CHAPTER - II

REVIEW OF LITERATURE AND RUN UP TO THE PRESENT THESIS

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2.1 INTRODUCTION

All activities cause an impact on environment. Bigger the activity stronger, the impact. In ecosystems not influenced by human perturbations, such activities even out and the impacts get assimilated or get fitted into the natural scheme of things. But human-induced developmental activities, especially big projects, have the potentiality to cause impacts which may disturb ecological balance beyond the ecosystem’s assimilative capacity. Till a few decades ago we had not realised that the furious pace of development may cause such environmental impacts which may harm the natural resource base and cause losses - not only ecological but consequent monetary losses as well - in the long run. Towards the end of the sixth decade this realisation began to dawn upon mankind and the science of environmental impact assessment (EIA) began to take shape.

2.2 CONCEPT OF ENVIRONMENTAL IMPACT ASSESSMENT - AN OVERVIEW

The major purpose of all environmental policies is to ensure that environmental quality is fully considered when taking the decisions on whether to take a developmental project or not. The vehicle used to accomplish this is environmental impact assessment whose specific objective is to provide a means for giving environmental quality a careful and appropriate consideration in the planning and decision-making process. EIA can be used for three principal functions:

   i) as a decision-making instrument, to decide whether an envisaged project
is acceptable from the point of view of its costs;

ii) as decision-making instrument to choose between different ways of doing a project or locations in which it can be done; and

iii) as a planning tool, to minimize adverse impacts that may be caused by the project.

By definition an environmental impact is any alteration of environmental conditions, adverse or beneficial, caused or induced by an action or set of actions. The attention given to environmental conditions as referred to here, will vary according to the nature, scale, and location of the proposed action (or actions). It is important that the impacts of a proposed action (project) on the quality of the of the physical environment be objectively weighed with the impacts on the social, aesthetic, and economic environments, over both the short and the long run.

Overall, the environmental impact assessment process provides a formalized procedure for generating, collecting, analysing and documenting information on all aspects of present status and possible impacts of a given project. In other words 'impact assessment' is an objective analysis conducted to identify and measure the likely economic, social, aesthetic, and environmental effects of the proposed action (activity or project) and the various reasonable alternatives. This requires the identification, measurement, and aggregation of the impacts to provide a total assessment.

The identification of impacts requires one to first describe and understand the conditions of the environment prior to the activity. There may be significant differences in impacts for a given activity in different areas. Geographical location is, therefore, one of the factors that affects the relative importance of an impact. For example, the impact of a specific project on water quality in an area with abundant water supplies would differ significantly from the impact of the same project on an area with scarce water resources. Furthermore, the timing and duration of each significant impact is to be determined. Impacts are to be described to establish their effect on the immediate project area, within the adjacent area and the community (or region) as a whole. The timing of impacts should be identified to establish whether they are likely to occur during construction, shortly after the project is completed, or at some later time. The nature of impacts should be identified to establish whether they are reversible or irreversible, and duration to establish whether they are short-term or long-term.

The measurement of impacts is the next logical step in the impact assessment process.
deally, all impacts should be translatable into common units. However, this is not possible because of the difficulty of defining several impacts (such as on income, on noise quality, and on are or endangered species) in common units. Another difficulty is that in some cases the quantification of impacts may be beyond the state-of-the-art. Therefore, one is generally faced with use of both quantitative and qualitative measurement techniques. In the latter case, it may be necessary to rely on expert judgment to answer the question of how the various dimensions of the environment are affected.

The final step involves the aggregation of project impacts into an overall assessment of the project’s effects. One problem at this point is how to aggregate among the different measured impacts (quantitative and qualitative) to arrive at a single measure, or score, for project impact. This would involve expressing the various impact measures in common units or establishing a weighting-of-importance scheme to generate this single measure. This desire is perhaps more ideal than realistic or practical. However, even though subjective and rather less-than-comprehensive in nature, schemes do exist for accomplishing this objective. In many cases, however, it may suffice to present the measurement of the impacts in simple terms relative to each impact area such as air quality, community economy, energy, environmental quality, fish and wildlife resources, historical preservation, land use, noise quality, solid waste, transportation, and water quality.

