PCE16136

WATER RESOURCES SYSTEMS PLANNING & MANAGEMENT

LECTURE NOTES

Module-I

Prepared By

Dr. Prakash Chandra Swain

Professor in Civil Engineering

Veer Surendra Sai University of Technology, Burla

Branch - Civil Engineering
Specialization-Water Resources Engineering
Semester – 2th Sem

Department Of Civil Engineering
VSSUT, Burla

Disclaimer

This document does not claim any originality and cannot be used as a substitute for prescribed textbooks. The information presented here is merely a collection by Prof. P.C.Swain with the inputs of Post Graduate students for their respective teaching assignments as an additional tool for the teaching-learning process. Various sources as mentioned at the reference of the document as well as freely available materials from internet were consulted for preparing this document. Further, this document is not intended to be used for commercial purpose and the authors are not accountable for any issues, legal or otherwise, arising out of use of this document. The authors make no representations or warranties with respect to the accuracy or completeness of the contents of this document and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose.

WATER RESOURCES SYSTEMS PLANNING & MANAGEMENT

(CE/WRE/ PCE16136)

Instructions (Hours/Week) Lectures 4-0-0

COURSE CONTENT

Module I

Introduction: General Principles of Systems Analysis to Problems in Water Resources Engineering, Objectives of Water Resources Planning and Development, Nature of Water Resources Systems, Socio Economic Characteristics.

Economic Analysis of Water Resources System: Principles of Engineering Economy, Capital, Interest and Interest Rates, Time Value of Money, Depreciation, Benefit Cost Evaluation, Discounting Techniques, Economic and Financial Evaluation, Socio-Economic Analysis.

Module II

Methods of Systems Analysis: Linear Programming Models, Simplex Method, Sensitivity Analysis, Dual Programming, Dynamic Programming Models, Classical Optimisation Techniques, Non-linear Programming, Gradient Techniques, Genetic Algorithm, Stochastic Programming, Simulation, Search Techniques, Multi Objective Optimisation.

Module III

Water Quantity Management: Surface Water Storage Requirements, Storage Capacity and Yield, Reservoir Design, Water Allocations for Water Supply, Irrigation, Hydropower and Flood, Reservoir Operations, Planning of an Irrigation System, Irrigation Scheduling, Groundwater management, Conjunctive Use of Surface and Subsurface Water Resources.

Module IV

Water Quality Management: Water Quality Objectives and Standards, Water Quality Control Models, Wastewater Transport Systems, River Water Quality Models and Lake Quality models.

Legal Aspects of Water & Environment Systems: Principles of Law applied to Water Rights and Water Allocation, Water Laws, Environmental Protection Law, Environmental Constraints on water Resources Development.

Course Contents

Module I

Introduction: General Principles of Systems Analysis to Problems in Water Resources Engineering, Objectives of Water Resources Planning and Development, Nature of Water Resources Systems, Socio Economic Characteristics.

Economic Analysis of Water Resources System: Principles of Engineering Economy, Capital, Interest and Interest Rates. Time Value of Money, Depreciation, Benefit Cost Evaluation, Discounting Techniques, Economic and Financial Evaluation, Socio-Economic Analysis.

Lecture Note 1

1.1 Introduction

Over the centuries, surface and ground waters have been a source of water supplies for agricultural, municipal and industrial consumers. Rivers have provided hydroelectric energy and inexpensive ways of transporting bulk cargo between different ports along their banks, as well as water-based recreational opportunities, and have been a source of water for wildlife and its habitat. They have also served as a means of transporting and transforming waste products that are discharged into them. The quantity and quality regimes of streams and rivers have been a major factor in governing the type, health and biodiversity of riparian and aquatic ecosystems. Floodplains have provided fertile lands for agricultural production and relatively flat lands for roads, railways and commercial and industrial complexes. In addition to the economic benefits that can be derived from rivers and their floodplains, the aesthetic beauty of most natural rivers has made lands adjacent to them attractive sites for residential and recreational development. Rivers and their floodplains have generated and, if managed properly, can continue to generate substantial economic, environmental and social benefits for their inhabitants. Human activities undertaken to increase the benefits obtained from rivers and their floodplains may also increase the potential for costs and damage when the river is experiencing rare or extreme flow conditions, such as during periods of drought, floods and heavy pollution.

These costs and impacts are economic, environmental and social in nature and result from a mismatch between what humans expect or demand, and what nature (and occasionally our own activities) offers or supplies. Human activities tend to be based on the 'usual or normal' range of river flow conditions. Rare or 'extreme' flow or water quality conditions outside these normal ranges will continue to occur, and possibly with increasing frequency as climate change experts suggest. River-dependent, human activities that cannot adjust to these occasional extreme conditions will incur losses.

The planning of human activities involving rivers and their floodplains must consider certain hydrological facts. One of these facts is that flows and storage volumes vary over space and time. They are also finite. There are limits to the amounts of water that can be withdrawn from surface and groundwater bodies.

