that the additional LE10invested to obtain alternative 2 is superior to invest the LE10 elsewhere at 6% (*MARR*).

Example 3.16: The following information showing the cash flows for two alternatives. If the *MARR* is 15%, which one is preferred?

	Alternative 1	Alternative 2
Initial cost	LE8000	LE13000
Annual costs	3500	1600
Salvage value	-	2000
Useful life	10	5

Solution: As all cash flows are expenditures, we use the incremental rate of return. Also, as the useful lives are different, we use the common multiplier for both alternative, 10 years for comparison. The cash flow for the two alternatives and the difference is shown in the next table.

location. The company operates with a MARR of 15% before taxes. Rate the alternatives based on a) *PW* comparison and b) *IRR* comparison.

	SITE 1	SITE 2	SITE 3
Land Purchase Price	100,000	150,000	160,000
Renovations	40,000	40,000	60,000
Resale	125,000	155,000	175,000
Expected Revenue	125,000	195,000	300,000
Annual Power Costs	35,000	55,000	75,000
Annual O & M cost	66,000	109,000	184,000

Solution: First, determine total initial cost, net revenues and rank the sites in order of first cost.

	SITE 1	**SITE 2**	**SITE 3**
Initial costs	140,000	190,000	220,000
Resale	125,000	155,000	175,000
Net Revenues/year	24,000	31,000	41,000

a) Present Worth Comparison where i =15%

Site 1: *PW* = -140,000 + 125,000(*P*/*F*, *15*, 10) + 24,000(*P*/*A*, *15*, 10)

= -140,000 + 30,898 + 120,450 = LE11,348

Site 2: *PW* = -190,000 + 155,000(*P*/*F*, *15*, 10) + 31,000(*P*/*A*, *15*, 10)

= -190,000 + 38,313 + 155,582 = LE3,895

Site 3: *PW* = -220,000 + 175,000(*P*/F, 15, 10) + 41,000(*P*/*A*, 15, 10)

= -220,000 + 43,257 + 205,770 = LE29,027

Therefore select Site 3 then Site 1 and then Site 2

b) *IRR* Comparison

Site 1: -140,000 + 125,000(*P*/*F*, *i*, 10) + 24,000(*P*/*A*, *i*, 10) = 0

By trial and error *i*= 16.66%, Select Site 1 since *IRR* > *MARR*

Incremental site 2- site 1

$-50{,}000 + 30{,}000(P/F, i, 10) + 7{,}000(P/A, i, 10) = 0$

By trial and error i= 11.69%

Select Site 1 since $\Delta IRR < MARR$

Incremental site 3- site 1

$-80{,}000 + 50{,}000(P/F, i, 10) + 17{,}000(P/A, i, 10) = 0$

By trial and error i= 19.79%

Select Site 3 since $\Delta IRR < MARR$

Therefore select Site 3 then Site 1 and then Site 2; same as of the previous result.

3.7 Benefit/Cost Ratio Method

The Benefit/Cost (*B/C*) method is based on the ratio of the annual benefits to the annual costs for a particular project. It is used to compare between investment options based on a range of benefits, disbenefits, and costs to the owner. Benefits are advantages, expressed in terms of a monetary value to the owner (*i.e.* dollars, etc.). Disbenefits are disadvantages, expressed in terms of a monetary value to the owner (*i.e.* dollars, etc.). Costs are anticipated expenditures for construction, operation and maintenance, etc. the following Table shows examples of benefits, disbenefits, and costs:

Item	Classification
Expenditure of 11 million dollars for a new highway	Cost
\$100,000 annual income to local residents from tourists due to the construction of new highway	Benefit
\$150,000 annual upkeep of highway	Cost
\$250,000 annual loss to farmer due to loss of highway right-of-way	Disbenefit

The formula used for benefit to cost ratio analysis is:

$$B/C = (\text{Benefits} - \text{Disbenefits}) / \text{Costs} \tag{3.4}$$

If the B/C ratio is ≥ 1.0, this means that the extra benefit(s) of the higher cost alternative justify the higher cost. If the B/C ratio is < 1.0, this means that the extra cost is not justified and the lower cost alternative is selected. An alternative method that can be used to compare between projects, is to subtract the costs from the benefits that is $(B - C)$. If $(B - C)$ is ≥ 0, this means that the project is acceptable. If $(B - C)$ ratio is < 0, this means that the project is rejected.

