ASSESSING ENVIRONMENTAL CONSEQUENCES OF WATER PROJECTS BASED ON A PSEUDO EXPERT SYSTEM APPROACH

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Abstract - Environmental Impact Assessment (EIA) of any development project is now a part of the project analysis today. This is not only required by national and/or international legislation, but also the growing environmental awareness of societies has forced project implementers to consider any environmental consequences beforehand and take the necessary measures to mitigate adverse effects. As a project cycle may include several steps, the consideration of environmental impacts at each level is now something inevitable. Although large numbers of environmental impact assessment procedures are available, an appropriate EIA procedure that is compatible with the level must be adopted. To this end, a tailor-made procedure for water resources planning process is devised, which is a computer model for the environmental assessment of planning components such as reservoirs and abstraction schemes etc. The model provides all the necessary facilities and knowledge thereby assisting the user to evaluate a particular impact by means of generic knowledge in relation to the impact and the site characteristics. As such, the model takes a form of expert system without a proper shell being used. The intention is to use the outcomes of this model for including environmental impacts along with the economical considerations in large-scale water resources planning process.

1. INTRODUCTION

It is a pre-requisite now to consider environmental consequences of any project, especially large ones, at the outset before they have actually occurred. This process includes examining no-project option as well. However, water is something essential for living communities and some of the water projects cannot be substituted especially those for potable water. Growing human population and industrial development require new schemes to be promoted or existing ones upsized. Since most of the water projects are large in size, their likely environmental impacts could be significant. Water project analysis, which is already complex in nature, gets even more complicated if environmental impacts are to be considered.

Water systems analysis start from initial screening of possible candidate options to meet a particular demand and ends in operating the scheme to be promoted. Then comes to actual construction and operation/maintenance stages. Therefore, environmental implications should be considered at each stage if an environmentally-sustainable project is to be undertaken. This paper deals with considering environmental impacts at the initial stage. Initial screening of water-resource options is mainly concerned with identifying the most appropriate development strategy for meeting the projected demands over the next 20 or 30 years by satisfying pre-set objectives such as cost effectiveness or environmental quality. On a national scale, the planning process is characterized by the need to screen a large number of potential options [1], with a view to determining the schemes to be developed and the timing and order of that development.

This initial screening process has typically required information relating to future demand, the performance of different size sources at various locations, the possible links between sources and demand centers, together with all the associated construction and operating costs even if only a financial analysis is to be undertaken. Faced with an enormous choice of possibilities for matching resources to needs, a systematic search procedure is normally required if an objective assessment is to be achieved. To that end, various forms of mathematical programming have been used [2,3,4] to identify the minimum net present value of development program. The objective function of such a program is as follows:

$$Min. \sum_i \sum_t c_{it} S_{it} + \sum_m \sum_t (p_{mt} L_{mt} + q_{mt} D_{mt} + r_{mt} F_{mt}) \quad (1)$$

where c_{it} : discounted cost of building source i in time period t

S_{it} : integer variable representing the introduction of source i in time period t

p_{mt} : discounted fixed cost portion of building link m in time period t

L_{mt} : integer variable representing the introduction of link m in time period t

q_{mt} : discounted variable cost portion of building link m in time period t

D_{mt} : continuous variable representing the capacity of link m built in period t

r_{mt} : discounted unit transmission cost for link m in time period t

F_{mt} : continuous variable representing flow in link m in time period t

To include environmental considerations in above function, they have to be quantified in monetary terms or put additional restraints to the model. Because of the difficulty to manage this and the uncertainties involved, in the past, scant attention would have been given to environmental considerations within the water-resources planning process until such time that scheme had already been selected, when detailed environmental assessment would be undertaken. At that stage, some attempts would be made to ameliorate and damaging environmental impacts identified. Nevertheless, consideration of environmental impacts in early planning process should improve future decision-making [5] and may save considerable time and effort in later planning stages [6]. Although large number of environmental impact assessment (EIA) procedures are available [7,8,9], it is still an outstanding that an appropriate EIA procedure should be adopted at the initial stage in its merit. This paper describes an environmental assessment model for assessing environmental impacts. The output of the model will then be able to incorporated in water planning process along with the economical considerations.

