Engineering Economy

BOOKS:

Engineering Economy by Leland Blank Anthony Tarquin, 7th edition
Fundamental of Engineering Economics by Chan S Park 3rd Edition

Objectives

- Understanding of the time value of money, cashflow and equivalence concepts.
- Ability to apply interest equations to equivalence calculations.
- Ability to apply various methods for economic analysis of alternatives.
- Ability to develop project cash flows for design alternatives
- Ability to make replacement decisions.
- Basic understanding of depreciation for engineering projects.

Chapter 1: Fundamentals of Engineering Economy

What is Economy

- It is the study of choice and decision-making in world with limited resources.
- It is the study of how individuals, businesses and governments used their limited resources.

ENGINEERING ECONOMY

*"**Engineering is the profession in which a knowledge of the mathematical and natural science gained by study, experience, and practice is applied with judgment to develop ways to utilize economically, the materials and forces of nature for the mankind".***

In the preceding definition the economical role of an engineer is emphasized as well as his technical role.

- Engineering Economy is about making decisions
- It is based on the systematic evaluation of the ***costs and benefits*** of proposed technical projects
- ***Successful design is the one that must sound technical and produces benefit.***

In fact any engineering project must be **physically and technically realizable but also it must be economically feasible**, therefore economics weigh heavily in the design process.

The factors upon which a decision is based are commonly a combination of economic and noneconomic elements. ***Engineering economy deals with the economic factors.***
Non-Economic elements are:

- ***Availability of certain resources,*** *e.g., skilled labor force, water, power, tax incentives.*
- ***Government laws that dictate safety,*** *environmental, legal, or other aspects.*

- ***Management's interest*** *in a particular alternative.*

Engineering economics is a powerful tool for engineers in decision making and analysis of new and running projects. Sample question arising from various engineering related activities may be found in the following list. These questions may be solved only by learning *how to use engineering-economy.*

For Engineering Activities

- Should a highway bypass be constructed around a city of 25,000 people, or should the current roadway through the city be expanded?
- Is it an economically wise decision to upgrade the composite material production centre of an airplane factory in order to reduce costs by 20%?
- If a computer-vision system replaces the human inspector in performing quality tests on an automobile welding line, will operating costs decrease over a time horizon of 5 years?
- Will we make the required rate of return if we install the newly offered technology onto our medical laser manufacturing line?

For Public Sector Projects and Government Agencies

- How much new tax revenue does the city need to generate to pay for an up grade to the electric distribution system?
- Do the benefits outweigh the costs of a bridge over the Intercostals waterway at this point?
- Is it cost-effective for the government to cost-share with a contractor to construct a new toll road?

For Individuals

- What is graduate studies worth financially over my professional career?
- Exactly what rate of return did we make on our stock investments?
- Should I buy or lease my next car, or keep the one I have now and pay off the loan?

Besides applications to projects in your future jobs, what you learn from this subject and in this course may well offer you an ***economic analysis tool for making personal decisions*** *such as car purchases, house purchases, and major purchases on credit, e.g., furniture, appliances, and electronics.*

Role of Engineering Economy

Engineering Economy is a **collection of mathematical techniques** that simplify the comparison of alternatives. In this sense, engineering economy may be regarded as a **decision – assistance tool** by which one of the alternative methods will be chosen as the most economical one.

- Remember: People make decisions – not "tools"
- Engineering Economy is a set of tools that aid in decision making – but will not make the decision for you

- Engineering economy is based mainly on estimates of future events – must deal with the future and risk and uncertainty.
- The parameters within an engineering economy problem can and will vary over time
- Parameters that can vary will dictate a numerical outcome – apply and understand
- Sensitivity Analysis

Example 1:

Two pilot engineers with a mechanical design company and a structural analysis firm work together. They have decided that, due to their joint and frequent commercial airline travel around the region, they should evaluate the purchase of a plane co-owned by the two companies. What are some of the economics-based questions the engineers should answer as they evaluate the alternatives to (1) co-own a plane or (2) continue to fly commercially?