There are also limits to the amounts of potential pollutants that can be discharged into them without causing damage. Once these limits are exceeded, the concentrations of pollutants in these waters may reduce or even eliminate the benefits that could be obtained from other uses of the resource. Water resources professionals have learned how to plan, design, build and operate structures that, together with non-structural measures, increase the benefits people can obtain from the water resources contained in rivers and their drainage basins. However, there is a limit to the services one can expect from these resources. Rivers, estuaries and coastal zones under stress from overdevelopment and overuse cannot reliably meet the expectations of those depending on them.

How can these renewable yet finite resources best be managed and used? How can this be accomplished in an environment of uncertain supplies and uncertain and increasing demands, and consequently of increasing conflicts among individuals having different interests in the management of a river and its basin? The central purpose of water resources planning and management activities is to address and, if possible, answer these questions. These issues have scientific, technical, political (institutional) and social dimensions and thus, so must water resources planning processes and their products.

River basin, estuarine and coastal zone managers – those responsible for managing the resources in those areas – are expected to manage them effectively and efficiently, meeting the demands or expectations of all users and reconciling divergent needs. This is no small task, especially as demands increase, as the variability of hydrological and hydraulic processes becomes more pronounced, and as stakeholder measures of system performance increase in number and complexity. The focus or goal is no longer simply to maximize net economic benefits while ensuring the equitable distribution of those benefits. There are also environmental and ecological goals to consider.

Rarely are management questions one-dimensional, such as: 'How can we provide more high-quality water to irrigation areas in the basin at acceptable costs?' Now added to that question is how those withdrawals would affect the downstream water quantity and quality regimes, and in turn the riparian and aquatic ecosystems.

Problems and opportunities change over time. Just as the goals of managing and using water change over time, so do the processes of planning to meet these changing goals. Planning processes evolve not only to meet new demands, expectations and objectives, but also in response to new perceptions of how to plan more effectively.

This chapter is about how quantitative analysis, and in particular computer models, can support and improve water resources planning and management. This first chapter attempts to review some of the issues involved. It provides the context and motivation for the chapters that follow, which describe in more detail our understanding of ‘how to plan’ and ‘how to manage’ and how computer based programs and models can assist those involved in these activities.

1.2 Need for Planning and Management

Planning and management of water resources systems are essential due to following factors:

(1) Severity of the adverse consequences of droughts, floods and excessive pollution. These can lead to

a. Too little water due to growing urbanization, additional water requirements, in stream flow requirements etc. Measures should be taken to reduce the demand during scarcity times.

b. Too much water due to increased flood frequencies and also increase in water requirements due to increased economic development on river floodplains.

c. Polluted water due to both industrial and household discharges.

(2) Degradation of aquatic and riparian systems due to river training and reclamation of floodplains for urban and industrial development, poor water quality due to discharges of pesticides, fertilizers and wastewater effluents etc.

(3) While port development requires deeper rivers, narrowing the river for shipping purposes will increase the flood level

(4) River bank erosion and degradation of river bed upstream of the reservoirs may increase the flooding risks

(5) Sediment accumulation in the reservoir due to poor water quality.

Considering all these factors, the identification and evaluation of alternative measures that may increase the quantitative and qualitative system performance is the primary goal of planning and management policies.

1.3 Planning and Management – Approaches

Two approaches which lead to an integrated plan and management policy are

- From the top down or the command and control approach
- From the bottom up or the grass-roots approach

Top down approach:

Water resources professionals prepare integrated, multipurpose "master" development plans with alternative structural and non-structural management options. There is dominance of professionals and little participation of stakeholders. In this approach, one or more institutions have the ability and authority to develop and implement the plan. However, nowadays, since public have active participation in planning and management activities, top-down approaches are becoming less desirable or acceptable.

Bottom up approach:

In this approach there is active participation of interested stakeholders – those affected by the management of the water and land resources. Plans are being created from the bottom up rather than top down. Top down approach plans do not take into consideration the concerns of affected local stakeholders. Bottom up approach ensures cooperation and commitment from stakeholders. The goals and priorities will be common among all stakeholders by taking care of laws and regulations and by identifying multiple alternatives and performance criteria. Tradeoffs are made between conflicting goals or measures of performance.

1.4 Integrated Water Resources Management (IWRM)

According to Global Water Partnership (GWP, 2000), IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of the vital ecosystems. An integrated water management model develops solutions by involving all the essential components into an optimization scheme. The resources are used in relation to social and economic activities and functions. There is a need for laws and regulations for the sustainable use of the water resources. Dublin principles for a good water resources management as described by the United Nations Water Conference in 1977 are:

- The “ecological principle” – to treat water as a unitary resource within river basins, with particular attention to ecosystems.

- The “institutional principle” – to respect the principle of subsidiarity through the involvement of government, civil society and the private sector.

- The “instrument principle” – to recognize water as a scarce economic community by imposing various penalties for excessive usage.

A management policy must be developed only after considering the factors such as cost effectiveness, economic efficiency, environmental impact, ecological and health considerations etc.