2.3 COMMONLY USED METHODOLOGIES

2.3.1 Ad-hoc methods

Ad-hoc methods provide qualitative assessment of the total impact while suggesting the broad areas of possible impacts and the general nature of these possible impacts. For example, impacts on plant and animal life might be stated as minimal but adverse, whereas the impacts on the regional economy might be stated as significant and extremely beneficial. These statements are qualitative and could be based on subjective or intuitive assessments, or could be qualitative interpretations of quantitative results. The simplest approach to evaluating the total impact of a project by this method would be to consider each environmental area and identify the nature of the impact upon it, such as no effect, problematic, short-term or long-term and reversible or irreversible.

This method, as the name suggests, is ad-hoc with little quantitatification or precision.
Nevertheless the method is useful when discussing impacts of very large systems such as Himalayas echology on flooding in plains downstream (CSE, 1990), acid rain on global environment (Cresser & Edwards, 1987), degradation of Indian lands (Gadgil, 1993), or aquatic weeds on water resources (Abbasi & Nipaney, 1993). It can also become effective pre-EIA excercise in some situations (Abbasi, etal. 1995).

**Checklists**

The use of *impact checklists* provides a method of combining a list of potential impact areas that need to be considered in the environmental impact assessment process with an assessment - often qualitative - of the individual impacts. This approach has been followed by a number of public agencies since it ensures that a prescribed list of areas is considered in the assessment process. A recent example of an elaborate checklist is the one developed for assessment environmental impact of water resources projects (Abbasi. 1991; Abbasi & Bhatia, 1993).

Checklists may be provided to facilitate rapid assessment of environmental impacts, qualitatively. Environmental protection authorities may provide such checklists for specific type of projects to ensure all important items are given due consideration. For example, there may be a specific checklist for water resources development projects, another for petrochemical industries, another for oil terminals and so on. In India, Central Governments Department of Environment, Forests & Wildlife has prepared extensive-checklists for a variety of developmental activities which it uses in impact assessment as well as post-project environmental monitoring.

Checklists do not provide for the establishment of direct cause-effect links to the various project activities and, generally, does not include an overall interpretation of the collective environmental impacts.

Items included in a checklist are often of a broad nature and the likely impacts are stated qualitatively as beneficial or adverse, reversible or irreversible, short-term or long-term local or widespread.

The main advantage of a checklist is that it promotes thinking about the array of impacts in a systematic way and allows concise summarization of effects. Disadvantages stem from the fact that checklists may be too general or incomplete; they do not illustrate interactions between effects; the same effect may be registered in several places under headings that overlap in content (double counting); and the number of categories to be reviewed can be immense, thus dis-
tracting attention from the more significant impacts. The identification of effects being qualitative and subjective (for example, *water quality will be adversely affected*), as such these predictions cannot be tested with accuracy and precision. Furthermore, no statements of likelihood of occurrence are being made. Because of the subjective nature of estimates, checklists are often not filled out identically by different investigators. It gives the descriptive evaluation of the impacts (Mongkol, 1982), but it is not always adequate for carrying out a comprehensive environmental assessment (Heer and Hagerty, 1977).

**Expert opinion**

If the number of experts is large and properly chosen, the above errors can be minimised. However the opinion polls or surveys tend to drown minority opinions, however much perceptive they may be. Further, the respondents get no opportunity to reconsider their views.

Opinion polls or surveys are widely used in social forecasting, and impact analysis (Agrawal, 1995; Kalshian, 1995). There it is a matter of finding out people’s ideas, perceptions and attitudes about societal change, and surveys become a useful tool.

**Panels**

In this method, a group of experts interacts across a table. Panels are suitable when the subject under consideration requires discussion and analysis. The process is very valuable for identification of important problems, for initial assessments, and for policy analysis and evaluation. Multidisciplinary problems are taken care of by a suitable choice of the panelists. For example the possible impacts of a ecology curriculum was assessed through panel approach (Abbasi et al., 1995)

Panels, however, suffer from the following major disadvantages:

i) views not in line with majority opinion may get eliminated, due to the pressure to obtain a consensus;

ii) the opinions of the most vociferous speakers, or the person with highest bureaucratic status will be given disproportionate representation;

iii) in the same way, the views of persons less vocal or junior in status may not be heard; and
iv) many people are afraid of abandoning views expressed by them earlier, even after realising their flaws, due to fear of losing face.

