An environmental impact assessment model for water resources screening

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Abstract

The increasingly complex environmental legislation together with the growing environmental awareness of societies has led the consideration of environmental impacts at each level of public project analysis. Although large number of environmental impact assessment(EIA) procedures are available, it is still outstanding that an appropriate EIA procedure must be adopted at each project level in its merit. This paper describes an environmental assessment procedure for including environmental impacts along with the economical considerations in large scale water resources planning process.

The inclusion of environmental impacts in water resources planning is carried out by weighing the costs of various water resources development options(both constructional and operating) to reflect their environmental impacts prior to their inclusion in an optimization procedure. The effect of such a weighting procedure, is to encourage the selection of environmentally-friendly schemes at the expense of environmentally-damaging ones. The weights are obtained through previously mentioned EIA procedure, for which a FORTRAN code is developed. By using user's own evaluations of environmental impacts, the model produces environmental performance indicators for a series of water resources development projects for which a screening procedure is to be applied. Coupling the model with an optimization procedure, it is possible to use these performance indicators in water resources screening process.

Keywords

Water resources planning, environmental impacts, Composite Programming

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1 INTRODUCTION

Water-resources screening process is mainly concerned with identifying the most appropriate development strategy for meeting the projected demands at minimum cost, over the next 20 or 30 years. On a national scale, the planning process is characterized by the need to screen a large number of potential options (Jamieson, 1986), with a view to determining: (1) which resources should be developed, (2) the timing and order of that development, and (3) the areas of demand to which each new resource should be assigned.

Typically, this has required information relating to future demand, the performance of different size sources at various locations, the possible links between sources and demand centres, together with all the associated construction and operating costs. 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 (O'Neill, 1972; Major and Schwarz, 1992; etc.) to identify the minimum net present value of development program. Alternatively, heuristic search techniques can be used which although not as rigorous, provide a practical solution (Page, 1994; National Rivers Authority, 1994).

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 (Lutz and Munasinghe, 1994) and may save considerable time and effort in later planning stages (United Nations, 1988). Although large number of environmental impact assessment(EIA) procedures are available(Clark et al., 1984; Biswas and Geeping, 1987; Gilgin, 1995), it is still an outstanding issue that an appropriate EIA procedure should be adopted at the initial stage in its merit. This paper describes an environmental assessment procedure for including environmental impacts along with the economical considerations in large scale water planning process.

2 THE ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

The inclusion of environmental impacts in water resources planning is carried out by using an Environmental Impact Factor(EIF) in an economic planning model. The EIF is a weighting factor and whose role in planning model is to raise the cost of a water-resource option if its environmental impact assessment indicates that it is environmentally damaging and to decrease otherwise. Using such a factor in an economic planning model has the effect of influencing the solution towards selecting environmentally-friendly schemes at the expense of environmentally-damaging ones. In mathematical terms, an EIF is defined within the boundaries:

$$0 < EIF < 2$$

where 0 represents the best possible outcome whereas 2 does the worst. By subdividing into:

$$0 < EIF < 1$$

$1 < EIF < 2$

environmental gain can be expressed by the former and the environmental loss by the latter. A value of *1* indicates neutrality.

A multi-criteria decision making technique referred to as Composite Programming(Bogardy and Bardossy, 1983; Brdossy et al., 1985) is used to derive the EIFs. Composite Programming(CP) is a distance-based technique, through which the possible alternatives can be evaluated based on several criteria. The output from CP is a measure of composite distance resulting from the aggregation of a series of basic indicators by means of a dual weighting mechanism as shown in Figure 1 (UNESCO, 1987). An example aggregation structure is presented in Table 1. The composite distance for any higher level indicator can be obtained from *n* lower-level indicators with associated weights, *aj*, and composite distances, *Lj* by means of:

$$L = \left[\sum_{j=1}^{n} a_j L_j \right]^{1/p} \qquad (1)$$

where *p* indicates second category weight, which is, unlike individual weights, *a,* 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 is reached for the alternative considered.

For a given *L*, the final composite distance from a so-called ideal point for an alternative, *0* representing the best possibility and *1* representing the worst possibility, the main features of CP are: (1) $0 < L < 1$, and (2) the larger *L* the worse the associated scheme. Therefore, a "best solution" or an order of alternatives in terms of their composite distances can be obtained.