1.5 Planning and Management Aspects

Technical aspects

It is first necessary to identify the characteristics of resources in the basin, including the land, the rainfall, the runoff, the stream and river flows and the groundwater Technical aspects of planning involves

- Predicting changes in land use/covers and economic activities at watershed and river basin levels

- Estimation of the costs and benefits of any measures being and to be taken to manage the basin’s water resource including engineering structures, canals, diversion structures

- Identification and evaluation of alternative management strategies and also alternative time schedules for implementing those measures

Economic and Financial aspects

Water should be treated as an economic commodity to extract the maximum benefits as well as to generate funds to recover the costs of the investments and of the operation and maintenance of the system. Water had been treated for long as a free commodity. Revenues recovered are far below the capital cost incurred. Financial component of any planning process is needed to recover construction costs, maintenance, repair and operation costs. In management policies, financial viability is viewed as a constraint that must be satisfied; not as an objective whose maximization could result in a reduction in economic efficiency, equity or other non-monetary objectives.

Institutional aspects

Successful project implementation needs an enabling environment. National, provincial and local policies, legislation and institutions are crucial for implementation of the decisions. The role of the government is crucial since water is (i) not a property right (ii) a resource that often requires large investment to develop and (iii) a medium that can impulse external effects. The main causes of failure of water resources development project are insufficient institutional setting and lack of a sound economic evaluation and implementation.

LECTURE NOTE 2

Concept of System

2.1 Introduction

A system can be defined as a set of objects which interact in a regular, interdependent manner. It is a collection of various factors arranged in an ordered form with some purpose or goal. A system is characterized by:

- A system boundary: Rule that determines whether an element is a part of the system or the environment

- Statement of input and output interactions with the environment

- Statement of interrelationships between the various elements of the system called feedback

State of the system represents the conditions or indicates the activity in the system at a given time e.g. water level in a reservoir, depth of flow. System analysis deals with arriving at the management decisions based on the systematic and efficient organization and analysis of relevant information.

2.2 System Components

Water resources management involves the interaction of three interdependent subsystems:

1. Natural river subsystem in which the physical, chemical and biological processes takes place

2. Socio-economic subsystem, which includes the human activities related to the use of the natural river system

3. Administrative and institutional subsystem of administration, legislation and regulation, where the decision, planning and management processes take place

Inadequate attention to one subsystem can reduce the effect of any work done to improve the performance of the others.

2.3 Classification of Systems

Physical system: One that exists in the real world Sequential system: A physical system with input, working medium and output Static system: Output depends only on current input Dynamical system:

Output depends only on current and previous inputs Time-varying system: Kernel changes with time (A kernel is a weighting function used to estimate the probability density function of a random variable in a nonparametric way) Time-invariant system: Kernel does not change Deterministic system: Kernel and inputs are known Stochastic system: Kernel and inputs are not exactly known Continuous-time systems: Inputs, outputs and kernel vary continuously with time Discrete time systems: Inputs, outputs and kernel are known at discrete times.

Hydrologic systems are distributed in time and space. Systems are divided into sub-systems for the purpose of solution. Hydrologic system is a physical, sequential and dynamic system.

The input-output relationship can be expressed as:

$$y(t) = \Phi\ [x(t)]$$

where x(t) and y(t) are time functions of input and output respectively; and Φ[x(t)] is the transfer function or the operation performed to transform input to output. For a catchment system, the input is water or energy of various forms and the transfer function may be the unit hydrograph

2.4 System Analysis

In system analysis an optimal plan is selected through a systematic search and evaluation of various alternatives that meet the objectives and constraints. System analysis consists of five steps:

- Defining the problem
- Identifying the system and its elements
- Defining the objectives and constraints
- Identify feasible alternatives that satisfy the above said constraints
- Identify the most efficient alternative that best meets the objectives

2.5 Need for Systems Approach

The system approach is necessary due to the following aspects:

- Water resource projects are large-scale and most of the times permanent ones
- They have huge impact on both society and economy
- They need the participation from various fields simultaneously

- Require large capital investments and hence have a major effect on economy
- Even a small improvement over traditional solution is thus desirable

Hence, the adoption of systems approach is better than conventional techniques based only on experience, to achieve an improved overall project output.

2.6 Advantages of System Approach

- Focuses on definite goals and objectives
- Systematic searching for alternatives
- Provides with modern technology to analyse the system scientifically and objectively
- Forces the user to identify the known and not readily known elements of the system
- Regularly provide feedback from each step thus providing flexibility for correction and modification
- Can deal with highly complex multi-objective multi-constraint problems

2.7 Disadvantages of System Approach

- System approach is not suitable when there is a lack of proper and full understanding of water resources systems and its conflicting objectives
- Most of the decisions are irreversible in nature and hence hazardous if used without recognizing and integrating the quantitative and non-quantitative dimensions of the system (physical, social, economic, political etc.)
- Can face some practical difficulties due to the gap between the theory and the practice. The transfer of technological advances to practical on field use requires professionals with both theoretical background and practical experience
- Most water resources systems are complex thereby demanding difficult mathematical computations
- Unavailability or high cost of software and also unavailability of a part of the data required
- Dealing with intangibles. Systems are not that simple to be fully expressed in mathematical terms

2.8 Modelling Of Water Resources Systems (WRS)

Models are simplified representations of actual real-world systems through assumptions and approximations.

