Integrating Environmental Impact Assessment and Economic Appraisal in Project Planning

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Abstract

This paper highlights some of the shortcomings of the methodology of Environmental Impact Assessment (EIA) and their practical consequences in developing countries. It argues that while the available methods are useful guides to decision making at the level of individual projects they are insufficient for the assessment of cumulative and large scale impacts.

It suggests that the promotion of sustainability should be clearly distinguished from environmental impact assessment of individual projects and it should also be conducted at a more aggregate planning level. For an environmental assessment process to be meaningful and to be able to serve the purpose of promoting sustainability, integration of environmental considerations in economic appraisal and development plans has been suggested.

To this end a project planning model that takes into account the cumulative impacts and the assimilative capacity of the environment has been proposed and a solution procedure developed. The suggested procedure helps keep the decision maker aware of the alternative decisions in terms of economic objectives and the environmental consequences thereby facilitating the process of arriving at a compromise optimal plan. The procedure helps in structuring and focusing the environmental analysis on key environmental benefits and costs of possible combination of projects, comparing alternative options in an integrated way along with other objectives and providing relevant information needed for environmentally sound decision making.

Introduction

Environmental Impact Assessment (EIA) is now widely practised in a large number of developed and developing countries to help decision makers consider the consequences of proposed projects. The effectiveness of environmental impact assessment is however hampered by a number of factors. One of the major deficiencies is that project EIA is insufficient for assessment of cumulative and large scale impacts. Another weakness is in the lack of adequate integration of EIA into a broader framework of decision making. Greater awareness of the limitations of environmental assessments of individual projects has given rise to interest in the use of environmental assessment at earlier stages of the planning process (Lee and Walsh, 1992; Wood, 1995).

Sustainability- or the version that is more palatable, sustainable development - has become accepted as a goal of many environmental policies, especially since the Bruntland Commission's report of 1987 (WCED, 1987) and the Rio declaration on environment and development. In the last decade the interdependence of the economy and the environment, the global scale of environmental problems and the necessity to address the environmental problems in an integrated manner at the strategic level has been fully recognised. It is now accepted that sustainability requires a more proactive approach encompassing a wide range of environmental factors and human activities. The increasing interest in measures to promote sustainable development has led to the growth of interest in integration of environmental considerations into project and development planning.

Unfortunately, though there is general acceptance of the principles of sustainability and carrying capacity, there are practical difficulties in operationalising the concept. Sustainability, carrying capacity, and their translation into objectives for environmental management have many theoretical and practical problems.[1] Despite the problems in operationalising the concept of sustainability, it provides a focus and objective for the environmental assessment and management. In an ideal situation environmental assessment of plans, policies and programs should be based on sustainability of environmental resource and the approach should cascade down to project planning. The concept of sustainability can be operationalised if it is based on carrying capacities, which in turn become the environmental thresholds that are not to be exceeded. Within these environmental constraints economic, social and other factors can be optimised (Therivel et al., 1992).

The methodology suggested in this paper adopts this approach. By extending and integrating environmental assessment to the stages of planning process a project selection model which takes into account the carrying capacity of the environment has been proposed and a solution procedure developed.

Sustainable Development - An Objective of Environmental Management

The objective of environmental management is to maintain the quantity and improve the quality of natural resources and therefore to ensure a sustainable development of society. There are many definitions of sustainable development . The most widespread definition of sustainable development is the one provided by the World Commission on Environment and Development (1987): “development is sustainable if it satisfies present needs without compromising the ability of future generations to meet their own needs”.

This is further elaborated as follows: “in essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential of human needs and aspirations" (WCED 1987). This concept of sustainable development is relatively easier to define from the point of view of an economist. It is the level of welfare that is to be sustained and promoted through economic, social, institutional and technological change. It implies the adoption of economic and social goals which are consistent with the environmental goals and are mutually attainable. Such an approach would involve integration of economic, social and environmental considerations when planning and selecting new projects and guiding future development (Lee and Walsh, 1992).

Other definitions of sustainable development focus on the physical or resource base of an economy. In these definitions sustainable development requires that the level of environmental capital should not decline through time and be at least kept at the same level (Perman, 1996; Hanley et al., 1997). This implies no reduction of aggregate natural resource stocks, maintenance of the ecological regenerative systems and compliance with constraints set by the carrying and regenerative capacity of the environment and the ecosystem.

