CHAPTER II

REVIEW OF LITERATURE
CHAPTER II
REVIEW OF LITERATURE

1. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The guidelines prepared by the National Environmental Board (NEB) of Thailand for Environmental Impact Assessment (EIA) suggests four levels of environmental impact assessment viz., (1) physical resources (ii) biological or ecological resources (iii) human use values and (iv) quality of life values. (NEB.1979). On the other hand, Andrew, divides the environmental impact assessment method into seven categories (Andrew R.N.L. 1973) viz; (1) ad hoc methods (2) checklists (3) matrices (4) overlays (5) networks (6) Quantitative or index methods and (7) models.

Brief descriptions of these categories with examples are given below.

1.1 Ad Hoc methods

This is the most common approach to impact assessment. Basically ad hoc methods indicate broad areas of likely impact by listing composite environmental parameters (for example, flora and fauna) likely to be affected by development activities.

1.2 Checklists

Checklists are an expansion on ad hoc methods in that they list environmental, social and economic components in more detail. Also, some checklists identify typical impacts resulting from certain types of development. Checklists serve as a guide for identification and consideration of a wide range of impacts.
The Multiagency Task Force, (1972) has mentioned that it has also provided a checklist for evaluating environmental impacts. It suggests that the impacts be expressed quantitatively whenever possible. Further for each impact the uniqueness of the affected component and the irreversibility of the expected changes should be considered where appropriate. It is the predicted future state of the environment, and not the present condition, which should be compared with the project proceeds. But it may be seen that the scope of the checklist is rather limited in terms of the features to be investigated. For example, when cultural resources such as archeological sites are included, social and economic factors are neglected. However, the explicit consideration of uniqueness and irreversibility distinguishes this method from many others. This forces those who prepare the impact statement to consider the post development situation.

Adkin and Burke have provided a checklist for evaluating the environmental impacts (Adkin W.G. and Burke D.1974). The components in the checklist are broken down into four categories viz., (i) transport (ii) environmental (iii) social and (iv) economic. Impacts on these components are evaluated on a -5 to +5 rating system. This method is an early attempt to systematize assessment of route alternatives but it suffers from a number of limitations. The coverage of ecological effects is deficient. Also, the rating of impacts and alternative routes require subjective judgement, and there are no guidelines to aid formulation of these judgements.

1.3 Matrices

In matrices used for evaluating environmental impact usually one dimension of the matrix provides a list of environmental, social and economic factors likely to be affected by a proposal. The other dimension provides a list of actions associated with
development. These actions relate to both the construction and operational phases. There are many variations to the matrix approach. The best known interaction matrix method was developed by Leopard and has been used more often than any other method in the preparation of EIS in the United States.

Leopold's method, (Leopold, et al. 1971), as mentioned above, is one of the best known and most widely used methods for EIS. It has been adapted in a number of ways for use in particular impact analyses. The method advocated is really an interaction matrix in which the existing characteristics of the environment (for example, endangered species) are listed vertically and proposed project action (for example blasting and drilling) are listed horizontally. 8800 interactions are identified in the matrix. However, preliminary trials indicate that specific projects will result in only 25-50 interactions. For each interaction a score of 1 (least magnitude or importance) to 10 (greatest magnitude or importance) should be given. It suggests that the cells indicating an impact are slashed and the scores for magnitude are placed at the bottom right hand section. A+ (plus) sign in the appropriate cell can denote beneficial impacts. It emphasizes that no two cells in any one matrix are equal and that, if separate matrices were prepared for alternative projects, only the cells indicating the same impact would be comparable. A completed matrix provides a visual representation of an impact statement, as the impact statement should contain a discussion of the impacts identified. The most important criticism of this method involves its focus on direct impacts. Second-and higher order impacts cannot be identified easily. Also the matrix does not allow for change in impacts over time.

use alternative is considered a useful approach as it can show the interactions between elements'. It also provides a system for identifying data requirements and the required scientific expertise. A three dimensional matrix is constructed on the basis of the following dimensions, viz; analysis of the relationships among various land uses, the institutions which influence or control these uses, and the ecological and environmental systems with which the uses interact. The effects of a second home development are used to illustrate its use, and it can be used to identify whether impacts are of first, second, or higher order.