As shown in Figure 2, the EIF can be derived from CP by transforming *L*, the composite distance, by means of the following expression which deliberately exaggerates the extreme values:

$$EIF = 1.414\sqrt{L} \qquad \text{if } 0 < L < 0.5$$

$$(2)$$

$$EIF = 2 - 1.414\sqrt{1 - L} \qquad \text{if } 0.5 < L < 1$$

In this way, it is possible to convert a series of basic indicators covering both detrimental and beneficial impacts to a corresponding EIF within the range of *0* to *2.*

3 IDENTIFICATION AND EVALUATION OF IMPACTS

Environmental impacts of water resource planning components are discussed by dividing them into the following categories: (1) Natural resource-use considerations, (2) Ecosystem implications, (3) Water, land and air quality changes and (4) Social impacts. To be consistent with the indicative and/or probabilistic nature of other considerations (costs, yields, demands, etc.), rather general impacts are taken into account in identifying

Table 1 An example aggregation structure of basic indicators, adopted from Fashokun (1993)

Basic Indicators	α	p	Second-level Indicators	α	p	Third-level Composite Indicators	α	p
Economic Sustainability	0.2							
Net Change in Foreign Exchange	0.3	1	Economy	0.6				
Revenue Generation	0.3							
Contribution to Priority List	0.2					Socio-		
Increase in Jobs	0.3				2	Economy	0.5	
Farmer Income	0.1							
Non-Farmer income	0.3	1	Social	0.4				
Project Output	0.3							
Water Quantity	0.6		Resource	0.5				2
Land Quantity	0.4	2	Utilisation					
Water Quality	0.4				2	Ecology	0.5	
Land Quality	0.2	1	Environment	0.5				
Effect on Wildlife and Vegetation	0.4							

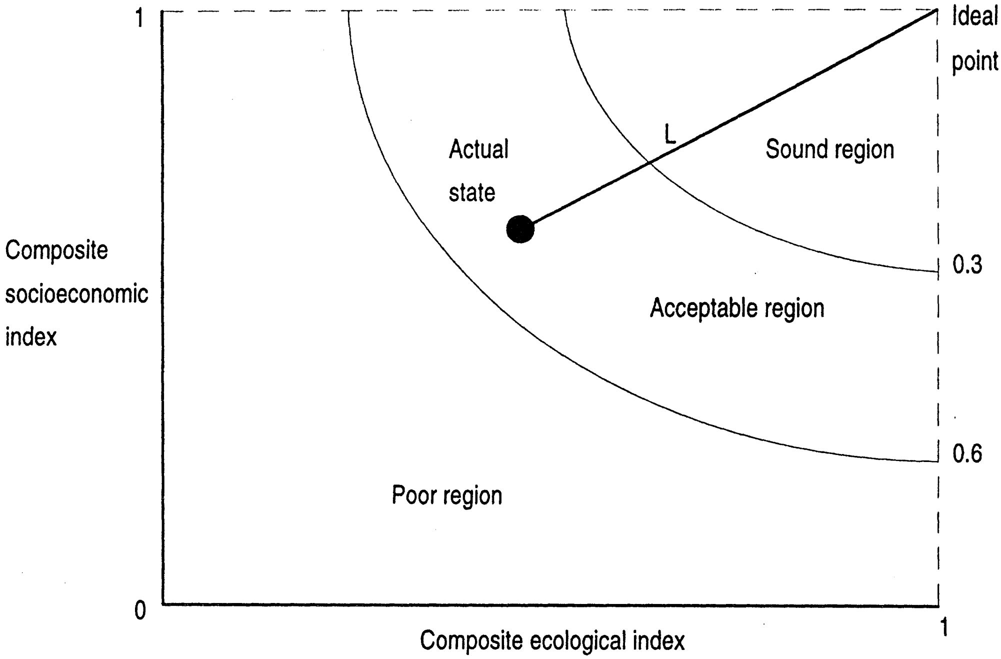

Figure 1 Evaluation of a project by Composite Programming, adopted from UNESCO (1987)