**Brainstorming**

This is a modified panel approach, and one which is very suitable for exploring out-of-the-way ideas. The meetings are held in an uninhibited environment, with imagination being given free rein.

When properly conducted, brainstorming sessions may yield a wealth of new ideas, which can later be assessed for feasibility and constraints. Although the great majority of ideas will be promptly culled out, worthwhile ideas might emerge. The technique has the great advantage of stimulating imagination and creativity.

### 2.3.2 Map overlay method

Overlay technique is sometimes also referred as McHarg's method. This methodology relies on a set of maps of environmental characteristics (physical, social, ecological, aesthetic) for a project area. These maps are overlaid to produce a composite characterization of the regional environment. Impacts are identified by noting the impacted environmental characteristics lying within the project boundaries.

This is a highly aggregative approach and is best suited to short list the alternatives where decision is mainly based on physical characteristics (Sondheim, 1978)

An example of effective use of McHarg's method is determination of areas to be avoided while locating during the course of a highway project in Malaysia (Nuruddin et al., 1987).

The approach seems most useful as a method for screening alternative sites or routes, preliminary to detailed impact analysis. Limitations of the approach include its inability to quantify as well as identify possible impacts and its failure in implicit weighting of all characteristics mapped. Use of the technique is possible only if suitable maps or data base adequate to draw maps exists in a country. This would be the primary difficulty in adopting this methodology in developing countries.
2.3.3 Matrices

While checklist are ‘one dimensional’ lists of potential impacts which tell whether an impact will occur or not, matrices are ‘two dimensional’ lists which also give an indication of the magnitude of the likely impacts. Matrices are thus checklists of a higher dimension and contain more information than the latter.

Broadly, matrices may be categorised in three different groups. Examples of the first category where magnitude of the relationship and importance are considered - are Leopold Matrix (Leopold et al, 1971), Fisher and Davies (Fisher, 1973) and Shopley and Fuggbe (Shopley, 1984). Extended Component Interaction Matrix comes under the second category. This matrix was developed to enable consideration of second and higher order impacts. In impact analysis, first order dependencies between the components are identified. The second and higher order impacts are then determined using matrix multiplication technique (Bisset, 1980).

A three dimensional matrix representing cause-effect matrix, cause-impact matrix, and effect-impact matrix was developed by Mongkol (1902); it comes under the third category of matrices. Here, the activities of the project are taken as causes, changes in resource relations and structures are taken as effects, and changes in quality of life, health, and productivity, etc., are considered as impacts.

Two dimensional matrices have been extensively used, and are continue to be so (AIL, 1990; NEERI, 1992 a-d; 1993; Sundaresan et al., 1989). In comparison matrices help in making qualitative judgment on the relationships among various parameters. They help to perceive and understand the complex interactions among the parameters. These are useful as preliminary assessment methods and are used as part of a comprehensive assessment. The matrix methods also find applications in cross-impact analysis, input-output analysis, and interpretive structural modelling. However, matrices cannot be used for identification of impacts. They operate only after the impacts are identified. And, when matrices are multiplied to get second and higher order impacts, the process becomes cumbersome.

A number of variations to the basic matrix approach described above have been used. Depending on how detailed the list of actions or effects is, what criteria are used to score impacts (magnitude, importance, duration, probability of occurrence, feasibility of mitigation), and what type of scale is used for scoring, quite different final impressions regarding severity of impact can be conveyed.
2.3.4 Delphi method

Delphi is a method based on intuition/expert opinion, especially designed to avoid the drawbacks associated with the other methods of opinion gathering.