Models can be classified as

(i) Physical model that designs the physical components of a project

(ii) Mathematical models that evaluate consequences of alternative plans by analyzing the various physical processes through arithmetical and logical statements

The features to be included and to be excluded will be decided by the modeller. Models are inexpensive and convenient. The accuracy of the model depends on the skill of the modeler and his/her understanding of the real system and decision making process and also on the time and money available. Models produce information - but not decisions. They aid planners and managers to improve their understanding and provide various alternatives that help in the decision making process.

Example:

An example of system management is water quality problem in which the objective is to maintain certain quality standards throughout the stream. The stakeholders involved are Pollution Control Agency (PCA) and the dischargers (municipal and industrial). The goal of PCA is to improve the water quality while that of the dischargers is to reduce the water treatment cost. This necessitates the need for a waste load allocation model with multiple objectives and conflicting constraints. Modelling is not suitable for each and every water resources planning and management problem.

It is appropriate when:

- The objectives are well defined and beneficiaries (organizations and individuals) are identified
- The best decision is not obvious among various alternatives that satisfy the stated objectives
- The system and objectives can be expressed reasonably through mathematical representations
- The impacts (hydrological, economic, environmental and ecological) resulting from the decision can be better estimated through the use of models
- The data is readily available for the estimation of parameters of the model

The main challenges for any planners and managers are to:

- identify creative alternative solutions
- find out the interest of each group involved in order to reach an understanding of the issues and a consensus on what to do
- develop and use models and reach a common or shared understanding and agreement that is consistent with the individual values by presenting the results
- make decisions and implement them duly taking care of the differences in opinions, social values and objectives

2.9 System Decomposition

A real WRS is a complex system with multiple objectives and decision makers, numerous variables and parameters, large spatial and temporal data base, numerous sub-systems and nonlinear complex relationships among variable.

While modeling, first the system is Water Resources Systems Planning and Management: Introduction and Basic Concepts: Modeling of Water decomposed into various subsystems. One such method is the Hierarchical approach by Haimes (1977) in which the complex large-scale systems are modeled by decomposing into independent sub-systems through the concepts of levels and layers. There are four major types of decompositions: temporal, physical-hydrological, political-geographical and goal-oriented or functional.

Temporal:

Normally planning horizon of WRS projects span large periods. In such period, the system conditions drastically change with time. Therefore, planning is done by segmenting the time periods. However, these segmented plans should be compatible and coordinated with each other.

Physical – hydrological:

Water resources program may consider several river basins. Instead of considering the entire basin together, each basin can be divided into sub-basins while modeling.

Political - geographical:

The basin considered may cover two or more national territories or different political or administrative units. These can be decomposed considering either political or natural boundary.

Goal oriented or functional:

Analysis is done with respect to economic and functional goals. For example, Demand – Supply models, Irrigation, Hydroelectric models.

Lecture note 3

Economic Analysis of Water Resources System

3.1 Introduction

Although the term “engineering economics” might seem far removed from the business world, in reality every small-business owner is an engineering economist. For instance, any time you use a cost-value comparison to decide between two alternatives for a project, capital purchase or potential investment, you’re practicing engineering economics. It is important to understand the basics of engineering economics because no matter how sound a project, capital purchase or investment may seem, it will fail if it is not economically feasible.

3.1 What Engineering Economics Is and Isn’t

Engineering economics principles focus on the process used to make an economics-based decision, not on the decision itself. Engineering economics plays an important role for business owners because it helps identify the steps required to make well-thought out decisions such as whether to lease or purchase office space, invest in new computers or update existing ones, or provide customer service in-house or outsource the customer service department.

3.2 The Seven Principles

Each of the seven principles of engineering economics moves you a step closer toward making an economics-related decision. The first two principles -- making a list of alternatives and identifying the differences between each alternative -- set up the thought process. The next three principles focus on evaluation criteria. These include establishing consistent evaluation criteria, developing common performance measurements and considering all relevant monetary and non-monetary criteria. The final two principles focus on analysis. These include weighing risks against potential rewards and performance monitoring.

1. Develop the Alternatives

The final choice (decision) is among alternatives. The alternatives need to be identified and then defined for subsequent analysis.

2. Focus on the Differences

Only the differences in expected future outcomes among the alternatives are relevant to their comparison and should be considered in the decision.

3. Use a Consistent Viewpoint

The prospective outcomes of the alternatives, economic and other, should be consistently developed from a defined viewpoint (perspective).

4. Use a Common Unit of Measure

Using a common unit of measurement to enumerate as many of the prospective outcomes as possible will make easier the analysis and comparison of alternatives.

5. Consider All Relevant Criteria

Selection of a preferred alternative (decision making) requires the use of a criterion (or several criteria).

6. Make Uncertainty Explicit

Uncertainty is inherent in projecting (or estimating) the future outcomes of the alternatives and should be recognized in their analysis and comparison.

7. Revisit Your Decisions

Improved decision making results from an adaptive process; to the extent practicable, the initial projected outcomes of the selected alternative should be subsequently compared with actual results achieved.