The most effective means of promoting sustainable development are still being debated. Lee and Walsh (1992) have however identified the following types of measures:

"- Setting environmental quality goals and/or emission targets to achieve these goals

- Institution strengthening to promote the combined attainment of environmental quality and economic development goals

- Greater use of economic instruments to guide economies to more sustainable development pathways

- Strengthening of procedures and assessment methods for integration of environmental considerations, alongside economic and social considerations, in formulating and evaluating new policies, plans, programmes and projects at all levels of decision making ."

Applying the fourth of these measures, which involves integration of environmental considerations in the formulation and evaluation of plans, has been discussed in this paper and forms the basis of the model that has been suggested.

EIA refers to the evaluation of the effects likely to arise from a major project. Its process should supply information to the decision makers on the likely consequence of their action. Although the significance of environmental impact may be expressed in economic terms it is not a requirement of an EIA and, in the majority of the cases, this is not considered to be practical, because of problems regarding the quality of data available and the reliability of economic valuation methods available. When the environmental impacts are not expressed in economic terms it becomes difficult to integrate the EIA findings in the decision making process and much is left to the value judgement of the decision maker(Lee and Walsh, 1992; Moynihan, 1993; Pearse et al., 1994; Davies, 1995). In order to increase the usefulness of EIA there is an increasing emphasis on the relationship of EIA to its broader decision making and environmental management context and an increasing recognition that some form of strategic environmental assessment is required (Wood, 1988; DOE, 1991; Glasson et al., 1994; IAIA, 1996).

Despite important methodological advances in EIA tools in the last two decades the following challenges to EIA have been identified by UNEP(1992):

"1. EIAs are rarely fully integrated at the earliest stage into policy, programme development and project planning;

2. the need to integrate physical, socioeconomic and environmental assessment of programmes, policies and projects, and

3. the principal objective of EIA to focus on and to be used in promoting sustainable development, and not only as a tool for minimisation of environmental degradation."

For the EIA process to serve the objective of sustainability there is a need to improve the existing process of project EIA. The effectiveness of EIA is hampered by a number of factors. Project EIA cannot in itself lead to comprehensive protection of the environment for several reasons. The EIA process does not adequately consider the cumulative impacts of projects. It reacts to development proposals rather than anticipating them. It only allows the proposals to be accepted or rejected. The types of projects that tend to be subject to an imposed requirement for EIA are often limited. 'Small' projects are normally exempt from the requirements of EIA but the combined impact of these 'small' projects, if they are large in number in an area, may be significant and need to be taken into account for effective environmental planning (Therivel et. al., 1992).

The cumulative impacts are important and cannot be over looked from the point of view of sustainable development. The cumulative impact of projects may not just only be additive and may exceed the sum of impact of individual projects. The impact of development projects may be more visible if the combined effect exceeds environmental threshold/saturation level. A stream may be self purifying up to a certain level of pollutants discharge and living organisms may continue to survive but loses its self purification capacity if the pollutant level exceeds the threshold level; it is then that the stream may not support life form any longer. The EIA process being project oriented may also fail to address the induced/indirect impacts and time-crowded/space crowded impacts.

One of the recent trends in EIA is its application at earlier, more strategic stages of development, that is, at the level of policies, plans and programmes. This so called strategic environmental assessment (SEA) being carried out earlier in the decision making process ensures that alternatives are adequately considered, cumulative impacts assessed, and decisions of individual projects made in a proactive rather than reactive manner (Glasson et al., 1994; Lee and Walsh, 1992).

One of the areas of interest of EIA practitioners has been to make policy and planning level assessment more practical, focused and relevant to decision making. Other themes relate to the use and adaptation of EIA methods and procedures to cope with greater uncertainty encountered at strategic level and the linkage of SEA to other tools and processes including ecosystem level approaches that establish “capacity based” perspectives on sustainable development (IAIA, 1997).