2. ENVIRONMENTAL IMPACT ASSESSMENT MODEL

2.1 Methodology

The purpose of Environmental Impact Assessment (EIA) model is to develop an environmental performance score for each component in the planning exercise and use it within an economic planning model by which the development plan is obtained. Depending on the environmental friendliness of a component, which is represented by the score mentioned, the cost of the component is altered: for environmentally-friendly schemes, the cost is increased and it is decreased for damaging ones. As such, overall planning model is pushed towards selecting environmentally-friendly schemes and away from the damaging ones. This can mathematically be represented by:

$$\begin{array}{ll} 0 < k < 1 & \text{if the scheme is environmentally friendly} \\ 1 < k < 2 & \text{if it is environmentally damaging} \end{array}$$

It is clear that the former expresses the environmental gain from the project whereas the latter does the environmental loss. A value of 1 shows the neutral situation.

To derive such a factor as described above, a multi-criteria decision making technique known as Composite Programming [10,11] is used. Composite Programming (CP) is a distance-based technique, whose output is a measure of composite distance resulting from the aggregation of a series of basic indicators by means of a dual weighting mechanism [12]. An example aggregation structure is presented in Table 1. The composite distance for any higher level indicator can be obtained from the values (S_{ij}) of n lower-level indicators with associated weights, α_i , and composite distances, L_i by means of:

$$L = \left[\sum_{i=1}^n \alpha_i S_{ij}^p \right]^{1/p} \quad (2)$$

where p indicates second category weight, which is, unlike individual weights, α_i , related to the groups. Clearly, the sum of individual weights in a group should be 1. These calculations are repeated for all indicators in the aggregation structure until one measure has been obtained for the option considered. All the options can then be compared by using this measure or the "best solution" obtained or the options ranked.

The environmental performance score (k) mentioned above can then be derived from CP by transforming L_i using the following expression which deliberately exaggerates the extreme values:

$$\begin{array}{ll} y = 1.41\sqrt{x} & \text{if } 0 < x < 0.5 \\ y = 2 - 1.41\sqrt{1-x} & \text{if } 0.5 < x < 1 \end{array} \quad (3)$$

2.2 Operational aspects

A DOS-oriented system has been developed by using FORTRAN 77, whose general structure is shown in Figure 1. The intention is the model to undertake EIAs for a series of pre-identified projects. However, it can easily be used for one-off assessment for a user-defined project. The model accommodates a series of project-type specific generic environmental data files, which include environmental impacts and associated weights entered in a way that the model recognizes the aggregation structure. Environmental impacts are classified in terms of: (1) Quantity implications, (2) Ecosystem implications, (3) Quality implications (4) Social implications. These are inserted in the data files as second-level indicators as shown in Table 1. To be consistent with the nature of the problem, rather general impacts are taken into account in identifying them. For example, the effect on, say, terrestrial ecosystem is discussed rather than dealing with each sub elements of this ecosystem. This will save considerable time in evaluating the impacts if considered the number of possible components involved in a planning study. Currently, the model includes eight type of projects: (1) reservoirs, (2) direct river abstractions, (3) groundwater abstractions, (4) effluent re-use schemes, (5) desalination projects, (6) estuary developments, (7) river/canal reaches and (8) pipelines/tunnels.

At the top level, when the model is in use, there is scheme selection step then the process continues up until a single impact is assessed as shown in Fig.2. When analyzing the impacts, the user is first invited evaluate the impact classes (second-level indicators) mentioned above. When evaluating an impact category or an impact at the further level, one of the following assessment values must be selected: (1) Negative significant, (2) Negative moderate, (3) Negative small, (4) Neutral, (5) Positive small, (6) Positive moderate and (7) Positive significant. Alternatively, he or she is given opportunity to go for the impacts associated with that class. If the user chooses to go for the latter, the program calculates the composite distances for the second-level indicators from the user-assigned basic indicator values. Once the second-level indicators are evaluated either by the user or from the basic indicators by the model, all subsequent higher-level indicators are calculated automatically to provide one single value for each scheme. This is can be done for construction, operation or both.