Solution:

Some questions (and what is needed to respond) for each alternative are as follows:

1. How much will it cost each year? (Cost estimates are needed.)
2. How do we pay for it? (A financing plan is needed.)
3. Are there tax advantages? (Tax law and Tax rates are needed.)
4. What is the basis for selecting an alternative? (A selection criterion is needed.)
5. What is the expected rate of return? (Equations are needed.)
6. What happens if we fly more or less than we estimate now? (Sensitivity analysis is needed.)

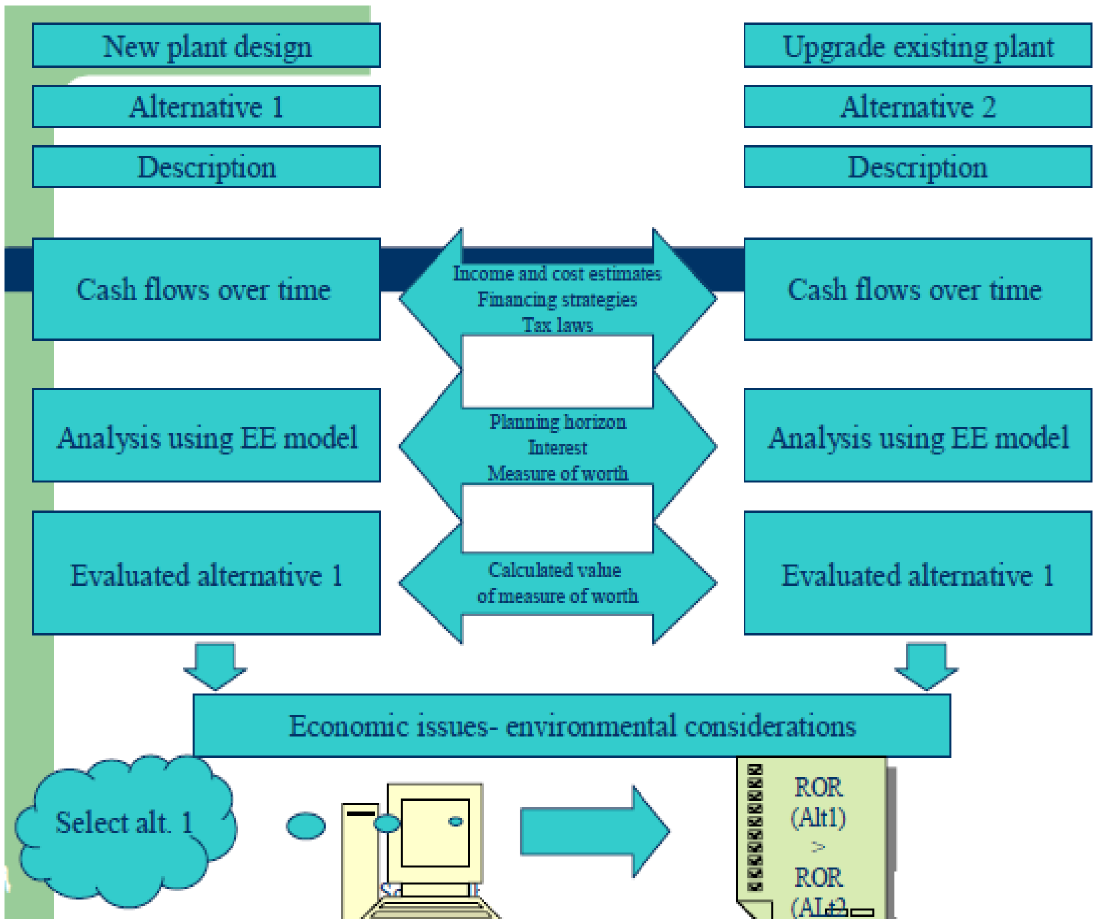
Why Engineering Economy is Important to Engineers

- **Engineering, without economy, makes no sense at all**. Engineering economics is a powerful tool for engineers in decision making and analysis of new and running projects.
- Engineers design and create.
- Designing involves economic decisions.
- Engineers must be able to **incorporate economic analysis** into their creative efforts
- Often engineers must select and implement from multiple alternatives
- Understanding and applying **time value of money, economic equivalence, and cost estimation** are vital for engineers
- A proper economic analysis for selection and execution is a fundamental task of engineering.