Instead of EIA of projects, environmental assessment at a more strategic/aggregate planning level would better serve the purpose of sustainable development as it would allow these impacts to be better addressed with consideration of a wider range of actions over a greater span of time and over a wider area. It would overcome the worst limitations of the existing system of project EIA, but would also be a proactive step towards attaining sustainability. The World Bank’s policy is also to promote the use of regional and sectoral Environmental Assessment (EAs), moving the analysis of environmental issues upstream in the decision making process. Experience indicates that their use can eliminate environmentally negative proposals and alternatives and facilitates focusing project EAs on issues specific to its location. Such an approach would require institutions to consider the consequences of a range of actions early on in the planning process, to choose the most appropriate action on the environmental as well as the socio-economic grounds, and to minimise any remaining environmental impacts. Such methodologies are likely to include elements of cost benefit and monetary valuation and would ensure the consideration of alternative policy options, including the 'do nothing' option , at an earlier time when an agency has greater flexibility. It would enable consistency to be developed across various policies, especially when trade-offs are needed to be made between the different objectives. It would also ensure that the principles of sustainability are properly integrated into the development, appraisal and selection of policy options and projects. Implementation of such an approach however is constrained by the technical and procedural difficulties that exist and the model suggested in this paper aims to resolve some of the difficulties.

Sustainability and the Planning Process

The concept of sustainability or sustainable development[2] in the planning process and selection of projects can be made operational in the form of carrying capacities. The carrying capacity is a function of a number of variables and would depend on the region, sector or the resource[3] in question. In these definitions regenerative and assimilative capacities of the environment are treated as natural capital and failure to maintain these capacities is considered capital consumption and therefore unsustainable. This requires that utilisation rates of renewable resources should not exceed the sustainable regeneration rates and that waste emission rates should not exceed the assimilative capacities of ecosystems[4] (Cesar, 1995). The carrying capacities may also be in terms of what is being ‘carried’, e.g. human population, waste discharge in a stream, noxious gas emissions (Janssen, 1992; Therivel et al., 1992).

In order to attain sustainability, the planning and the project selection should be such that to ensure that the carrying capacities are not exceeded. To ensure this the planner should have information on the current state of resources and their future uses and the possible use of alternatives. Mitigation measures must be made available to be implemented if the uses exceed, or threaten to exceed, the carrying capacity. In turn for the planning and selection process information regarding the environmental impacts of individual projects would also be required.

In defining sustainable development and environmental quality, the defining of an appropriate spatial scale is necessary for the planning process to be meaningful. If sustainable development is defined on a regional scale, objectives and constraints need to be specified for each region and no substitution of pollution may be allowed between regions. In contrast, sustainable development defined at a national level may allow such substitution as long as the total level of natural capital at the national level is maintained.

International Association of Impact Assessment in their International study on the Effectiveness of Environmental Assessment (1996) have identified that the use of EA as a sustainability assurance (rather than impact minimisation) mechanism may require adjustments to EIA and SEA, such as:

“- focusing on environmental bottom lines to stay within the source and sink capacities of natural systems;

- avoiding the loss of irreplaceable and high value environmental stock by full cost analysis to determine the acceptability of impacts;

- requiring an in kind compensation for all other losses to ensure no net loss of natural capital .”

Despite a growing awareness of the seriousness of environmental problems the following characteristics of environmental problems, which are typical features of market failures, make these problems difficult to solve:

- environmental costs do not reflect their true social costs and benefits as markets for them are often distorted or absent;

- there are associated uncertainties and ignorance with respect to the reality and relevance of their effects;

- they can occur in complicated systems hence not always easily detectable and attributable;

- they are usually unequally distributed; and

- being public goods with no well defined property rights they often result in a conflict between individual and collective interests.

The requirements listed above clearly show that the pursuit of sustainable development is a complex multiobjective problem (Janssen, 1992; Keeny et al., 1993; Nardini, 1997). Achievement of the objectives of environmental management requires a combination of several decision rules. Environmental problems are complex due to the multiplicity of management objectives but also because of their temporal, spatial and institutional characteristics. The decision rules of environmental management reflect the different aspects of sustainable development and include objectives like economic efficiency, intergenerational equity and environmental quality.

Environmental management has similarities with other sectors of public planning, especially sectors managing a common resource. The absence of adequate prices, the multitude of claims to scarce resources and the complexity of environmental problems are similar to the problems encountered in developmental decision making and the tools of development can be suitably adopted to incorporate environmental effects into the decision making and the planning process. To identify the similarities it would be worth while to look into the manner in which the projects are to be selected and consider some of the shortcomings.

The manner in which development projects are identified, designed, appraised and selected is of fundamental importance to the development process. In recent decades a significant number of investment projects implemented in many developing countries by aid agencies, international donors and public sectors have “yielded little or nothing” (Little and Mirrlees, 1991) and at times have had an adverse impact on the environment. These failures are mainly related to the inadequacy, and in some cases the absence, of a systematic process of integrating projects into development programmes and plans and the disproportionate emphasis on the financial and economic viability of projects at the expense of other important planning aspects.