Toftner R.O. (1973) believes that the impact statement might be a useful starting point for better environmental planning. However, impact statements often consider only primary impacts. A matrix, which allows secondary and tertiary impacts, is necessary to have a complete picture. He considers transport developments to cause the most far-reaching effects, for example, on land use patterns, land consumption, population densities expansion of commerce and industry. Through investigations of such secondary and tertiary impacts, the quality of information available to decision-makers will be improved. The matrix discussed serves only as a checklist of primary, secondary and tertiary factors to be considered in an impact statement. Since it is not an interaction matrix the impact cannot be identified. Also, the category intake checklist is broad, leaving the detailed break up of these categories for impact identification to those carrying out impact assessments.

1.4 Overlays

The use of overlay maps has been restricted to route or site selection. Few examples of their use in environmental impact analysis have been reported. A first, series of maps, each containing data on environmental, social and economic variables, are
prepared. By overlaying the maps, areas possessing a preferred combination of these variables can be identified.

Mcharc, also studied the comprehensive highway route selection method. (Mcharc 1. 1968) His paper contains a description of one of the first methods to be advocated for impact analysis. The method is based on an overlay of map transparencies, each map dealing with specific environmental and land-use characteristics. Each of these characteristics is shaded differently to represent three degrees of “compatibility with the highway.” By using overlayed maps, one of which is the proposed route, a comprehensive picture showing the spatial distribution and intensity of impacts can be obtained. This composite picture can also be used to select alternative routes by examining areas showing the greatest compatibility with the highway. This method has served as the basis for a more sophisticated method developed by Krauskopf and Bundle. While resource requirements of the manual overlay method are less demanding than those of computerized versions, this method provides less information.

1.5 Networks

Networks are based on known linkages within systems. Thus, actions associated with a project can be related to both direct and indirect impacts. For example, impacts on one environmental factor may affect another environmental or socio-economic factor and such interactions are identified and listed on a network diagram. This diagram is subsequently used as a guide to impact identification and the presentation of results. While there are few examples of the use of networks in impact assessment, the Sorensen network represents an early attempt to provide a method for tracing impacts using a network format. For example, Gilliland M.W. and Risser P.G. (1977), used system diagrams for
environmental impact assessment. The usefulness systems analysis and of energy flows between environmental components as measures of environmental impacts are illustrated using results obtained from impact statement for the white Sands Missile Range, New Mexico. The procedure includes five steps: (i) Construction of a systems diagram representing the important interaction between environmental components and between man and these component (ii) evaluation of the pathways and storage (iii) analysis of the data (iv) identification of impacts requiring more detailed attention and (v) examination of impacts outside the boundaries of the system. Construction of a systems diagram and estimation of the impact of human activities on pre-development estimation of energy flow between specified environmental components permits a quantitative comparison of the impacts of alternatives. Hence, actions to mitigate environmental impacts can be easily made. But it should be noted that a systems approach does not deal with economic, social, and aesthetic impacts, nor does it guarantee that the boundaries for analysis have been chosen correctly. Use of this approach requires collection and interpretation of a large amount of data on energy flows between environmental components. In some locations this data may be difficult to obtain. Consequently, this method is only useful if implemented by a large organization having considerable expertise at its command.