Performing an Engineering Economy Study

"An alternative is a stand-alone solution for a given situation". The engineer is always faced with alternatives in virtually all jobs he may be assigned to. Engineering economy provides him by a rational approach to select the best alternative.

However, it is by no means a method of exclusively listing the alternatives. A successful engineering-economy analysis should only be expected if all the possible alternatives are identified. It is the responsibility of the engineer that all potential solutions are recognized as alternatives. Sample alternative development and analysis are shown in figure 1 below.



The steps in an engineering economy study are as follows:

1. Identify and understand the problem; identify the objective of the project.
2. Collect relevant, available data and define viable solution alternatives.
3. Make realistic cash flow estimates.
4. Identify an economic measure of worth criterion for decision making.
5. Evaluate each alternative; consider noneconomic factors; use sensitivity analysis as needed.
6. Select the best alternative.
7. Implement the solution and monitor the results.

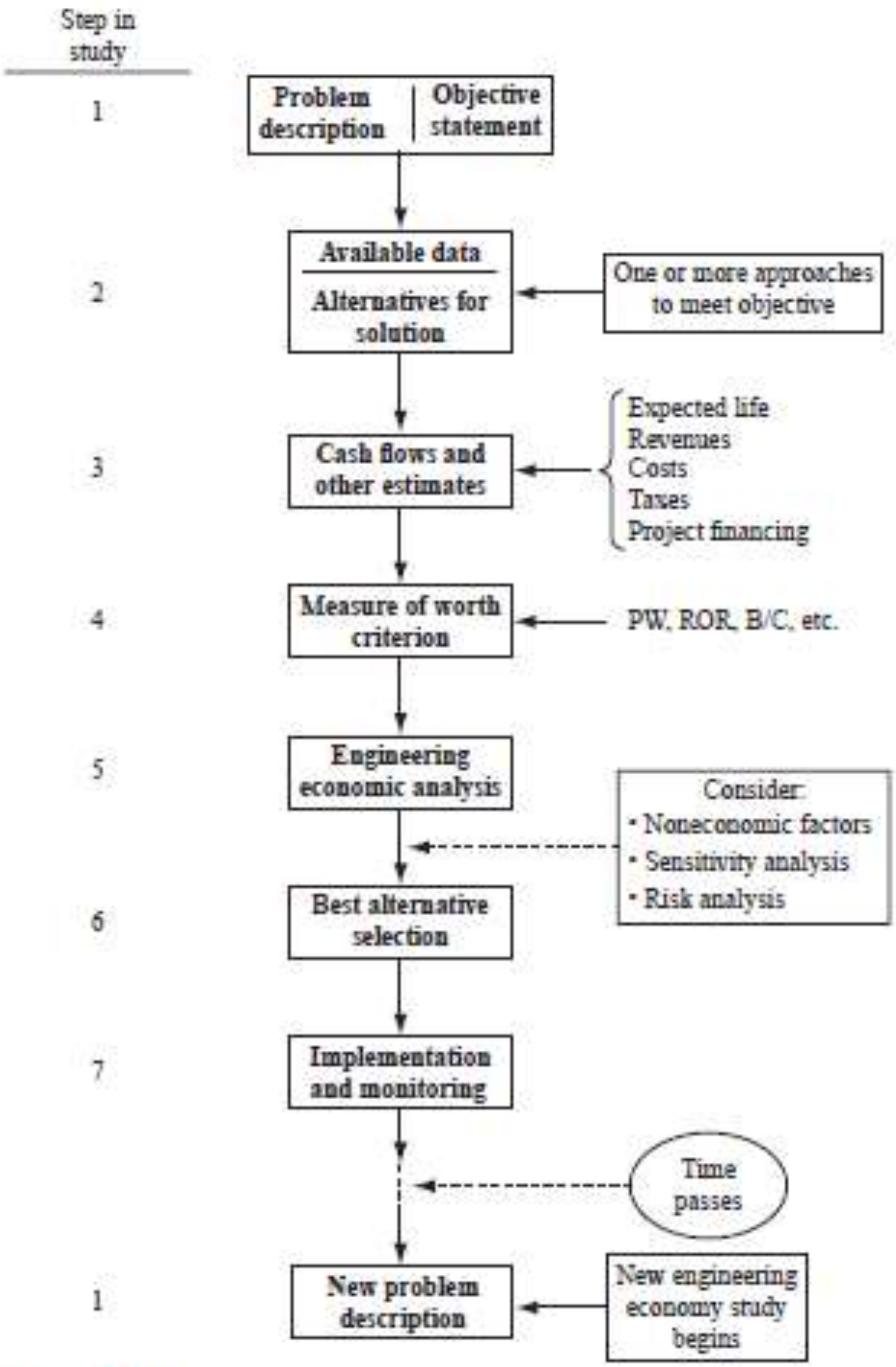


Figure 1–1
Steps in an engineering economy study.

TIME VALUE OF MONEY

It is often said that money makes money. The statement is indeed true, for if we invest money today, by tomorrow we will have accumulated more money than we have originally invested. This change in the amount of money over a given time period is called **the time value of money**; **it is the most important concept in engineering economy.** On the other hand, if a person or a company borrows money today, by tomorrow more money than the original loan will be owed. This fact is also explained by the time value of money.

MEANING OF INTEREST:

The appearance of the time value of money in actual life is termed **"interest" (I);** which is a measure of the increase between the original sum (borrowed or invested) and the final amount (owed or accrued). Thus, if money was borrowed at some time in the past, the interest would be:

I (interest) = present amount owed – original loan.

If money was invested at some time in the past, the interest would be.

I (interest) = total amount accumulated – original investment.