Delphi has three special characteristics: (i) anonymity among participants, (ii) scope for statistical treatment of responses, and (iii) iterative feedback. A structured, formal and detailed questionnaire is given, by mail or in person. The different participants do not meet. The responses of the participants are analysed, combined, averaged, and represented in quartiles and medians. Question for the second round are then made, with modifications if necessary (as perceived by the programme director or the participants). the averaged responses to the first questionnaire are provided to the participants. Apart from the original questionnaire, the participants may be asked to respond to scaled objective items, and sometimes to open-ended responses. After scrutinizing the answers to the second round, respondents in the upper and lower quartiles may be asked to justify their responses. Further iterations are continued if necessary, to the point where diminishing returns set in. A convergence of opinion often emerges but the organizor of Delphi avoids forcing convergence or conditioning responses.

Delphi can be used to forecast technological or social events and policy shapes. It has following advantages over panels and surveys:

i) it can be used when the problem may not be amenable to analytical techniques, but solutions could be found from a subjective group judgment;

ii) it can be applied when issues are controversial and there are serious disagreements amongst experts;

iii) it can be applied when issues are of such a nature that individuals are unwilling to take a public stance; and

iv) it enables participation of greater number of individuals than can effectively interact in face-to-face meetings; or time and cost constraints make frequent meeting infeasible.

Although widely used (Abbasi 1995a; Abbasi & Vineethan, 1995). Delphi has been criticized on a number of grounds:
i) there is pressure towards convergence and this may suppress other valid perspectives;

ii) the role of the Delphi coordinator is crucial and subjective biases may be introduced through this route;

iii) lack of item clarity or common interpretation of scales and feedback may lead to invalid results; and

iv) it is time consuming and if the questionnaires are long, one may tend to fill them in a casual manner.

Delphi can be used in the early stages of EIA to identify the impacts and importance ratings of a new project for which readymade information are not available. The information obtained through Delphi method can, of course, be used as input to other methods.

2.4 LESS COMMONLY USED METHODS

2.4.1 Content analysis

Content analysis is an extensive search of the related literature in order to enlist activities and their impacts. It can be useful if the project to be assessed and its setting are similar to the ones studied in the past. However such situations are rare.

2.4.2 Survey methods

Survey methods are used to collect opinion of a large number of respondents. These methods suffer from such shortcomings as researcher bias and respondent bias. But they are very useful when no recorded material is available about a system or about the perceptions of population in the system. There are several techniques listed under the category. Finsterbusch et al. (1983) list the following major survey methods:

i) face-to-face interview,

ii) telephone interview,

iii) self-administered questionnaire
iv) leave-and-pickup questionnaire, and
v) mail questionnaire.

This list is not exhaustive. Several new techniques, such as newspaper ballots and feedback mail, are evolving (Coats, 1976b).

Survey methods are useful to identify the issues and the impacts, and can involve a large number of people in the process. However, they are not useful during the other stages of EIA.

2.4.3 Strategic impact and assumptions identification method (SIAM)

SIAM was developed by Mason, Milroff and Eirshoff for socio-economic assessment (Abonyi, 1980, 1982). It helps to identify the impact, stakeholders in terms of inputs and outputs and the underlying assumption of the relationship between inputs/outputs and the stakeholders.

Then the assumptions are weighted based on which the issues and impacts are identified. These identified stakeholders are then involved in the EIA process.

SIAM is applied by Abonyi for Highway infrastructure assessment study (1980), and Lead-Zinc smelter project assessment study (1982). SIAM exercise deals mainly with the primary impacts. It is possible, and is often necessary, to deduce the secondary and tertiary impacts and the related assumptions.

2.4.4 Priority-trade off-scanning (PTS) approach

The priority-tradeoff-scanning approach was developed by Davos (1977) for the evaluation of options in environmental management. The method includes the development of the following three matrices

i) the goal-achievement matrix (GAM),

ii) the goal-priority-tradeoff matrix (GPTM), and

iii) the interest-priority-tradeoff matrix (IPTM).