Sorensen J. (1971) has attempted to provide a framework for identification and control of resource degradation and conflict in the case of multiple use of the coastal zones. This structured method allows for identification and control of resource degradation and conflicts in coastal zones. The framework is based on adverse, environmental impacts that occurred in the coastal zone of California as a result of a variety of coastal land use. It is also based upon stepped matrices, occasionally referred to as a network, listing a number of land uses (for example residential development and crop farming). Factors associated
with these land uses (for example, fencing) are related to initial condition changes. These, in turn, are linked to consequent condition changes and final effects. Further information may be slotted into the framework (after the column dealing with the effect). For example, physical actions taken to ameliorate impacts can be listed. Similarly, codes of practice or regulations, which may be required to control the effects of a particular land use, can be inserted into the framework. The framework acts as a checklist to possible adverse environmental impacts. Thus, it can be used to identify and control conflicts between different land uses. The compatibility of a particular land use with an existing land use can be identified by investigating its likely adverse impacts using the stepped matrix framework. This approach to impact identification is one of the best known attempts to make the identification of indirect impacts explicit.

1.6 Quantitative Index Methods

These methods are based on a list of factors thought to be relevant to a particular proposal and are differentially weighted for importance. Likely impacts are identified and assessed. Impact results are transformed into a common measurement unit (for example, a score on a scale of environmental quality). The score and the factor weighting are multiplied and the resulting score is added to provide an aggregate impact score. By this means, beneficial and harmful impacts can be summed up, and the total score can be compared. Additionally all impact scores for two alternative sites can be aggregated and compared. The alternative resulting in the "best" score will be the preferred option.

Dee N., et al (1973), have developed a method for assessing the impacts of water quality management projects. It is based on a checklist of environmental parameters.
divided into 19 components and a matrix to identify the likely impacts. Impact measurement incorporates two elements. First, a set of ranges is specified for each parameter to express impact magnitude on a scale of 0 to 1. The use of an "environmental assessment tree" is advocated to combine the parameter scores into a summary score for each of the 19 components. Second, a set of weights is used to determine the significance of the impacts on each component. A total score for each alternative can be obtained by multiplying each component score by its weight and summing all the components. The method, especially the assessment trees, has been developed for water resource projects. New environmental checklists and assessment tree would have to be constructed for other types of projects.

Stover L.V. (1972), developed a method for EIA. The most distinctive feature of this method is the approach for aggregating impacts. Environmental impacts are assessed for 50 environmental functions. These functions are grouped into the following categories: ecological and geophysical features, land use, chemical entities, biological communities, and human well being. Separate estimates are made for short-term and long-term impacts of each of the 50 environmental functions. Impacts are classified subjectively into five classes; 1 extremely beneficial, 2 very beneficial, 3 no effect, 4 detrimental, and 5 very detrimental. Very detrimental formations are given a numerical score of -5 on the scale while an extremely beneficial impact is given a score of +5. The score is multiplied by the number of years over which the short-term impact is likely to occur. Long-term impacts are scored on a scale +10 to -10, where +10 stands for extremely beneficial and -10 for extremely detrimental. The aggregate score for environmental impact can be compared with alternative developments or with the situation in which there is no development.
1.7 Models

Recently, considerable attention has been focused on the use of systems modeling in impact analysis. However, the development of models for assessing particular projects is at an early stage. There are few examples of models utilized for the assessment of the wide variety of impacts resulting from major projects. Usually, only a particular impact of great significance or a number of key impacts are modeled (for example, the effects of a nuclear power station on a salmon population). It may require more time before a modeling approach can cope with the wide diversity of impacts. Modeling is being used in the development and assessment of alternative strategies for resource management (but again the models only deal with a few key issues). In the future the use of models in large-scale resource management problems may become common. However, considerable work on assessing the impacts of resource management strategies by models has been carried out at the Institute of Resource Ecology, University of British Columbia by Yorque and Holling.
2. EVALUATION ENVIRONMENTAL VALUE

There are four major categories of direct valuation techniques. These are (i) the use of market prices to evaluate benefits and costs arising from changes in environmental quality (ii) the hedonic pricing approach which decomposes market prices into components of environmental and other characteristics (iii) the contingent valuation approach which is a non-market techniques using survey to ascertain peoples willingness to pay for environmental aesthetics and (iv) the travel cost approach which is a market based technique that uses travel costs as a surrogate for the price of non-priced recreational and other amenities. Each of these approaches has its advantages and disadvantages, both from a theoretical standpoint and from the standpoint of empirical applicability (Jonathan A. Lesser, et. al. 1996).