In either case, there is an increase in the amount of money that was originally invested or borrowed, and the increase over the original amount is the interest. **The original investment or loan is called "principal" *P*.**

The interest is always defined as an "Interest rate" ***i* (%). It expresses the interest per unit time as a percentage of the principal.**

$$Interest\ rate\,(\%) = \frac{Interest\ accrued\ \ per\ unit\ time}{Original\ \ amout} \times 100\,\%$$

INTEREST PERIOD

The time unit which is most commonly (and unless otherwise stated) used to declare interest rates is one year (e.g. 10% per year, 10% per annum or just 10%). However, interest rates may sometimes be quoted over shorter periods of time (e.g. 1% per month). **The time unit used to express an interest rate is called an "interest period".**

INTEREST RATE (IR) AND RATE OF RETURN (ROR)

From a computational point of view, interest is the difference in money between what you end with and what you started with. **Interest is paid when an entity borrows money and repays a larger amount; interest is earned when an entity save or invested money and obtained a return of a larger amount.**

Interest = amount owed now – original amount or principal

$$\textbf{Interest rate, \% } = \frac{\textbf{interest accrued per time unit}}{\textbf{original amount}} \textbf{ x 100\%}$$

The time unit is called the interest period and is typically one year.
Interest paid over a specific period of time is expressed as a percentage of the original amount and is called the rate of return (ROR) or return on investment (ROI).

$$\textbf{Rate of Return, \% } = \frac{\textbf{interest accrued per time unit}}{\textbf{original amount}} \textbf{ x 100\%}$$

The equations are the same but interest rate paid is more appropriate from the borrower's perspective and the rate of return earned is better for the investor's perspective i.e.
IR – borrower and
ROR or ROI – investor.

INFLATION

- Inflation is the devaluation of a currency relative to a previous value.
- Country's currency becomes worth less over time, thus requiring more of the currency to purchase the same amount of goods or services in a time period
- From the borrower's perspective it is another interest rate; from the investor's perspective, inflation reduces the ROR.