3.3 Engineering Economic Analysis Procedure

1. Problem recognition, definition, and evaluation

2. Define the goal or objectives

3. Define the feasible alternatives

4. Collect all relevant data/information

5. Evaluate each alternative

6. Select the "best" alternative

7. Implement and monitor the decision

3.4 Principles in Action

The way you put the principles of engineering economics into action depends on what kind of decision you must make. For example, potential economic alternatives for an out-of-date computer network might include updating the current system or building a new system from scratch. During this process you might analyze how each alternative will affect the cost, expected performance and useful lifetime of the system to decide which alternative will provide the most value to the company. Evaluation criteria might include factors such as the purchase and installation costs, annual operating costs, maintenance costs and both principal and interest payments if you plan on using outside financing. Compare the risks of each alternative against potential economic and non-economic rewards. After making a decision, compare actual results to expectations.

3.5 Capital

In economics, capital consists of anything that can enhance a person's power to perform economically useful work. Capital goods, real capital, or capital assets are already-produced, durable goods or any non-financial asset that is used in production of goods or services.

Adam Smith defines capital as "That part of a man's stock which he expects to afford him revenue". The term "stock" is derived from the Old English word for stump or tree trunk. It has been used to refer to all the moveable property of a farm since at least 1510.

How a capital good is maintained or returned to its pre-production state varies with the type of capital involved. In most cases capital is replaced after a depreciation period as newer forms of capital make continued use of current capital non profitable. It is also possible that advances make an obsolete form of capital practical again.

Capital is distinct from land (or non-renewable resources) in that capital can be increased by human labour. At any given moment in time, total physical capital may be referred to as the capital stock (which is not to be confused with the capital stock of a business entity).

In a fundamental sense, capital consists of anything that can enhance a person's power to perform economically useful work—a stone or an arrow is capital for a caveman who can use it as a hunting instrument, and roads are capital for inhabitants of a city. Capital is an input in the production function. Homes and personal autos are not usually defined as capital but as durable goods because they are not used in a production of saleable goods and services.

In Marxian political economy, capital is money used to buy something only in order to sell it again to realize a financial profit. For Marx capital only exists within the process of economic exchange—it is wealth that grows out of the process of circulation itself, and for Marx it formed the basis of the economic system of capitalism. In more contemporary schools of economics, this form of capital is generally referred to as "financial capital" and is distinguished from "capital goods".

3.6 In narrow and broad uses

Classical and neoclassical economics regard capital as one of the factors of production (alongside the other factors: land and labour). All other inputs to production are called intangibles in classical economics. This includes organization, entrepreneurship, knowledge, goodwill, or management (which some characterize as talent, social capital or instructional capital).

This is what makes it a factor of production:

1. The good is not used up immediately in the process of production unlike raw materials or intermediate goods. (The significant exception to this is depreciation allowance, which like intermediate goods, is treated as a business expense.)

2. The good can be produced or increased (in contrast to land and non-renewable resources).

These distinctions of convenience have carried over to contemporary economic theory. There was the further clarification that capital is a stock. As such, its value can be estimated at a point in time. By contrast, investment, as production to be added to the capital stock, is described as taking place over time ("per year"), thus a flow.

Marxian economics distinguishes between different forms of capital:

1. Constant capital, which refers to capital goods.

2. Variable capital which refers to labour-inputs, where the cost is "variable" based on the amount of wages and salaries are paid throughout the duration of an employee's contract/employment.

3. Fictitious capital, which refers to intangible representations or abstractions of physical capital, such as stocks, bonds and securities (or "tradable paper claims to wealth").

Earlier illustrations often described capital as physical items, such as tools, buildings, and vehicles that are used in the production process. Since at least the 1960s economists have increasingly focused on broader forms of capital. For example, investment in skills and education can be viewed as building up human capital or knowledge capital, and investments in intellectual property can be viewed as building up intellectual capital. These terms lead to certain questions and controversies discussed in those articles.

3.7 Modern types of capital

Detailed classifications of capital that have been used in various theoretical or applied uses generally respect the following division:

3.8 Financial capital

It represents obligations, and is liquidated as money for trade and owned by legal entities. It is in the form of capital assets, traded in financial markets. Its market value is not based on the historical accumulation of money invested but on the perception by the market of its expected revenues and of the risk entailed.

Natural capital

It is inherent in ecologies and which increases the supply of human wealth.

Social capital

It in private enterprise is partly captured as goodwill or brand value, but is a more general concept of inter-relationships between human beings having money-like value that motivate actions in a similar fashion to paid compensation.

Instructional capital

It defined originally in academia as that aspect of teaching and knowledge transfer that is not inherent in individuals or social relationships but transferrable. Various theories use names like knowledge or intellectual capital to describe similar concepts but these are not strictly defined as in the academic definition and have no widely agreed accounting treatment.

Human capital

It is a broad term that generally includes social, instructional and individual human talent in combination. It is used in technical economics to define balanced growth which is the goal of improving human capital as much as economic capital.