There are various views towards the integration of projects and plans. In the top-down approach projects are regarded as instruments for the implementation of policies. They are the ‘building blocks’ of a plan, a means of reducing uncertainties (Little and Mirrlees, 1974 and 1991) and are selected in order to achieve certain broad macro objectives. In the bottom-up approach projects are designed and selected to address specific problems and issues at the micro level, hence the plan is based on the outcome of the selected projects.

Both approaches have their advantages and problems. A circular process starting with a perspective medium-term plan with broad macroeconomic targets (e.g. for consumption, production and investment) and the determination of the available resources may prove to be a more effective approach. Projects are then designed with these broad objectives in mind (Little and Mirrlees, 1974).

Projects are generally regarded as the instruments of micro-planning and will require to be checked for overall consistency and feasibility at macro-level. Individually feasible projects may prove to be collectively unfeasible and inconsistent. The optimal set of feasible projects, in turn, may impose adjustments in the initial macro objectives. As the macro-plan changes, micro-level adjustments for achieving feasibility and consistency become necessary.[5]

In brief "the integration of projects and plan can take place through an iterative macro-planning and micro-planning process in which the feasibility and optimality of individual projects are observed at the micro-level, while overall consistency and optimality are checked at the macro-level stage of selecting projects" (Noorbakhsh, 1994).

The case of EIA and environmental management is somewhat analogous. What may appear feasible and environmentally sustainable at the project (micro) level may not remain feasible and consistent at the macro level as the cumulative impacts of all the selected projects may exceed the "carrying capacity" of the environment. With respect to the question of optimality while EIA can ensure optimality at the project level, it is not designed to address this issue at the macro level.

For an environmentally optimal plan it is necessary that the projects under consideration be optimally designed with respect to their environmental effects. However, this in itself becomes a sufficient macro optimality condition only if the environmental effects of all projects are equal.[6] This not being the case, achieving overall optimality requires that the decision to select or reject a project not only be based on a project level EIA but also be conducted at a more aggregate macro planning level.

Integration of EIA in Decision Making

Project appraisal methodology has found great appeal in developing countries in investment decision making. Appraisal of economic costs and benefits in terms of shadow prices using a specific unit of account (numeraire) is assumed to provide the scale to judge the utility of projects for the country's development (Little and Mirrlees, 1974; UNIDO, 1972; Bridger, 1983; Curry, 1994). Attempts have been made to integrate environmental impacts in the project appraisal methodology by valuing the environmental effects in terms of economic costs and benefits (Winpenny, 1991; Hanley, 1993; Dixon, 1994). However while integrating EIA with Cost Benefit Analysis (CBA) problems of both relevance and consistency occur.

Where projects are appraised according to some economic efficiency criteria and all the components of social cost and social benefit are measurable in economic/monetary terms, the EIA provides the physical measures of expected environmental costs and benefits which are converted into economic measures for inclusion in a standard cost-benefit analysis for use in appraisal and decision making. In this situation EIA and CBA are mutually relevant and consistent. Also when projects are appraised according to commercial criteria and all externalises are internalised through a system of charges/taxes (for negative impacts) and grants/subsidies (for positive impacts) the integration of EIA and CBA should not raise problems of relevance and consistency (Lee and Kirkpatrick, 1996).

In practice however because of methodological problems, such as valuation of environmental impacts, variation in appraisal and decision making context and multiplicity of objectives, problems of relevance and consistency usually arise.

Lee and Kirkpatrick (1997) have concluded that given the wide variety of legal and institutional context within which decision making takes place there is no ‘best’ way of integrating environmental assessment with economic or other forms of appraisal. However, they have taken two polar cases of ‘strong’ and ‘weak’ integration to illustrate the advantages and disadvantages of the two approaches where the former is more demanding in its data requirements while the latter has serious shortcomings.