Inflation impacts:

- Purchasing Power (reduces)
- Operating Costs (increases)
- Rate of Return on Investments (reduces)

CASH FLOW DIAGRAMS:

For any enterprise, firm or even a person there are cash receipts (income) and cash disbursements (costs) which occur over a certain time span. These are referred to as "cash flow". Positive cash flow represents inflow or receipt while negative cash flow indicates outflow or disbursement.

A "cash flow diagram" is a graphical representation of cash flows drawn on a time scale having the interest period as the unit or division. The length and direction of any cash flow arrow should indicate the amount of cash flow and whether it is a receipt or a disbursement. This is explained in the following figures.

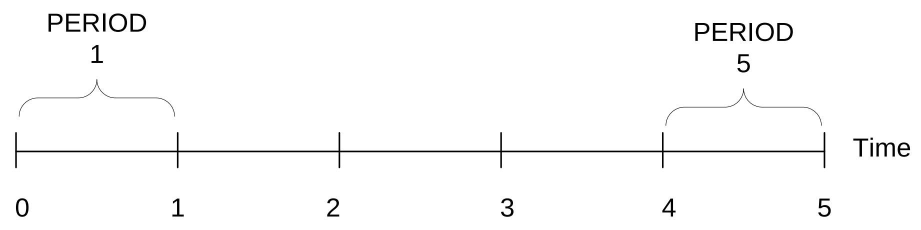


Figure: A typical cash flow time scale

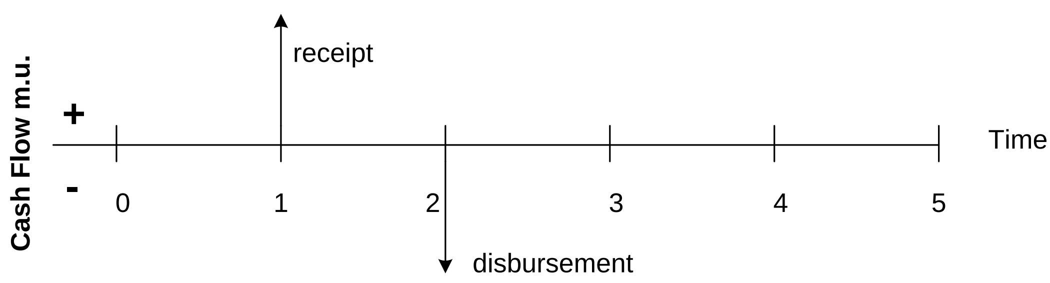
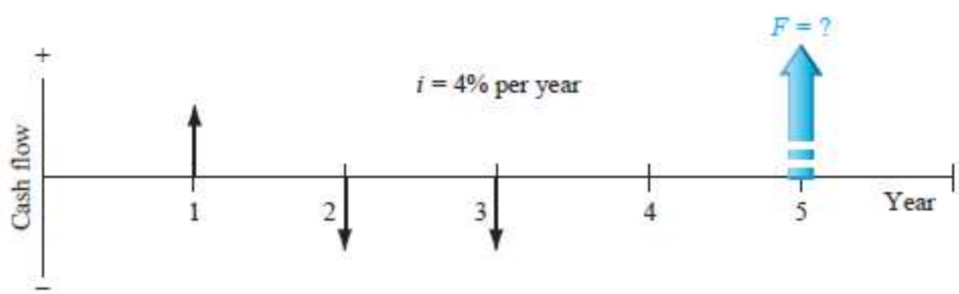


Figure: Representation of receipts and disbursements on a cash flow diagram



Example of Positive and Negative Cashflow

In practice, cash flow may occur at any time within an interest period. However, a simplifying assumption is made that all cash flow occurs at the end of the interest period. This is known as the "end-of-period convention". Accordingly, if several receipts and disbursements take place within the same interest period, the net cash flow (which is the algebraic sum) is assumed to occur, or to be concentrated, at the end of the interest period.

The cash flow diagram is a useful tool which gives a clear diagrammatic synoptic representation of the statement of any situation or problem. It may be marked to show what is known and what is to be found.