Public and private sector accounting differ in goals, time scales and accordingly in accounting. The ownership and control of some forms of capital may accordingly justify differentiating it in an economic theory. A blanket term that attempts to characterize all that clearly physical capital that is considered infrastructure and which supports production in unclear or poorly accounted ways is public capital. This encompasses the aggregate body of all government-owned assets that are used to promote private industry productivity, including highways, railways, airports, water treatment facilities, telecommunications, electric grids, energy utilities, municipal buildings, public hospitals and schools, police, fire protection, courts and still others. However it is a problematic term insofar as many of these assets can be either publicly or privately owned.

Separate literatures have developed to describe both natural capital and social capital. Such terms reflect a wide consensus that nature and society both function in such a similar manner as traditional industrial infrastructural capital, that it is entirely appropriate to refer to them as different types of capital in themselves. In particular, they can be used in the production of other goods, are not used up immediately in the process of production, and can be enhanced (if not created) by human effort.

There is also a literature of intellectual capital and intellectual property law. However, this increasingly distinguishes means of capital investment, and collection of potential rewards for patent, copyright (creative or individual capital), and trademark (social trust or social capital) instruments.

3.8 Interest and Interest Rates

Interest is the charge for the privilege of borrowing money, typically expressed as annual percentage rate (APR). Interest can also refer to the amount of ownership a stockholder has in a company, usually expressed as a percentage.

Two main types of interest can be applied to loans: simple and compound.

1. Simple interest is a set rate on the principle originally lent to the borrower that the borrower has to pay for the ability to use the money.

2. Compound interest is interest on both the principle and the compounding interest paid on that loan. The latter of the two types of interest is the most common.

Some of the considerations that go into calculating the type of interest and the amount a lender will charge a borrower include:

- Opportunity cost or the cost of the inability of the lender to use the money they're lending out.
- Amount of expected inflation
- Risk that the lender is unable to pay the loan back because of default
- Length of time that the money is being lent
- Possibility of government intervention on interest rates
- Liquidity of the loan being made

A quick way to get a rough understanding of how long it will take in order for an investment to double is to use the rule of 72. Divide the number 72 by the interest rate, 72/4 for instance, and you'll double your investment in 18 years

An interest rate is the amount of interest due per period, as a proportion of the amount lent, deposited or borrowed (called the principal sum). The total interest on an amount lent or borrowed depends on the principal sum, the interest rate, the compounding frequency, and the length of time over which it is lent, deposited or borrowed.

It is defined as the proportion of an amount loaned which a lender charges as interest to the borrower, normally expressed as an annual percentage. It is the rate a bank or other lender charges to borrow its money, or the rate a bank pays its savers for keeping money in an account.

Annual interest rate is the rate over a period of one year. Other interest rates apply over different periods, such as a month or a day, but they are usually annualised.

3.9 The Time Value of Money

Evaluation criteria establish measures of economic worth that make it possible to decide between two possible cost or investment alternatives. The alternative that provides the greatest return for the least cost or investment is usually the best solution. Common measures of worth include calculations based on the time value of money, a concept that uses time, interest rates and the investment amount to determine which alternative is the wisest decision. These calculations might include the rate of return, cost-benefit ratio, cost capitalization and present, future and annual worth. Their value lies in forcing you to consider long-term benefits and costs -- not just an initial purchase price or investment.

3.10 Depreciation

In economics, depreciation is the gradual decrease in the economic value of the capital stock of a firm, nation or other entity, either through physical depreciation, obsolescence or changes in the demand for the services of the capital in question. The net increment to the capital stock is the difference between gross investment and depreciation, and is called net investment.

3.11 Differences between Tangible and Intangible Assets

Economic depreciation is different than the depreciation recognized for tangible assets as those assets are used to create revenue. While land does not depreciate, buildings and other tangible assets do recognize depreciation, which is the decline in value of a physical asset as the asset is used over time.

Assume, for example, that a roofing company uses a truck to perform residential roofing work, and that the truck is used for seven years. As the truck is used each year to generate revenue, the company also posts depreciation expense for the decline in value of the asset. Intangible assets, such as a patent or other intellectual property, do not depreciate in value.

3.11 Factoring in Liquidity

Real estate's lack of liquidity makes the impact of economic depreciation more profound for the owner. Liquidity refers to the ability of an owner to sell an asset, and assets that sell on exchanges, such as stocks and bonds, are more liquid than real estate and other assets. If, for example, an investor wants to sell 100 shares of IBM common stock, that investor can check the bid price on a stock exchange and place a trade to sell the stock on any business day. Real estate, on the other hand, requires the seller to find a buyer, and the two parties must negotiate until the parties agree on a price. In addition, the sale normally requires an appraisal of the property, and a real estate sale can take months to complete.