Rather than solving problems using present worth or annual cash flows analysis, we can base the calculations on the benefit-cost ratio, B/C. the B/C is the ration of benefits to costs, or:

$$B/C = PW \text{ of benefit} / PW \text{ of costs} = EUAB / EUAC \geq 1 \qquad (3.5)$$

Example 3.18: Two routes are considered for a new highway, Road A, costing LE4,000,000 to build, will provide annual benefits of LE750,000 to local businesses. Road B would cost LE6,000,000 but will provide EL700,000 in benefits. The annual cost of maintenance is LE300,000 for Road A and LE320,000 for Road B. If the service life of Road A is 20 years, and for Road B is 30 years, which alternative should be selected if the interest rate is 8%?

Solution: Tabulate the given data:

Given Data	Road A	Road B
Initial Cost	LE4,000,000	LE 6,000,000
Annual Benefits	LE 750,000	LE 700,000
Annual Maintenance Cost	LE 300,000	LE 320,000
Service Life	20 years	30 years

B/C = (Benefits – Disbenefits) / Costs

$EUAC$ for Road A = 4,000,000 (A/P, 8%, 20) + 300,000

= 4,000,000 (0.10185) + 300,000 = LE707,000

$EUAC$ for Road B = 6,000,000 (A/P, 8%, 30) + 320,000

= 6,000,000 (0.08883) + 320,000 = LE552,980

B/C for Road A = 750,000 / 707,000 = 1.06

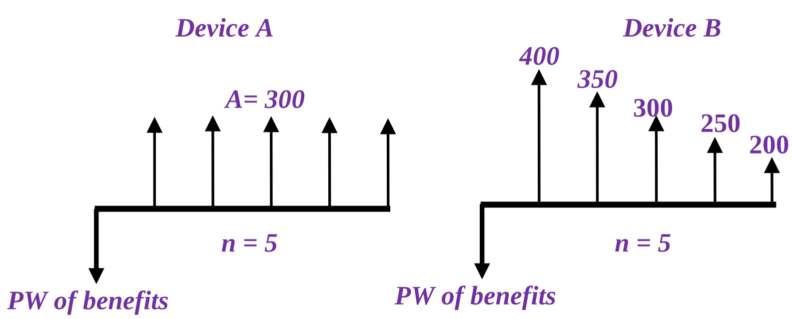
B/C for Road B = 700,000 / 552,980 = 1.26

Choose Road B

Example 3.19: Solve example 3.4 again using the B/C ration.

Solution:

The cash flow of both alternatives is shown I e figure below.



<u>Device A:</u>

PW_{cost} = LE1000

$PW_{benefit}$ = 300(P/A, 7%, 5) = 300(4.100) = LE1230

Then B/C = 1230/1000 = 1.23

<u>Device B:</u>

PW_{cost} = LE1000

$PW_{benefit}$ = 400(P/A, 7%, 5) – 50(P/G, 7%, 5)

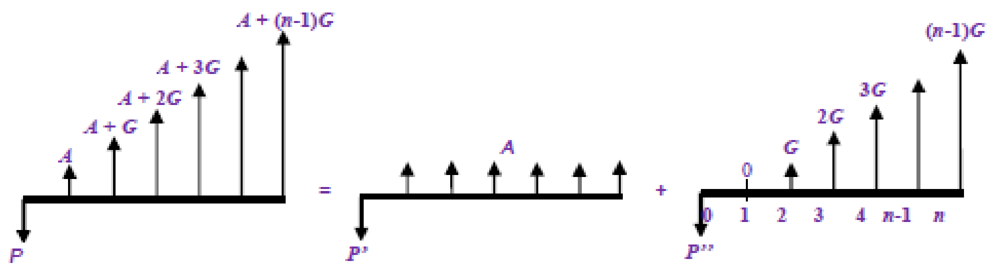
= 400(4.100) – 50(7.647) = LE1258

Then B/C = 1258/1000 = 1.26

To maximize the B/C ratio, choose device B.

2.8 Arithmetic Gradient Uniform Series Payments

In case of the cash flow or payments is not of constant amount A, there is a uniformly increasing series. The uniformly increased payments may be resolved into two components as shown below.



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$$F = \frac{G}{i}\left[\frac{(1+i)^n - 1}{i} - n\right] \qquad (2.25)$$

Accordingly, the present worth of F could be determined by dividing Eq. 2.25 by $(1+i)^n$.

$$P = G\left[\frac{(1+i)^n - in - 1}{i^2(1+i)^n}\right] \qquad (2.26)$$

$$A = G\left[\frac{(1+i)^n - in - 1}{i\,(1+i)^n - i}\right] = G\left[\frac{1}{i} - \frac{n}{(1+i)^n - 1}\right] \qquad (2.27)$$