In the real life situation a decision maker is confronted with a situation with diverse, often conflicting, non certain, non commensurable social and economic objectives. In such a situation the integration of EIA with CBA may not offer any tangible advantages to the decision makers. Appraisal of costs and benefits in terms of a single accounting unit may not help achieve overall consistency. The usual suggestion in the literature is that projects should be appraised with respect to present social value (PSV), and then selected accordingly until the available development budget is exhausted (Little and Mirrlees, 1974). In following this suggestion, consistency is only achieved with reference to the budget constraint and other scarce resources are not taken into account; for instance projects often fail because of non availability of skilled labour. The assumption of the Litlle and Mirrless approach that all the objectives are convertible into a single *numeraire* is not entirely satisfactory and the problem becomes more acute when environmental considerations are also to be taken into account. Planning for sustainable development which takes into account environmental impacts is better addressed if it is looked at as a multiobjective problem and the methodology of shadow prices and CBA is suitably modified

The process of the integration of projects and plan is a complicated process consisting of different phases involving the planners and the decision makers, and requiring specifically tailored planning tools of analysis (Noorbakhsh, 1989). By suitably modifying the model and incorporating the carrying capacities of the environment as additional constraints the environmental considerations can be integrated into the planning process.

The usual suggestion in the literature of project appraisal is that projects should be appraised and ranked according to their PSV and then selected from the top of the list until the available development budget is exhausted. This may be presented in the form of an integer programming (0- 1) model as follows.

$$\text{Maximise} \quad X_0 = \sum_{p=1}^{P} b_p X_p$$

$$\text{subject to} \quad \sum_{p=1}^{P} a_p X_p \leq B$$

$$\text{for } p = 1,2, \ldots, P \qquad X_p = \begin{cases} 1, \ if \ \ project\ p\ is\ accepted. \\ 0, \ if \ \ project\ p\ is\ rejected. \end{cases}$$

P = number of projects under consideration,

b_p = PSV of project p,

a_p = investment requirement of project p ,

B = available development budget.

The solution to this model would select an optimum set of projects with respect to their sum of PSV (calculated by using, for example, either the Little and Mirrlees or UNIDO method) within the budget constraint. The most important shortcomings of this model are that it technically accommodates only a single objective (though composite) and assumes that the budget constraint is the only resource constraint (Noorbakhsh, 1989). In situations where the environmental impacts are measurable in economic terms or where externalities are internalised by a system of taxes and grants the environmental costs and benefits can possibly be included in the PSV. But given the characteristics of environmental problems its valuation or internalisation may not be feasible in most real life situations and if, in addition to environmental costs and benefits, the sustainability and the environmental carrying capacities are to be integrated into the planning process a multiobjective approach may be more satisfactory.

With respect to the multiplicity of objectives one may envisage two kinds of 'objectives'. Those of a general nature which are to be optimised with no limits on them, such as one representing the level of welfare (for example, aggregate consumption), and those which are more specific and are required to be only achieved within known limits.

While the former can be in terms of the selected *numeraire* in CBA, the environmental carrying capacities and the sustainable assimilation and depletion rates may be included as additional constraints/targets in the project selection model along with other targets. In fact the second type of *objectives* are requirements by nature and may be separated from the overall objective function and presented in the form of targets in an optimisation model. This is one possible way of allowing different objectives to be considered separately in the model.

Sustainability of renewable resources can be included in the project selection and the planning process by ensuring that the rate of utilisation of these resources is less than its regeneration, while upper limits which are less than the assimilative capacity of the environment may be imposed in case of the pollutants and the waste generated .

With respect to the feasibility of projects, three reasons may be envisaged for the individually feasible projects becoming collectively infeasible within this framework: insufficient resources, unrealistically high levels of targets with respect to scarce resources and the insufficiency of projects for achieving the target levels.

With these points in mind and following we can now suggest the following optimisation model for the selection of projects at the aggregate level of planning.[7]

Maximise $X_0 = \sum_{p=1}^{P} b_p X_p$

subject to $\sum_{p=1}^{P} a_{pk} X_p - \sum_{p=1}^{P} d_{pk} X_p \leq R_k$, for k=1,2, ... , K

$\sum_{p=1}^{P} m_{pj} X_p \geq T_j$, for j= 1,2, ..., J

for p =1,2, …, P $X_p = \begin{cases} 1, \text{ if project } p \text{ is accepted.} \\ 0, \text{ if project } p \text{ is rejected.} \end{cases}$

K = number of scarce resources including the environmental resources,

R_k = availability of scarce resource k including the carrying capacity of the environment,

a_{pk} = resource requirement of project p of the k^{th} resource,

d_{pk} = contribution of project p to scarce resource k,

m_{pj} = contribution of project p to the j^{th} target,

T_j = level of the j^{th} target,

J = number of targets.