As can be seen from the previous paragraphs, the model relies on user's value judgements in assessing impacts, the user is provided with impact descriptions and guidelines to assess them as seen from Table 2. Moreover, the site characteristics are also provided so that the user can match the guidelines provided with the site specific information. These can be accessed repeatedly when the model runs. Clearly, site specific

Figure 1: General structure of the EIA model

Table 1: Aggregation structure of basic indicators for operational environmental impact assessment of desalination projects

Basic indicators	Weights	Balancing factors	Second-level indicators	Weights	Balancing factors	Final
Water resource gain	0.65	1	Quantity Implications	0.20	1	Overall
Utilisation of waste heat	0.35					
Hyper saline conditions in the discharge area	0.35	1	Quality Implications	0.20		
Metal pollution in the discharge area	0.20					
Ambient sea water temperature increase	0.25					
Air, land and water quality concerns due to required power production	0.20					
Effect of hyper saline and hot water on marine ecosystems	0.35	1	Ecosystem Implications	0.25		
Effect of metal pollution on marine ecosystem	0.20					
Effect on fish diversity and population	0.25					
Indirect ecosystem impact of required power production	0.20					
Effect on community due to operation	0.15	1	Social Implications	0.35		
Community impact of water supply and use of waste heat	0.35					
Employment opportunities due to operation	0.10					
Effect on fisheries	0.15					
Power dependency	0.25					

3. APPLICATION OF THE EIA MODEL

By way of example, the EIA procedure described in preceding section is demonstrated in the case of a groundwater abstraction scheme. The scheme is based on pumping up water to augment the river flows nearby. The water table in the aquifer is raising and abstracting water is essential to protect infrastructure on the surface. Therefore, there is an absolute environmental gain from this scheme apart from the cost considerations. The results are shown in Table 3. In the table, an expert who is familiar with the scheme provided the assessment values for the indicators. As can be seen from the Table, almost all the impacts were assessed positively and the final environmental performance value for the scheme was found to be 0.882, which in the optimization procedure would decrease the corresponding cost.

Table 2: A hypertext portion in relation to reservoir operation impacts.

Impact name: Resettlement
Impact description: Social problems and inequities, problems due to re-location, land degradation. Resettlement is dependent upon the good management, considering cultural and economic characteristics of the population, financial resources available including relocation cost and compensation for the transferred community and the existence of the suitable area for relocation.
Guidelines for assessment: The assessment of the impact is based on the number of people to be moved, the cost of relocation and the type of area used for relocation as follows: Negative small: Small number of people and reasonable relocation management (fair compensation and suitable area for settlement) Negative moderate: Small number of people but unreasonable relocation management or considerable number of people and reasonable relocation management Negative significant: Considerable number of people and unreasonable relocation management

Figure 2: Operation steps of the EIA model

3. CONCLUSIONS

A feasible approach for quantifying environmental impacts for water resources planning process was formulated. The approach has been put in an operational form so that the theory can be applicable to a real-world problem. The resulting model has a generic form that can be applied to any problem of water resources planning. However, the model should be customized in terms of the case study under consideration. It would then be easier for a user to run the model and put appropriate values for the impacts. The more the accurate and enough information is put in the model the more the results are satisfactory. It should be noted that the model presented forms an integral part of an overall model by which a environmentally adjusted planning strategy can be undertaken [13].

Table 3: Outputs from the EIA model in the case of a groundwater abstraction

CONSTRUCTIONAL ENVIRONMENTAL IMPACT ASSESSMENT OF A GROUNDWATER ABSTRACTION SCHEME			
INDICATORS	WEIGHTS BALANCING FACTORS		INDICATOR VALUE
Lack of visual intrusion	1.00	1.0	0.177
Effect on surface ecosystem due to construction	0.44	1.0	0.500
Pipeline laying impact on vegetation and wildlife	0.56		0.661
Impact of infrastructure construction; noise, mud	0.27	1.0	0.500
Landscape/land use impact of pipeline/structures	0.27		0.500
Implementation benefits	0.45		0.177
QUANTITY IMPLICATIONS	0.18	1.0	0.500
QUALITY IMPLICATIONS	0.29		0.177
ECOSYSTEM IMPLICATIONS	0.25		0.591
SOCIAL IMPLICATIONS	0.29		0.353
COMPOSITE DISTANCE: 0.389			
ENVIRONMENTAL PERFORMANCE VALUE: 0.882			

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