Simple and Compound Interest

When more than one interest period is involved, the terms simple and compound interest must be considered.

Simple Interest

Simple interest is calculated on the principal only, ignoring any interest that was accrued in preceding interest periods.

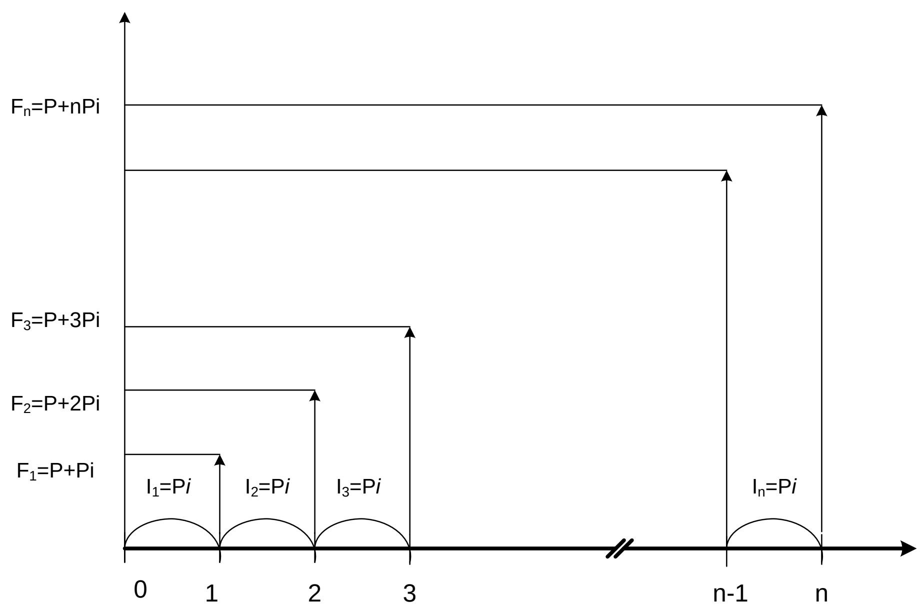


Figure: Diagram representing the accumulation of a principal based on simple interest

The total interest for (n) interest periods will be

$$I = P \times i \times n$$

And the future value F of the principal P after the (n) periods will be

$$F = P + P \times i \times n \ = P(1 + i \times n)$$

Compound Interest

In calculation of compound interest, the interest for an interest period is calculated on the principal plus the total amount of interest accumulated in previous periods. Thus, compound interest means "interest on top of interest" (i.e., it reflects the effect of the time value of money).

The interest for any period (I_n) and the accumulated amount after that period (F) are consecutively given by

