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N.I.H.

Systems Analysis and Optimal Water Resources Development Scenario in India

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ASTRACT

The present paper highlights the National Water Policy of India that has been modified in the year 2002 and the emphasis given to the application of systems techniques in various related issues in the policy. After brief description of systems techniques, major water resources planning issues have been discussed. The need of systems tools for water resources planning and management is described. Finally, a detailed overview of systems applications in Indian context is presented.

INTRODUCTION

Water resources planning and management is broadly concerned with the accurate assessment, identification and development of different water resources systems. The careful planning for allocation of water resources to different developmental activities has become extremely important to meet the ever increasing demand for water supply, hydro-power, and irrigation etc. It emphasizes the need for planning and development of the water resources of a river basin, which is a complex and difficult task, and creates numerous social, economical, environmental and engineering problems. Most of these difficulties are due to variable inflows and large number of possible alternatives. Optimum planning of a large-scale river basin as a unit of water resources system is having a high priority in the economic development of a country. This has resulted in an urgent need for accurate and efficient management of the water resources for its conservation and use. System engineering provides systematic methodologies for studying and analyzing various aspects of a system and its response to various parameters by using mathematical models. It assists in the decision making process for all pertinent constraints by using optimization techniques. Efficient planning of limited water resources is an important requirement in comprehensive planning of the water resources of a river basin.

INDIA'S NATIONAL WATER POLICY 2002

According to the National Water Policy 2002, water resources development and management will have to be for a hydrological unit such as drainage basin as a whole or a sub-basin, taking into account surface and ground waters for sustainable use incorporating quantity and environmental considerations. All individual developmental projects and proposals should be formulated and considered within the framework of such an overall plan keeping in view the existing agreements/awards for a basin or sub-basin so that the best possible combination of options can be selected and sustained. Water should be made available to water short areas by transfer from other areas including transfers from one river basin to another, based on a national perspective, after taking into account the requirements of the areas/basins. Integrated and coordinated development of surface water and ground water resources and their conjunctive use, should be envisaged right from the project planning stage and should form an integral part of the project implementation. Irrigation intensity should be such as to extent the benefits of irrigation to as large a number of farm families as possible, keeping in view the need to maximize production. Irrigation being the largest consumer of fresh water, the aim should be to get optimal productivity per unit of water. In view of the vital importance of water from human and animal life, for maintaining ecological balance and for economic and developmental activities of all kinds, and considering its increasing scarcity, the planning and management of this resources and its optimal and equitable use has become a matter of the utmost urgency.

SOME WATER RESOURCES SYSTEMS PLANNING ISSUES

The approach and appropriate technique will naturally vary from problem to problem as the configuration, state of development of the system and stage of decision making vary over a vast range. A large number of the systems analysis studies on river basin planning for large river systems generally have considered basic problem constraints only. A very few such studies in the Indian context have incorporated the interest of co-basin states in terms of sharing of the river waters with intra basin water transfers and limiting its use under numerous techno-economic and management constraints pertaining to treaties/agreements/tribunal awards.

In India irrigation sector is a major user of water and the irrigation projects are being planned to provide 75% dependability of yield on an annual basis. Though 75% project dependability in terms of meeting the annual targeted demand is considered, the extent of failure in annual yield during the failure years is not taken into account. In order to safeguard against unacceptable risk of extreme shortages during critical periods, additional reliability criteria need to be identified. Quantifying these criteria and incorporating them into planning models may result in improved designs and operating policies. Hence, it is felt that the irrigation planning criteria should include the provision for some proportion of annual yield to be made available during the failure years. An appropriate modeling approach and solution methodology is to be devised in accordance with the specific characteristics of the problem.

The chief issue to be addressed in the irrigation planning studies, is the assessment and optimal utilization of *annual yield of system of reservoirs,* which involves modeling of a large-scale multi-reservoir system for integrated operations planning and design. In accordance with the reported findings regarding the modeling approaches, a widely used linear programming optimization based approach employing the implicit stochastic *yield model* is considered suitable due to following advantages: (a) longer period of flow record can be considered to incorporate desired reliabilities for different purposes while keeping the problem computationally tractable, (b) the possibility of incorporating an irrigation planning criteria to provide for a portion of annual target during failure years, (c) linear programming has ability to accommodate high dimensionality with comparative ease, universal optima are obtained, and no initial policy is needed.

Other planning issues for a multipurpose development may be the determination of the firm and the secondary annual reservoir yields, specifically for hydropower, and the within-the-year and the over-the-year, reservoir carry-over storages for water conservation to mitigate droughts. The inter-basin water transfers is another current important issue, to transfer from water surplus basins to water deficit basins. Similarly other important issues are discussed later.

SYSTEMS ANALYSIS TECHNIQUES

Following are the two broad categories of the systems analysis techniques:

Optimization

- makes standard systematic searches for the optimal solution
- guarantees global optimal solution
- an approximate model representation of the system

Simulation

- makes non standard trial and error searches for a better solution
- does not guarantee global optimal solution
- a realistic model representation of the system.