3.12 Economic and Financial Evaluation

Financial management involves planning, allocation and control of financial resources of a company. Financial management is essential as it controls the financial operations of a company. For a construction company, the decision to bid for a project will depend on its financial status which in turn will be governed by financial management principles. The decision to bid for a project will depend on various factors namely whether the company have enough funds or require outside financing, whether to acquire the equipment through purchase or acquisition through renting or leasing, whether to carry out the entire work or subcontract a portion of the work etc. If the company uses its own funds for the project, it may have an adverse effect on its financial status as it will reduce the liquid asset thus affecting company's working capital. The construction industry differs from other industries because of its unique characteristics and accordingly the financial management principles are applied for using the financial resources of the company. Generally the construction companies receive the payments from the owners at specified time intervals as the construction work progresses and owners often retain certain amount subject to the satisfactory completion of the project. Thus the terms and conditions for receipt of payments from owners affect the cash flow of the construction companies and need the changes in allocation of financial resources. Further construction companies often subcontract some portion of the work (as required) to the subcontractors, which in turn affect the cash flow. The financial management decisions include the decisions for investment, financing and distribution of earnings. For construction companies the investment decisions relate to investment in the business i.e. investment of funds in acquiring the assets (both current assets and long-term assets) to be utilized in the projects for the expected return along with the risk of cash flows associated with uncertain future conditions. The financing decisions depend on decision to investment the funds and the resources possessed by the construction companies. In addition the financing decisions are also controlled by other factors namely source of financing (from banks or other financial institutions), cost of financing i.e. interest cost on the loan and the financing duration. The decision for distribution of earnings or profits of the company depends on the dividends to be paid to the stockholders and the retained earnings to be reinvested in the business to increase the return. Thus for any company or organization, financial management has to ensure the supply of funds in acquiring the assets and their effective utilization in business activities, to ensure the expected return on the investment considering the risk associated and optimal.

3.13 Benefit Cost Evaluation and Discounting Techniques

Quantifying alternatives for any item is the most important aspect of decision making for selecting the best option. For example, a construction company is planning to purchase a new concrete mixer for preparing concrete at a construction site. Let’s say there are two alternatives available for purchasing the mixer; a) an automatic concrete mixer and b) a semi-automatic concrete mixer. Then the task is to find out best alternative that the company will purchase that will yield more profit. For this purpose one has to quantify both the alternatives by the following parameters

- This initial cost that includes purchase price, sales tax, cost of delivery and cost of assembly and installation
- Annual operating cost
- Annual profit which will depend on the productivity i.e. quantity of concrete prepared
- The expected useful life
- The expected salvage value
- Other expenditure or income (if any) associated with the equipment
- Income tax benefit

3.14 Discounting techniques

Discounting techniques are used to find the feasible one among various alternatives. Commonly used discounting techniques are (1) Benefit-cost ratio method (2) Present worth method (3) Rate of return method and (4) Annual cost method. The first two methods are explained here.

3.15 Benefit – Cost (BC) ratio method

BC ratio, R is defined as the ratio of the present worth of benefits and the present worth of cost. It can be expressed as

$$R = \frac{B}{C} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}}$$

where B_t and C_t are the monetary values of benefits and costs incurred at time t respectively, i is the discount rate and n is the life of the project in time steps (years or months or weeks).

The steps to be followed for choosing the best alternative are:

(i) Calculate the BC value for each alternative

(ii) Retain all alternatives with BC>1 and reject the rest. If sets of mutually exclusive alternatives are involved then go to steps (iii), (iv) and (v).

(iii) Rank the set of mutually exclusive alternatives in the order of increasing cost. Calculate the BC ratio using incremental cost and incremental benefit of the next alternative above the least costly alternative.

(iv) Choose the more costly alternative of the incremental BC >1. Otherwise choose the less costly alternative.

(v) Repeat the analysis for all alternatives in the order of rank.

3.16 Present worth method

In this method, the net worth (benefit – cost) for each year is computed and discounted to the present with using the present worth factor. Their sum is the Net Present Value (NPV).

$$NPV = \frac{B_0 - C_0}{(1+i)^0} + \frac{B_1 - C_1}{(1+i)^1} + \ldots.. + \frac{B_n - C_n}{(1+i)^n}$$

where B_t and C_t are the monetary values of benefits and costs incurred at time t respectively, i is the discount rate and n is the life of the project. The steps for selecting the best alternative are:

(i) Determine the NPV of each alternative.

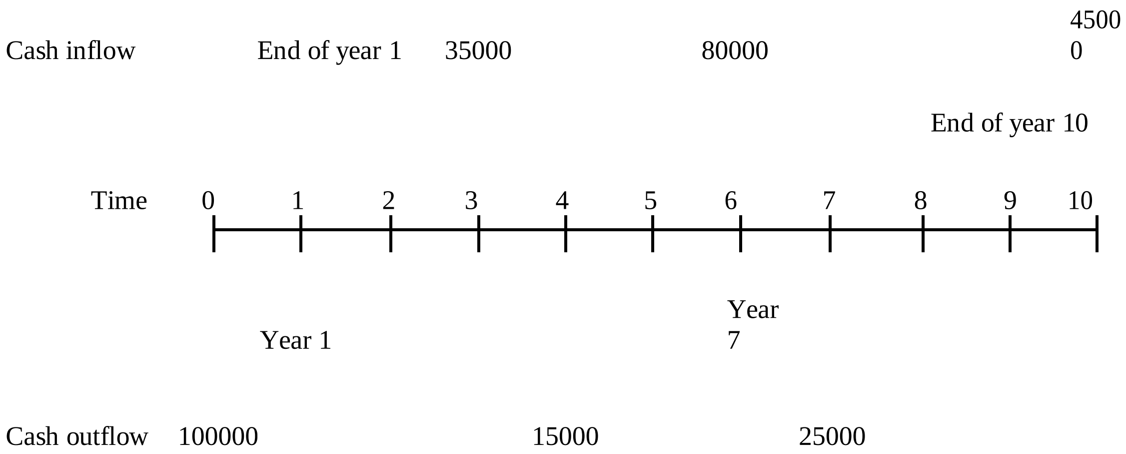
(ii) Retain those alternatives with NPV > 0 and reject the rest. If there is any mutually exclusive alternative, then proceed to steps (iii) and (iv). Otherwise, stop.