The goal-achievement matrix consists of the goals, their relative weights, costs, and benefits representing columns, and groups representing rows. These are determined for several
groups of people. In the goal-priority-tradeoff matrix the priority of goals is determined and the alternative options are ranked for each goal by every group. The interest-priority-tradeoff matrix consists of groups both rowwise and columnwise. An element $p_{ij}$ of the matrix is the option that the $i$th group is willing to accept when accounting for the interests of the $j$th group.

This method is essentially meant to deal with the various groups of people in collecting their perceptions or perspectives. It is particularly useful when the perspectives are highly divergent. Unlike in Delphi, no statistical analysis is used in this method; rather every group is presented with perceptions or ranking of the other groups and interest tradeoffs are developed to narrow down the divergence.

2.4.5 Sondheim method

A rating and weighting method was proposed by Sondheim in 1978, which includes a procedure to prepare rating and weighting matrices. These matrices are developed by two separate panels. Rating matrix ranks the alternatives and weighting matrix gives importance. A third matrix, decision matrix, is compiled by multiplying rating and weighting schemes.

It differs from matrix methods in the process of developing the matrix. However, it does not consider inter-relationships among the variables.

2.5 EMERGING METHODOLOGIES

2.5.1 Cross-impact analysis

This consists of a family of methods which study the effect of occurrence or non-occurrence of a set of events on the occurrence (or nonoccurrence) of the same events. In cross-impact analysis individual components are not only evaluated independently but also in relation to each others (Coats, 1976).

This is a means of utilising a matrix representation to analyse interactions between probable future events, or between elements of particular technological events. Elements or events to be analysed for interactions are arrayed in the first row and column of a matrix. Interaction between the elements is represented by means of a number which may reflect the importance of the interaction, probability of occurrence or other parameters of importance.
This procedure, if applied to all the events, takes a long time to estimate all conditional probabilities and is also very cumbersome to do. When fully and quantitatively implemented, cross-impact analysis requires considerable time and computer resources.

Examples of this category are ISM and MICMAC, which are based on the analysis of inter-parameter relationship and classifies behaviour of variables.

2.5.2 Networks or impact tree analysis

Environmental sub-systems are interconnected and any impact on one of this subsystems effects several other subsystem. Thus a 'primary' impact leads to secondary, tertiary and higher order impacts.

Network methods recognize this interactive nature of environmental components and take an ecological approach for identifying the secondary and tertiary impacts.

Network methods start with a list of project activities or actions and then generate cause-condition-effect networks (i.e., chains or events), thus taking into cognisance the fact that a series of impacts may be triggered by a project action. Hence this method provides a road map type of approach to the identification of second-and third-order effects. The idea is to start with a project activity and identify the types of impacts which would initially occur. The next step is to select each impact and identify the impacts which may be induced as a result. This process is repeated until all possible impacts have been identified. Sketching this in network form results in what is commonly referred to as an impact tree. Figure 4 illustrates an 'impact tree' for a stream-bank stabilization project. One advantage of this type of approach is that it allows the user to identify impacts by selecting and tracing out the events as they might be expected to occur. A major problem in constructing cause-condition-effect networks is achieving the degree of detail necessary for informed decision making. On the other hand, if the environmental condition changes are described in detail and all possible inter-relationships are included, the resulting impact networks could be too extensive and complex to be really useful.

A method developed by Bardossy (1983) belongs to this category and has been applied to the Multi criteria decision making (MCDM) of water resources.
2.5.3 Modelling

A model may be defined as 'a mathematical, physical, electrical or any other form of representation which is intended to parallel or mimic in terms of structure, properties, or function some real world system'. As is most often used, a model consists of a set of structurally interrelated variables which are fitted into a set of mathematical equations and which are processed with the help of a computer. The variables chosen are those which quantify the various aspects of technological growth. The cause-effect relationships are expressed by means of the equation, and the input and system parameters change with the time dimension. To begin with a model is constructed on the basis of logical relationships and assumptions, and is tested against historical performance of the system. If disagreement occurs, sensitivity analyses are performed and model revised till actual past performance and model performance coincide. The model can then be run forward in time to obtain forecasts.