Other variables and coefficients are defined as before.

In this model other objectives appear in the form of targets (requirements) to be satisfied. The levels of targets should be determined beforehand and should be in harmony with the macro economic objectives and the accepted environmental parameters. More specifically target related to environmental considerations may be directly included in the model. The waste assimilative capacity (sink/carrying capacity) may also be treated as a scarce resource with suitable upper limits fixed for the region for different wastes /pollutants generated.[8]

The above formulation ensures that a certain level of financial returns, as well as certain levels of environmental and other targets are achieved while maximising the economic returns. Furthermore, the first set of K constraints will ensure that the aggregate resource requirements and emission levels of/from the projects are within the sustainable limits.

At this stage it seems appropriate to make a general point. Theoretically, the process of planning may be seen as a programming exercise in the optimal allocation of scarce resources. This consists of optimising an objective function which represents the welfare implications of putting scarce resources to various uses, subject to a set of constraints related to the sustainable uses and sustainable availability of such resources.

As previously mentioned, carrying capacity is linked to definitions of time, area and resources; different carrying capacities are interlined; and outside factors such as technological innovation affect carrying capacity. The model tends to consider regions as self contained and closed. However, in reality regions are not closed, and the carrying capacity of one region is affected by that of another. Region based environmental planning has problems as well: links between regions have to be forged and flows between regions makes it difficult to predict carrying capacities adequately. Nevertheless, the suggested model can be modified to take into consideration regional links provided that the required information can be made available.

Within the above framework the analyst is able to bring to the attention of decision makers not only the collective effects of projects on environmental resources but also possible sources of inconsistency between various targets in addition to other useful information. The model allows for enough projects to be picked up in order to alleviate pressure on specific environmental resources which are critical for the selection of projects with high returns to the overall objective which in turn have a high usage of those resources. For example a project which is highly desirable with respect to its economic returns may have serious costs in terms of its use of environmental resources. If these effects are beyond the availability of such resources then the model allows for the possibility of remedial projects to be selected in order to make improvements on relevant resources. This feature would lend itself to the existing approach of EIA which would expect projects to address remedial plans for their environmental effects in the form of Environmental Impact Report (EIR) and Environmental Management Plan (EMP) to be included in the project report.[9] It would be also possible to include as targets those environmental goods which have already surpassed their sink/carrying capacity. The model would then ensure the selection of enough number of projects to restore the lost carrying capacity.

Solution Procedure

The solution to the above model, if existing, would select an optimal set of projects which would satisfy all constraints and targets. The state of no solution, which is a more likely outcome, would be of analytical use to decision makers in the sense that it is either reflecting the inconsistencies between the targets and resources or revealing that the set level of targets are not achievable with the given projects.

Such results may provide a lead for subsequent actions including adjustments in the targets, designing of new projects in order to address inconsistencies in the model or redesigning of projects which put pressure on (contribute to) specific, environmental resource (targets).

In addition the analyses of the 'partial' optimal solutions to the model may provide information which could be helpful in deciding on the trade-offs between the targets. This would require a specific manipulation of the solution procedure as explained below.

We first solve the model for all K resource constraints and the first target requirement only. No solution outcome would indicate that the included target is set too high for the available resources and/or projects. This may require subsequent appropriate adjustments either in the target level or resources and /or the inclusion of new projects which would affect the relevant target which causes infeasibility.

In the case of having an optimal solution the values of the objective function ($\overline{X}_0^1$) and the selected target (T_{11}) are registered. Then with the selected projects in mind the achievable levels for the excluded targets (T_{1j}, for j=2,3,…J) for this solution are computed.

The next step is to drop the first target from the model and include the next target and repeat the above procedure. Once this procedure is repeated for all targets we will have a set of solutions with different characteristics (Table 1)

Table 1. Optimal solutions for the suggested sub-models

Solution i=	Objective Value	Pay-off matrix j= 1	2	…	J	State of resource constraints s_1	s_2	...	s_K
1	$\overline{X}_0^1$	T_{11}	T_{12}	…	T_{1J}	s_{11}	s_{12}	…	s_{1K}
2	$\overline{X}_0^2$	T_{21}	T_{22}	…	T_{2J}	s_{21}	s_{22}	…	s_{2K}
.	.	.	.	…	.	.	.	…	.
.	.	.	.	…	.	.	.	…	.
.	.	.	.	…	.	.	.	…	.
J	$\overline{X}_0^J$	T_{J1}	T_{J2}	…	T_{JJ}	s_{J1}	s_{J2}	…	s_{JK}

For J solutions we have a pay-off matrix for various targets with the maximum achievable level on its diagonal. The non-diagonal elements of this matrix give the achievable levels for all other targets for solution i when target j is at its maximum achievable level. The values of the objective function and the 'slack variables' will provide useful information for making a decision on the trade-off between the targets which will be discussed with reference to the example provided below.