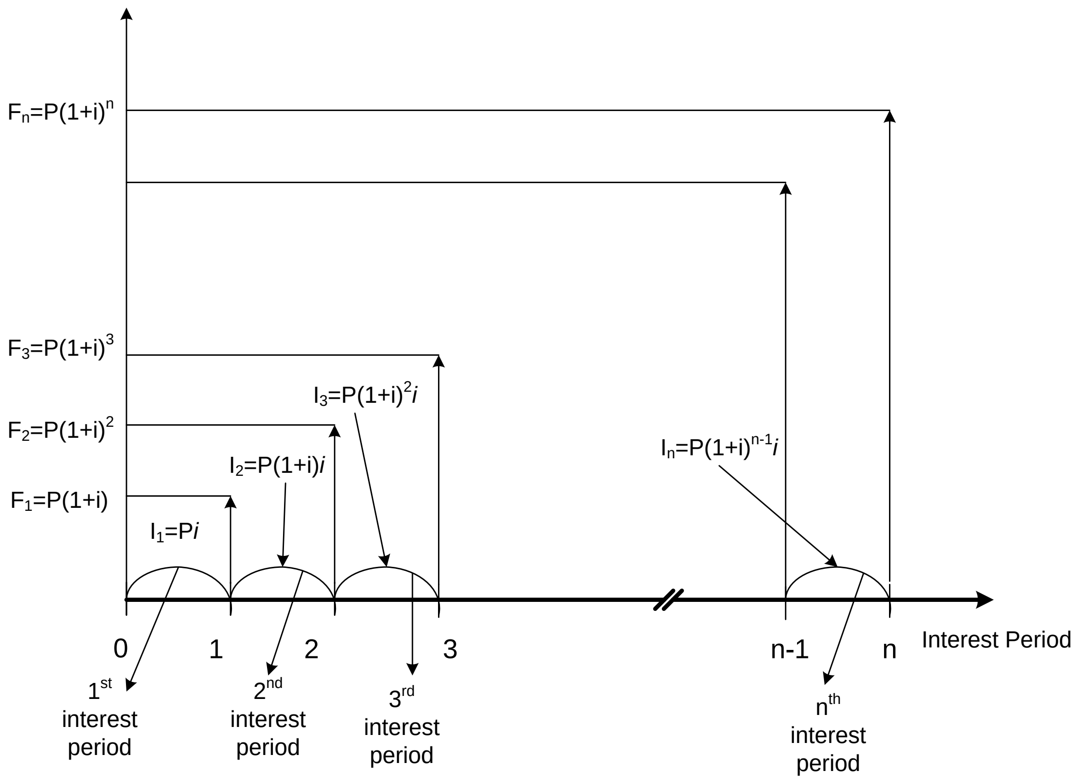


Figure: Diagram representing the accumulation of a principal based on compound interest

I_n = interest of interest period number n

$$I_n = P\left(1+i\right)^{n\text{-}1} i$$

F_n = accumulated amount after n interest periods

$$F_n = P\left(1+i\right)^{n}$$

EQUIVALENCE

Example

You travel at 68 miles per hour

Equivalent to 110 kilometers per hour

Thus: 68 mph is equivalent to 110 kph

Economic Equivalence

Economic Equivalence is the Equality in terms of Economic Value

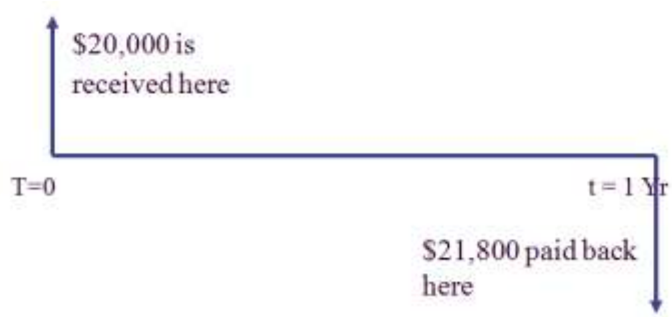
Two sums of money at two different points in time can be made economically equivalent if we consider an interest rate and No. of time periods between the two sums

The time value of money changes according to:

1. The interest rate,
2. The amount of money involved,
3. The timing of receipt or payment,
4. The manner in which interest is compounded