Modelling techniques give us an extremely powerful means of environmental impact analysis. The following drawbacks of modelling have been pointed out.

i) The construction of a formal model, complete with software and data base is very time-consuming and expensive.

ii) The nuances of a complex issue may not be adequately represented in a model.

iii) There may be a tendency to quantify factors which are intrinsically difficult to quantify.

iv) There is a danger that the model may be used as a substitute for critical thought and its output accepted without analysing the factors that led to it.

KSIM, GSIM and system dynamics are the examples of this category.

An evaluation of the methodologies on the basis of functional classification, nature of parameter estimation, subjectivity and computerization is presented in Table 2.1.

2.6 NEED OF COMPUTERIZATION

Thus, EIA is one of the major tools in environmental planning and management. The aim is to minimize the environmental degradation associated with unplanned human activities in the context of the existing political and socio-economic frameworks. However, when conducting envi-
### Table 2.1 Summary of EIA methodologies

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<th>Methodologies</th>
<th>Functional Classifications</th>
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An environmental impact assessment of a multi-faceted project, one may come across a bewilderingly large number of possible quantifiable impacts. This makes identifying and assessing the environmental impacts an enormously complex task. To quote:

"...as a science, EIA is as multidisciplinary, interdisciplinary and transdisciplinary as environment itself because all aspects and dimensions of environment - physical, biological, social, temporal, economic,... to name a few, have to be studied and weighted in EIA..."  (Pg. 1)

(Abbasi, 1993a)

Identification and assessment procedures of various impacts therefore require collection and manipulation of large amounts of data, and more importantly, communicating the final results to decision-makers and members of the public in a manner intelligible to them as many of them are unlikely to be experts in environmental sciences. To overcome these difficulties, considerable attention has been devoted to develop computer-aided structured approaches to assessment; commonly called EIA methodologies or methods. Computer based approaches can effectively handle the immense data of an EIA study, and can do the analysing and assessing in a much shorter time than otherwise.

A Computer based approach can also provide a powerful interactive tool for managers and planners, regulators and policy makers, because it makes access to a large number of relevant database, problem simulation methods and decision support tools. The thesis proposes some frameworks for computer-aided EIA and demonstrate their applicability as effective and swift tools.

2.7 ANALYSIS FRAMEWORK

The existing methodologies have some advantages; they also suffer from major shortcomings. Attempts to overcome these shortcomings has led to search of newer techniques and development of newer methods. The review reveals that:

i) thus far most of the 'emerging' methodologies have not been able to stand the test of extensive field trials; in other words these methodologies are largely confined to paper;

ii) the reasons for this, essentially, are that most of the newer methodologies either
require information on the precise nature of inter-parameter relationships (which simply are not available in most cases), or they are computationally or experimentally too cumbersome (and/or unwieldy or costly) to be of much practical utility,

iii) no single system of methodologies is available which enables all the three stages of EIA to be accomplished viz a) identification of parameters to be studied b) assessment of their trends and c) impact summation, and

iv) ‘as a whole’ assessment of an environmental system and analysis of developmental policies are not carried out in such a way that planners and policy makers - who are unlikely to be the subject experts - could understand the results

We have made attempts to develop methodologies to overcome some of the abovementioned shortcomings. A system of three methodologies has been developed which may enable all the three stages of EIA to be accomplished. It includes

1) a formulation and software package INTRA for the identification of key parameters out of a large number one invariably encounters during any EIA. It also helps us in arranging the influencing parameters in the order of their importance to generate a hierarchical structure. We hope that such a methodology would help us in understanding the nature, directions and importance of the influence of various parameters enabling us to determine which ones play a dominant role and which ones are merely peripheral.

ii) a designer software package incorporating the tests and tools needed to process basic data pertaining to typical EIA, and

iii) a methodology and software package to integrate the individual environmental impacts for generating net impact scores. This system also enables generation of scenarios and deciding which of the scenarios are environmentally viable.

Three computer software packages INTRA (INTer-parameter Relationship Analysis), SMART-ALEC (Statistical Measurement for Assessing Regional Trends - And Longterm Environmental Consequences) and CREAM (Computer-aided Rapid Impact Evaluation And Management) have also been developed for each step of the proposed EIA system.