An Illustrative Example

The data requirements of the above model are those usually required for the appraisal of projects. The following example illustrates the data requirements and the solution procedure for the proposed model.

We consider six hypothetical development projects (A to F) with different present economic values, resource requirements and contributions to targets. We have two constraints: a budget and one pollution constraint. There are five targets: employment, foreign exchange earning, financial returns, food production and restoration of carrying capacity of an environmental resource (for example improving the quality of air which is already highly polluted). Each project requires resources and contributes to the set targets (Table 2).

Table 2. Project data and resource availabilities

Constraints / targets	**Resource requirements / target contributions**						**Resource availability / target level**
Project	**A**	**B**	**C**	**D**	**E**	**F**	
Constraints:							
budget	6	5	4	4	3	4	15
pollution	5	6	4	4	1	2	18
Targets:							
employment	7	5	4	3	3	4	16
foreign exchange	1	9	2	6	2	0	21
financial returns	3	6	7	2	6	3	19
food production	5	8	2	1	7	2	20
environmental restoration	7	3	2	1	3	7	17
Present Social Value	21	19	14	13	12	10	

For the data in Table 2 there exists no solution as the set targets overall, in the light of available resources, are not achievable and in the case of some (foreign exchange target) there are not enough projects available for achieving the required level.

Following the solution procedure explained above we keep the resource constraints and the employment requirement and solve the sub-model. The *optimal* solution indicates that we should select projects A, B and C with $\overline{X}_0^1 = 54$ and $T_{11} = 16$. We then compute the contribution of the selected projects to the remaining targets: $T_{12} = 12$, $T_{13} = 16$, $T_{14} = 15$ and $T_{15} = 12$.

Next we drop the employment target and include the foreign exchange earning target and solve the model. There exist no solution as this target has been set too high with respect to the available resources. Given the existing resource constraints and the proposed projects the optimal feasible solution for this sub-problem results in an adjusted target level of 17 for foreign exchange earnings with projects B, C and D being selected. We then repeat the above procedure for other targets. All solutions are presented in Table 3.

Table 3. Optimal solutions for the hypothetical example

Solution	Objective	Pay-off matrix j=					unused resources		Projects
i=	Value	1	2	3	4	5	s_1	s_2	selected
1	54	16	12	16	15	12	0	3	A,B,C
2	46	12	17	15	11	6	2	4	B.C.D
3	45	12	13	19	17	8	3	7	B,C,E
4	52	15	12	15	20	13	1	6	A,B,E
5	50	16	10	12	15	17	0	5	A,B,F

While the suggested solution procedure highlights the sources of inconsistency in the set targets and allows for adjustment, the final set of optimal solutions in Table 3 provides the decision makers with valuable information regarding the relative *costs* and *benefits* of achieving the set individual targets in terms of the value of the overall objective function and losses in the other targets. Indeed one of the above solutions may be preferred.

If this is not the case then the analyst may try to find a trade-off between the targets (and also between the targets and the objective function) using various criteria. One procedure could be the use of a set of weights, provided by the decision maker, for finding a weighted sum of the achievable targets for each solution with the aim of finding the *best* solution. Another approach is to compute a *loss-matrix* from the pay-off matrix in Table 3 on the basis of the deviation of the achievable targets in different solutions from their maximum achievable levels. The analyst can then apply the *minimax loss* criterion by finding the maximum loss associated with each solution and selecting the solution corresponding to the minimum of maximum losses. This approach will result in solutions 1 and 4 being equally the *best* solutions.