SYSTEMS ANALYSIS TECHNIQUES – AN OVERVIEW

Some of the good (-) and the bad (·) points of the various systems analysis techniques, widely used in practice, are mentioned below:

Linear Programming (LP)

- a linear model
- handles large size problems

- a problem is solved as one problem and no need to decompose into multi-level problems
- standard computer softwares available
- standard PC based software LINDO/LINGO package (can solve a problem of unlimited constraints and variables) available

data handling a Herculean task

Dynamic Programming (DP)

- a linear/non linear model
- handles small size problems
- a large problem is decomposed into multi level problems and then each level problem is solved individually
  - standard computer software not possible, every software is partially problem specific
  - may create dimensionality problem for some models

Simulation (S)

- a non linear model
- handles large size problems
  - very generalized and efficient softwares needed
  - practically every problem is different, every computer software is problem specific.

SUSTAINABLE INTEGRATED RIVER BASIN PLANNING AND MANAGEMENT

India has a vast water resources potential. National Water Policy emphasizes for optimal water resources development. There are many River Water Disputes and the various Tribunals have given awards for Narmada, Godavari, Krishna, Ravi-Beas and Cauvery (interim award) for sharing of the river waters among their respective co-basin states. Water share agreements for Yamuna, and Subernarekha rivers among their respective co-basin states have been made.

For Inter-Basin Water Transfers the Supreme Court has given directives to go for inter-basin water transfers. Hence, there is an immediate need for the Optimal Sustainable Integrated River Basin Planning and Management. Some of the important studies needed for the optimal water resources development are:

- River basin water balance studies
- Conjunctive water use development
- Hydro-thermal development
- Consideration of Tribunal Awards
- Consideration of inter-basin water transfers
- Environmental considerations
- Determination of firm and secondary reservoir yields
- Determination of within the year and over the year, carry over reservoir storages

- Reliability considerations
- Political, and social economic considerations
- Ecological considerations
  - Project planning studies
    * project by project analysis
    * sub-basin wise analysis
    * basin as a whole analysis
  - Capacity expansion and sequencing of projects
  - Reservoir operation and regulation

SYSTEMS ANALYSIS AS A TOOL FOR OPTIMAL PLANNING

The National Water Policy of India emphasizes the need for optimal water resources development. Every, politician, bureaucrat, engineer, high level committee and organization, dealing with Water Resources Development is talking of the Optimal Water Resources Development.

The application of the Systems Analysis can play a major role in optimal water resources planning and management. The issues mentioned earlier for the sustainable integrated river basin planning and management should be analyzed. A recommended approach will be the combined use of optimization-simulation models. The optimization models act as the preliminary screening models and then simulation is used for further screening.

The following is needed to strengthen the base:

(a) Awareness drive needed among water resources engineers regarding use of systems analysis techniques through short term and long term specialized training courses.
(b) Wider applications of the systems analysis techniques through sponsored research and consultancy projects should be encouraged.
(c) Indigenous user friendly computer software should be developed for the systems analysis techniques.
(d) The outcomes of systems studies should be implemented in practice by the implementing authorities.

APPLICATIONS OF SYSTEMS ANALYSIS TO WATER RESOURCES DEVELOPMENT IN INDIA

The application of the Systems Analysis Techniques to the Water Resources Problems in India started about 30 years ago. The some of the noteworthy applications are: Duggal (1975), Srivastava (1976), Khepar (1981), Chaturvedi and Srivastava (1981), Vedula and Rogers (1981), Singh (1981), Chaturvedi and Rogers (1982), Kashyap (1982), Kashyap and Chandra (1982), Chaube (1983), Thangraj (1987), Loganathan and Bhattacharya (1990), Mohan and Vedula (1990), Mohan and Keskar (1991), Rao and Vijay (1991), Singh (1991), Chara (1992), Mohan and Raipure (1992), Vedula and Majumdar (1992), Srivastava and

Patel (1992), Bony (1993), Mohan and Arumugam (1994), Sadeghian (1995), Assadullah Kohistani (1995), Vedula and Nagesh Kumar (1996), Mohan and Arumugam (1997), Sunita Devi (1997), Waikar (1998), Mishra (1998), Ravi Kumar and Venugopal (1998), Jain et al. (1999), Sinha et al. (1999a and 1999b), Talukdar (1999), Srinivasan et. al. (1999), Dahe (2001), Dahe and Srivastava (2002).

There are two books by Chaturvedi and Rogers (1985) and Chaturvedi (1987). The first book is the compilation of some of the applications of the systems analysis techniques to the water resources problems in India. The second book gives an overall view of the systems analysis, applied to the water resources problems.

Apart from the applications mentioned above there are many dissertations at the Master's level available at different Institutions in India.

Attempts are being made at different institutions in India at the research level, specially at the Department of Hydrology, IIT Roorkee, Roorkee, towards seeking solutions for a wider spectrum of the problems related with the optimal development of the water resources of rivers, for river basin systems, ranging from small to large, in India.