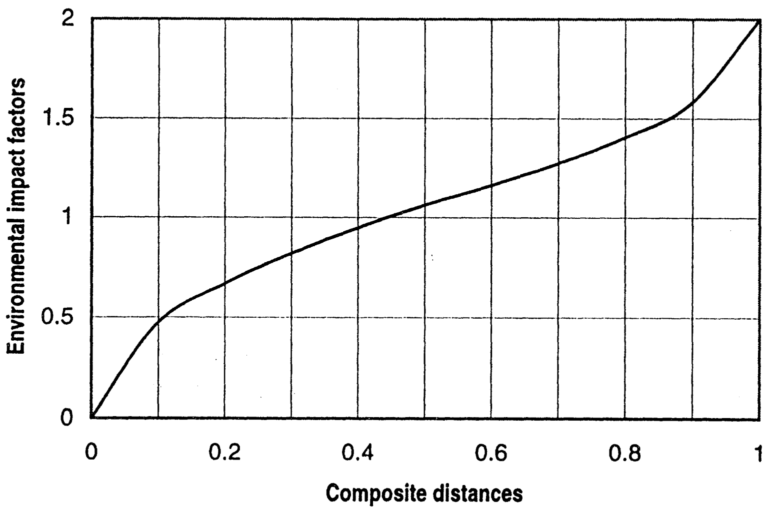

Figure 2 Development of EIFs from Composite Distances

the relevant impacts under each category. 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. Clearly, different types of resources/links will affect the environment in different ways and therefore each has its own specific set of considerations. Similarly, there are different considerations for each type of resource/link during the construction and operational phases.

Since the previously described EIA methodology, when in use, is prescribed to evaluate a water resource development in a range between ideal and worst cases, the evaluation of an impact has to be made accordingly. Therefore, when evaluating an impact, the following categories are used as assessment values: (1) Negative significant, (2) Negative moderate, (3) Negative small, (4) Neutral, (5) Positive small, (6) Positive moderate and (7) Positive significant

4 ENVIRONMENTAL IMPACT ASSESSMENT MODEL

The general structure of the model, which is currently a DOS-oriented system developed by using FORTRAN 77, is shown in Figurte 3. Although it can be used for undertaking one-off environmental impact assessment for a user defined project, basically the model is designed for carrying out Eras (first for construction then for operation) for a series of pre-identified water resources projects. 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.

When in use, the user is first invited to evaluate the impact classes (second-level indicators)mentioned above. 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.

5 CONCLUSIONS

Having formulated what appears to be a feasible approach for incorporating environmental considerations into the water-resources planning process, the intention is to integrate the methodology into an economic water resources planning model so that a what it might be called "environmentally sensitive economic water resources planning model" can be obtained(Yurdusev, 1996). Having done that, the overall methodology will be applicable to any regional or even national water resources planning study(Yurdusev, 1997). This will not only lead to an environmentally sensitive plan but also give opportunity to make direct comparison between a pure economic plan and the one with environmental considerations. Therefore, the cost of including such considerations into water resources planning is to be quantified.