Alternatively the loss-matrix can be normalised or standardised to a common scale unit and even weighted if desired.[10] The main purpose is to take all losses into consideration in finding the best solution. Depending on the selected criteria various standardisation procedures may be employed for elements of the loss-matrix or pay-off matrix. Amongst them we may refer to computing standard scores, division of each element of the pay-off matrix by the column sum, division of the column elements of the pay-off matrix by the diagonal element (maximum achievable target), or a standardisation procedure which would reflect the relative position of the targets in different solutions in relation to the difference between the highest and lowest values for the targets, i.e. $(T_{ij} - \min_i T_{ij}) / (T_{jj} - \min_i T_{ij})$ where T_{ij} is the value of target j in solution i and T_{jj} is the maximum value for the jth target (the diagonal elements of the pay-off matrix).[11]

We applied the last standardisation procedure to the pay-off matrix for different solutions. The results are presented in Table 4. According to the aggregate targets achieved solution 4 is the best solution followed by solution 1.

Table 4. Standardised targets

Solution i=	Pay-off matrix j= 1	2	3	4	5	Summation
1	1	0.286	0.571	0.444	0.545	2.847
2	0	1	0.429	0	0	1.429
3	0	0.429	1	0.667	0.182	2.277
4	0.750	0.286	0.429	1	0.636	3.101
5	1	0	0	0.444	1	2.444

In recommending the best solution we may be interested to take into consideration losses in the value of the objective function in different solutions. Table 5 reveals percentage losses in the objective function from its highest value next to percentage losses in the recommended aggregate measure of targets. This exercise would provide the decision makers with more information regarding the trade-off between the aggregate targets and the objective function. For example solution 1 results in no loss in the highest value of the objective function coupled with 8% loss in the highest standardised aggregate measure of the targets, while solution 4 results in a 2% loss in the value of the former and no loss in the latter.

Table 5. Aggregate targets and objective function losses

(1) Solution i=	(2) Objective value	(3) % Loss in (2)	(4) Aggregate targets	(5) % Loss in (4)
1	54	0	2.847	8
2	46	8	1.429	54
3	45	9	2.277	27
4	52	2	3.101	0
5	50	4	2.444	21

Conclusion

In order to promote sustainability there appear to be profound advantages in extending EIA from projects to plans as limiting EIA to project level may fail to consider aspects of consistency and optimality. The future development of EIA lies in the integration of EIA in the planning process at the project and macro levels. The planning system in most countries bears strong similarities to the EIA process and the two procedures could be integrated for better decision making in order to promote sustainable development. This would require developing appropriate tools of analysis which could be flexible enough to address complicated issues of dealing with different objectives. The suggested model is a step in this direction. Ignoring the fact that there are other objectives at macro level which may be in conflict with environmental objectives usually results in the latter being ignored or toned down. The inclusion of various objectives in the suggested model allows the decision maker to become aware of the consequences of various decisions in terms of their effects on different objectives. The suggested analytical solution procedure provides useful insight into the extent of inconsistency in the set targets and deviation from their optimum achievable levels which may be helpful in deciding on their trade-off.

Looking further ahead, the long term objective has to be sustainability of development. Decisions taken over the next generation may well determine whether the society becomes a sustainable one, or whether it overshoots resource and environmental thresholds.

Notes

1. In the literature a number of approaches for operationalising the concept of sustainability has been suggested. For details on the possible approaches see Hanley et al., 1997.

2. The terms sustainability and sustainable development are treated as synonyms in the paper.

3. For an operational definition of sustainability the resources are generally subdivided into renewable, exhaustible and environmental resources. See Barbier and Markandya, 1990 for a detailed discussion.

4. In the case of exhaustible resources the concept of sustainability can be integrated into the planning process by optimising the efficiency with which such resources are used which in turn is determined, interalia by the rate at which the renewable resource can be substituted by other kinds of resources.

5. Such an approach can be quite effective if planners have sufficient time to go back and forth. In practical planning situations sufficient time may not be available and one may be left with a one sided one directional analysis.

6. Even then their collective environmental effects may results in infeasibility. This condition is only a sufficient condition when the individual environmental effects of projects are nil.

7. The suggested model and its solution procedure is a modified version of the model presented in Noorbakhsh, 1989.

8. In the paper for the sake of simplicity the assimilation function of the environmental stock is assumed to be linear.

9. For an example of such requirements in India see Benham and Brew, 1996.

10. For an approach which derives a set of weights on the basis of the spread of the deviation of targets from their optimum values see Noorbakhsh, 1989.

11. It would also be possible to formulate this problem as a goal programming model in order to minimise the overall deviation from targets.

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