MAJOR ORGANISATIONS WORKING IN THE FIELD OF WATER RESOURCES SYSTEMS ANALYSIS

- Department of Hydrology, and Water Resources Development Training Centre, Indian Institute of Technology, Roorkee.
- Other Indian Institute of Technologies, and Indian Institute of Science, Bangalore.
- National Institute of Hydrology, Roorkee.

OTHER ADVANCE TECHNIQUES RECENTLY IN USE FOR THE WATER RESOURCES SYSTEMS MODELING

(i) Fuzzy sets
(ii) ANN (Artificial Neural Network)
(iii) GA (Genetic Algorithm)

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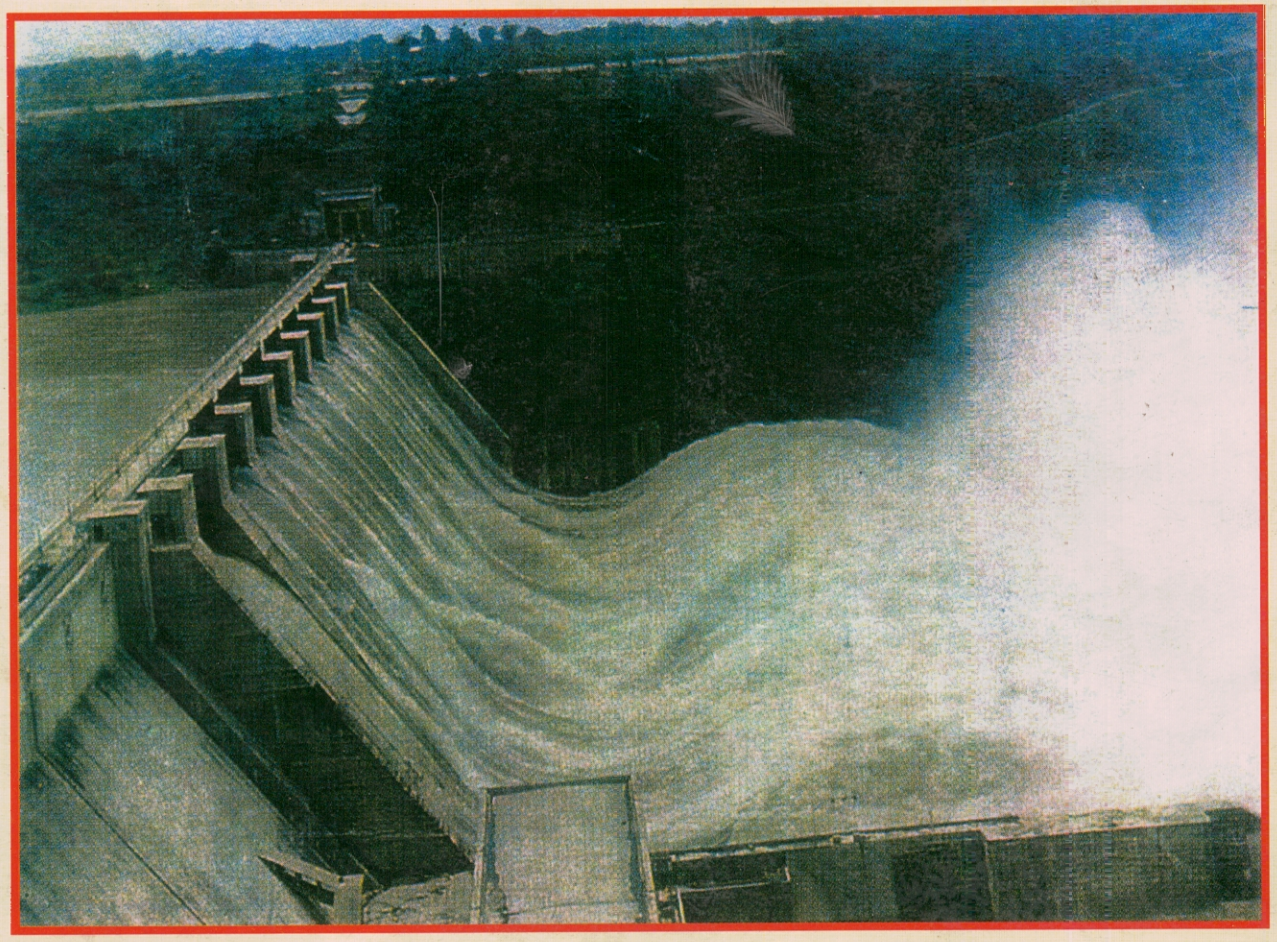
"No grain is ever produced without water, but too much water tends to spoil the grain. An inundation is as injurious to growth as dearth of water"

- Narada Smrithi XI.19



"The whole country was prosperous because of two crops grown in the year with irrigation facilities...the district officers measure the land and inspect the sluices by which water is distributed... so that every one enjoys his fair share of the benefit.."

- Megasthanese, Greek Ambassador 300 BC

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