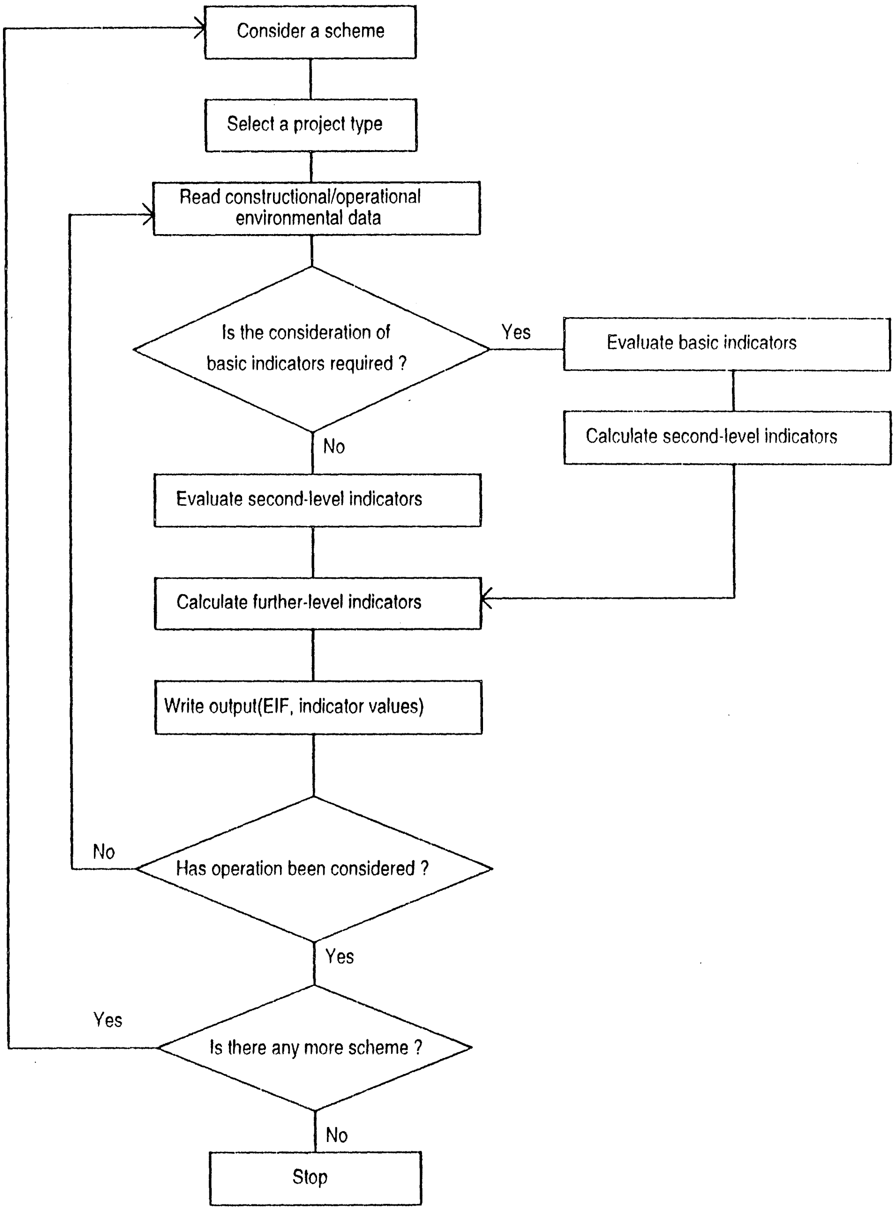

Figure 3 General structure of Environmental Impact Assessment model

REFERENCES

Bardossy, A.; Bogardi, I. and Duckstein, L. (1985) Composite Programming as an Extension of Compromise Programming. In *Mathematics of Multiobjective Optimization,* edited by P. Serafine), Springer-Verlag, New York, USA, pp.375-408.

Biswas, A. K., and Geping, Q.(eds.) (1987) *Environmental Impact Assessment for Developing Countries*, Natural Resources and the Environmental Series Volume 19, Tycooly International, London , UK.

Bogardi, I. and Bardossy, A.(1983) Application oc MCDM to Geological Exploration. In *Essays and Surveys on Multicriteria Decision Making,* edited by P. Hansen. Springer-Verkag, New York, USA.

Clark, B. D.; Gilad, A.; Bisset, R. and Tomlinson, P. (1984) *Perspectives on Environmental Impact Assessment.* Reidel, Dordrecht, Nederlands.

Fashokun, A., O. (1993) *Decision Support Systems and Application to Outline Water Master Planning.* University of Newcastle(UK), Civil Engineering Department, Msc Dissertation.

Gilgin, A. (1995) *Cutting Egde for the 21st Century.* Cambridge University Press, London, England.

Jamieson, D. G. (1986) An integrated multi-functional approach to water-resources management. *Journal of Hydrological Sciences* **31**(3).

Lutz, E. and Munasinghe, M. (1994) Integration of Environmental Concerns into Economic Analyses of Projects and Policies in an Operational Context. *Ecological Economics*, 10, 37-46.

Mayor, D. C. and Schwarz, H. E. (1992) *Large-scale Regional Water Resources Planning.* Kluwer Academic Publishers, Dordrecht, The Netherlands.

O'Neill, P. G. (1972) A mathematical programming model for planning a regional water-resource system. *Journal of the Institution of Water Engineers* **26**, 47-61.

Page, C.(1994) The Resplan Model and its Application to the NRA National Water Resources Strategy. British Hydrological Society National Meeting, Newcastle upon Tyne(UK).

United Nations Educational Social and Cultural Organization(UNESCO) (1987). *Methodological Guidelines for the Integrated Environmental Evaluation of Water Resources Development.* United Nations Environmental Programme(UNEP), Paris, France.

United Nations (1988) *Water Resources Planning to Meet Long-term Demand: Guidelines for Developing Countries.* United Nations Publications, New York, USA.

Yurdusev, M. A. (1996) Integration of Environmental Concerns into Large-scale Water Resources Planning Models. Forthcoming.

Yurdusev, M. A. (1997) An Environmentally-sensitive Plan for England and Wales. Forthcoming.

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