WATER RESOURCES SYSTEMS ENGINEERING

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1.0 System Defined

A system may be defined as an assemblage or combination of elements or components interacting with one another and working towards a common objective. The properties and behavior of each of component of the system has an effect on the properties and the behavior of the system as a whole. Each component of the system depends upon the properties and behavior of at least one other component of the system. These properties of the components ensure that the system as a whole has some characteristics or behavior pattern that cannot be exhibited by any of its sub-systems.

The objectives or purposes of a system must be explicitly defined and understood. Establishing the purpose and defining its measure of effectiveness is often very difficult.

1.1 The Element of a System.

Systems are composed of components, attributes and relationships. Attributes are the properties of the components of a system. These attributes characterize the parameters of the system. For example a reservoir may be considered as system components of the reservoir system include the dam, the spillways, the drainage gallery, the sluice gates etc. The attributes include dimensions like length, breadth, height of elements, material properties like modulus of elasticity, poison’s ratio, number and spacing of gates; performance characteristics such as coefficient of discharge, coefficient of permeability; characteristics of inputs and outputs such a inflow hydrograph and outflow hydrograph, etc.

Relationships are the links between components and attributes. The relationships may be spatial (Component in terms of spatial position), temporal (relationships among components over time), functional (generally derived from laws of nature) or logical such as runoff occurs only if rainfall rate is higher that infiltration capacity, flood discharge over spillway occurs only if the water level in the reservoir is above the crest level of the spillway and gates are open, etc.

1.2 Systems Approach

Generally a system is idealized. Factors of negligible importance are ignored and only important factors are taken into consideration. The parameters and variables which are controlled and whose design is the objective of the study are grouped together are constituting the system. All uncontrolled variables and inputs to the systems are considered as part of the environment. For a given system, the environment consists of all objects outside the system which affect and is affected by the system. The environmental factors include the inputs to the system, external physical environment, the technical, socio-economic and political factors which constrain the behavior or development and management of the system. The system not only exists in an environment but also coexists with the environment.

The knowledge and understanding of the behavior of the system as a whole as well as the individual components, and the laws of nature in terms of constitutive laws, are useful in formulating the system relationships.

System analysis of large systems is a team effort. Each member of the team must be an expert possessing the necessary technical knowledge in his or her specialty. In addition, the various individuals involved must be aware of the interface between their respective specialty areas and economic factors, socio-political factors, ecological factors, and the like. Decisions require consideration of these factors in the early stages of system planning and design. Thus, technical expertise must include not only the basic knowledge of individual specialty fields, but an understanding of the environment into which the system is being brought into being.

1.3 Water Resources Systems

Water resources systems are generally large scale and complex. They consist of multiple units such as reservoirs, canals, power houses , etc and serve multiple purpose such as irrigation, hydro-electric power generation, flood control etc. The water resources systems are designed to serve several socio-economic objectives such as efficiency, income distribution, enhancement of environmental quality etc.

The basic purpose of water resources system is *"to modify the unreliable, naturally existing water supply from one which is inadequately distributed in time and place to one which is reliably distributed in both time and place. The value of water is not determined so much by the volume of supply as by the assurance of the reliability of that supply at the time and place it is needed to accomplish the many social and economic purposes for which it constitutes a necessary resources," (Hall, 1970).* Some of the characteristics of large scale water resources projects are; they generally result in more or less permanent physical changes in our environment such as creation of large scale reservoirs which may have adverse environmental impact, change in land use patter because of the availability of irrigation water, and the like; they are highly capital intensive and have major effects on the economy of the region; they require team effort from economists, sociologists, politicians, agronomists, administrators and environmentalists; they require enormous amount of reliable data on hydrology, economy, engineering, soil, agriculture and environment; they are affected by economics and hydrologic uncertainties.

1.4 Conventional Method of Analysis

The conventional method is planning, design and operation of water resources project has been to consider a set of demands and to satisfy them by considering a tentative plan. The tentative plan is prepared with due regard for basin-wide needs. The objectives of the plan are often stated in physical terms such as attaining a particular degree of flood protection, irrigating a certain number of hectares of land, or supplying a specific quantity of water for municipal and industrial needs etc. Engineering analysis is then done to meet these demands at least cost.

Improvement of the tentative plan is then done by doing incremental analysis, with the aim of improving the objective. The incremental analysis method consists of "*adding or substracting from the tentative plan substantial segments of purpose, level of output, or sizes of structures, and determining through operation studies the resulting physical effect on the system as a whole and on the consequent benefits and costs*" (Maass, et.al. 1962). Incremental gross benefits and incremental costs are obtained as the difference between gross benefits and costs before and after adding or subtracting increments. If the incremental gross benefits are higher than the incremental costs, the increment is normally added to the plan. The increment may be adding a separable unit such as a reservoir or a power plant, or a separable purpose, such as irrigation or flood control. It may also be part of a unit or purpose; for example adding an increment to the reservoir capacity or power plant capacity, or adding an increment to the level of output, such as irrigation or power.

Incremental analysis of the plan continues until at the reasonable increments have been tried and there is no further growth of net benefit. Usually incremental analysis is done on single purpose first, to choose the best single purpose designs. Using this as the basis, optimal two purpose plans and finally an optimal three purpose plan is obtained for a three purpose design.

1.5 Methods of Systems Analysis

With the advent of digital computers, the methodology of planning, design and development of water resources projects has changed. The techniques of system analysis, namely mathematical programming techniques and simulation techniques are now used. Among the mathematical programming techniques, the linear programming and dynamic programming techniques are very commonly used in water resources system analysis. The popularity of linear programming technique is because of the availability of general solution algorithms namely simplex algorithm to solve any linear programming problem. Dynamic programming, on the other hand, has its appeal because of the ease with which it can handle problems which can be formulated as multistage decision problems or sequential decision problems.

The limitation of linear programming method is that it requires the objective function and the constraint equation to be linear while in reality they may not be. Some special types of non-linearities can be handled by using place wise linearization method or separable linear programming method. Dynamic programming method can handle non-linear or even discontinuous functions. However, it is subjected to the 'curse of dimensionality'.

These two programming or optimization techniques are generally used as screening models. The design that is obtained by the optimization, technique is then applied to this design using generated inflows and an operating policy and the performance of the design evaluated against a suitable performance criteria. If the criteria is not satisfied, the design is varied around the starting design by making changes in the design variables and applying the simulation techniques again. This procedure is repeated till a satisfactory design is obtained. Thus a combination of optimization technique and simulation technique is generally used in system analysis of water resources systems.

There are other optimization methods which are used of specific cases. These include convex programming, geometric programming, quadratic programming, integer programming, stochastic programming etc. Stochastic programming incorporates the probabilistic and time series information into the model.