(iii) Choose the one with greatest NPV from the set of mutually exclusive alternatives.

(iv)If in a set of mutually exclusive alternatives, some have benefits that cannot be quantified but are approximately equal, then choose the one with least cost.

3.17 Cash flow diagram

The graphical representation of the cash flows i.e. both cash outflows and cash inflows with respect to a time scale is generally referred as cash flow diagram. A typical figure is given below.



3.18 Compound interest factors:

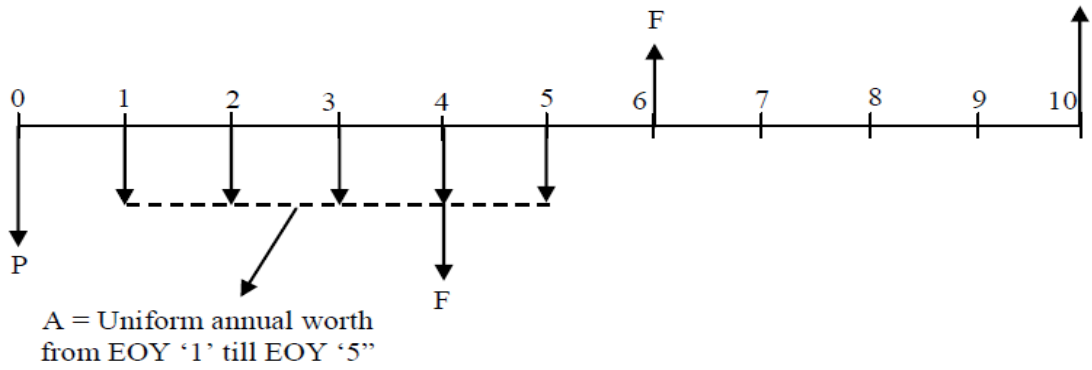
The compound interest factors and the corresponding formulas are used to find out the unknown amounts at a given interest rate continued for certain interest periods from the known values of varying cash flows. The following are the notations used for deriving the compound interest factors.

P = Present worth or present value.

F = Future worth or future sum.

A = Uniform annual worth or equivalent uniform annual worth of a uniform series continuing over a specified number of interest periods n = number of interest periods (years or months).

i = rate of interest per interest period i.e. % per year or % per month.



(Cash flow diagram showing P, F and A)

Name of the factor (1)	Abbreviation (2)	Functional representation (3)	Mathematical expression (4)	Given (5)	To find out (6) = (4) x (5)
Single payment compound amount factor	*SPCAF*	$(F/P,i,n)$	$(1+i)^n$	P	F
Single payment present worth factor	*SPPWF*	$(P/F,i,n)$	$\frac{1}{(1+i)^n}$	F	P
Uniform series present worth factor	*USPWF*	$(P/A,i,n)$	$\frac{(1+i)^n-1}{i(1+i)^n}$	A	P
Capital recovery factor	*CRF*	$(A/P,i,n)$	$\frac{i(1+i)^n}{(1+i)^n-1}$	P	A
Uniform series compound amount factor	*USCAF*	$(F/A,i,n)$	$\frac{(1+i)^n-1}{i}$	A	F
Sinking fund factor	*SFF*	$(A/F,i,n)$	$\frac{i}{(1+i)^n-1}$	F	A

Table of formula for various factors of investment

Interest factors (Discrete compounding) with rate of interest ‘i’ (%) and number of interest periods ‘n’

Sunk cost: The money spent already which has no economic relevance in deciding future alternatives

Salvage value: The value of the unused life of an element at the end of the period of analysis. The salvage value, S = I (1 – U/L), where I = initial value, U = unused life and L = total life.

References:

1. Loucks, D.P., Stedinger, J.R. and Haith, D.A. (1982) "Water Resources Systems Planning and Analysis", Prentice Hall Inc. N York

2. Chaturvedi, M.C. (1987), "Water Resources Systems Planning and Management", Tata McGraw Hill Pub. Co., N Delhi.

3. Hall. W.A. and Dracup, J.A. (1975), "Water Resources Systems", Tata McGraw Hill Pub. N Delhi

4. James, L.D. and Lee (1975), "Economics of Water Resources Planning", McGraw Hill Inc. n York

5. Kuiper, E. (1973) "Water Resources Development, Planning, Engineering and Economics", Buttersworth, London

6. Biswas, A.K. (1976) "Systems Approach to Water Management", McGraw Hill Inc. N York

7. Taha H A, (1996), "Operations Research", Prentice Hall of India, N Delhi.