Principles of Equivalence

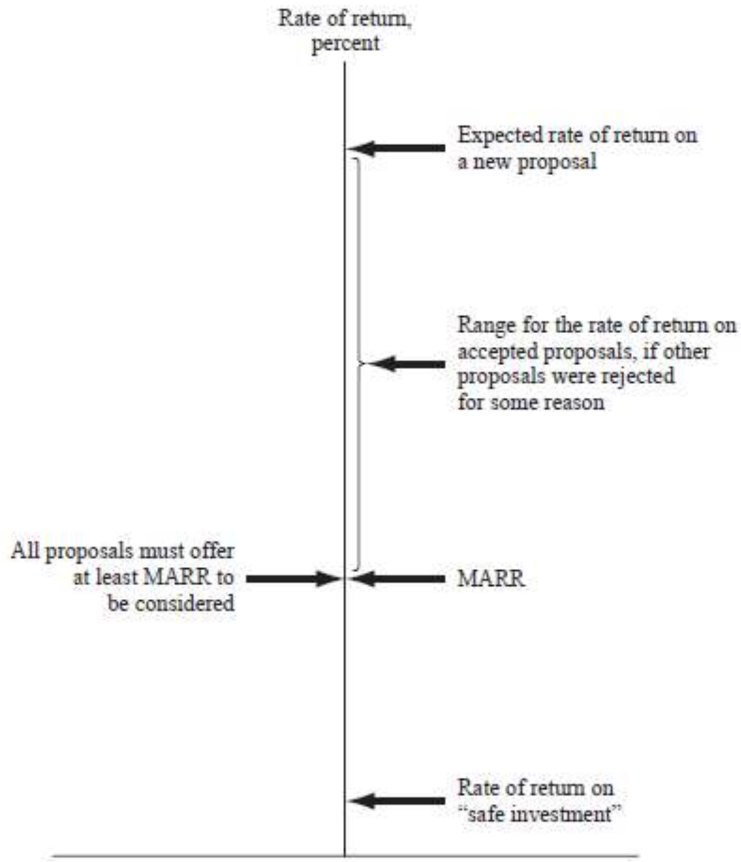
1. Equivalent cash flows have the same economic value at the same point in time.
2. Cash flows that are equivalent at one point in time are equivalent at any point in time.
3. Conversion of a cash flow to its equivalent, at another point in time must reflect the interest rate(s) in effect for each period between the equivalent cash flows.



$20,000 now is economically equivalent to $21,800 one year from now if the interest rate is set to equal 9%/year

MINIMUM ATTRACTIVE RATE OF RETURN (MARR)

The Minimum Attractive Rate of Return (MARR) is a reasonable rate of return established for the evaluation and selection of alternatives. A project is not economically viable unless it is expected to return at least the MARR. MARR is also referred to as the hurdle rate, cutoff rate, benchmark rate, and minimum acceptable rate of return.



- A firm's financial managers set a minimum interest rate that that all accepted projects must meet or exceed.
- The rate, once established by the firm is termed the Minimum Attractive Rate of Return (MARR).
- The MARR is used as a criterion against which an alternative's ROR is measured, when making the accept/reject investment decision.
- In the United States, the current U.S. Treasury Bill return is sometimes used as the benchmark safe rate. The MARR will always be higher than this, or a similar, safe rate.

It always costs money in the form of interest to raise capital. The interest, expressed as a percentage rate per year, is called the cost of capital. As an example on a personal level, if you want to purchase a new widescreen HDTV, but do not have sufficient money (capital), you could obtain a bank loan for, say, a cost of capital of 9% per year and pay for the TV in cash now. Alternatively, you might choose to use your credit card and pay off the balance on a monthly basis. This approach will probably cost you at least 15% per year. Or, you could use funds from your savings account that earns 5% per year and pay cash. This approach means that you also forgo future returns from these funds. The 9%, 15%, and 5% rates are your cost of capital estimates to raise the capital for the system by different methods of capital financing. In analogous ways, corporations estimate the cost of capital from different sources to raise funds for engineering projects and other types of projects.

In general, capital is developed in two ways—equity financing and debt financing. A combination of these two is very common for most projects.

Equity financing: The corporation uses its own funds from cash on hand, stock sales, or retained earnings. Individuals can use their own cash, savings, or investments.

Debt financing: The corporation borrows from outside sources and repays the principal and interest according to some schedule. Sources of debt capital may be bonds, loans, mortgages, venture capital pools, and many others. Individuals, too, can utilize debt sources, such as the credit card and bank option.

Combinations of debt-equity financing mean that a weighted **average cost of capital (WACC)** results. If the HDTV is purchased with 40% credit card money at 15% per year and 60% savings account funds earning 5% per year, the weighted average cost of capital is 0.4(15) + 0.6(5) =9% per year.

For a corporation, the established MARR used as a criterion to accept or reject an investment alternative will usually be equal to or higher than the WACC that the corporation must bear to obtain the necessary capital funds.

$$\mathbf{ROR \geq MARR > WACC}$$

The above inequality must be correct for an accepted project. Exceptions may be government-regulated requirements (safety, security, environmental, legal, etc.), economically lucrative ventures expected to lead to other opportunities, etc.