2.1 The Use of Market Prices

The first and easiest valuation technique is to estimate environmental costs and benefits from market prices. We cannot measure the value of a lost view simply by walking in to the local shopping mall and inquiring about the price of views. By contrast, it may be possible to place a value on the damage caused to crops by pollution because one can easily determine the market price of crop goods.

A standard result in microeconomics is that if a good is sold in a competitive market and there are no externalities or underemployed resources, the market price will be equal to both the marginal buyer’s willingness to pay and the opportunity cost of supplying that good. For example, suppose that pollution reduces wheat yields by only 1 bushel when the same supply of land, labour, equipment, fertilizer, water and other inputs is used. The
total production of wheat is measured in millions of tons. Thus, the loss of 1 bushel of wheat can be considered a very small change in supply. The value of the lost production is equal to the market price of that one-bushel of wheat.

2.2 The Hedonic Pricing Approach

The hedonic pricing approach (HPA) is based on a straightforward premise that the value of an asset, whether a piece of land, a car, or a house, depends on the stream of benefits that are derived from that asset. These include the benefits of environmental amenities. One of the most common applications of the HPA has been comparing the values of real estate with different environmental amenities to estimate the value of those amenities. Houses have different views or are located in areas with better schools or lower crime rates. Houses may also differ in their exposure to pollution. By using regression techniques, an HPA model can, in theory, identify what portion of the property value differences can be attributed solely to environmental differences. From this, we can infer individuals willingness to pay (WTP) for environmental amenities and, therefore, the overall social value of a given amenity. The HPA can also be used to estimate WTP to avoid disamenities.

In the case of environmental externalities, the HPA is often applied to environmental attributes associated with specific commodities. An HPA model may not be applicable to certain environmental externalities if those externalities cannot be decomposed or differentiated within existing market prices. One example is housing prices and atmospheric carbon dioxide levels. Because carbon dioxide emissions are a global issue, one should expect housing price to differ depending on local emissions of carbon dioxide.
2.3 The Contingent Valuation Method

The premise of the contingent valuation methodology (CVM) is straightforward, if one wishes to know the value of something (for example view, clean air, safety, etc.) just ask the people. CVM asks people what they are willing to pay for an environmental benefit or to what extent they are willing to tolerate an environmental cost. Inquiries may be done through the use of direct questionnaires or surveys or through the use of experiments that determine how individuals respond. The biggest potential advantage of CVM is that it is applicable to all situations. Whereas a hedonic study might be unable to distinguish between the effects of different pollutants, a CVM could ask individuals about specific pollutants and the desired environmental change directly. CVM also ask people about choices that they may not actually make in real life, such as making direct payments for cleaner air.

2.4 Travel Cost Methods

The fourth technique used to estimate the value of environmental amenities is the travel cost method (TCM). This method is often used to estimate the value of public recreation sites, which usually have a zero or nominal admission price. The travel cost method is based on three observations. First, the cost of using a recreation site is more than that of the admission price. It includes the monetary and time costs of travelling to the site and may include other costs. Second, people who live at various distances from a recreation site face different costs for using the site. Third, if the value that people place on a site does not vary systematically with distance, travel cost can be used as a proxy for price in order to derive a demand curve for the recreation site.
One can develop the theory behind travel cost models by examining the relationship between distances from a recreation site and number of visits by a single individual. Suppose one wants to know the value that individuals place on trips to a pristine beach that lies within the national park of the cost of Maine. An individual taking a day trip to this beach will incur several costs. The monetary costs of the trip will include gasoline, wear-and-tear, and the admission price to the park. A less obvious type of cost is the opportunity cost of time. Time spent at the beach and travelling to and from the beach could have been spent in other ways. It could have been spent in other leisure activities, it could have been spent studying or writing, it could have been spent working. The value of the time used for the trip toward its next best use is the opportunity cost of time for spending the day at the beach. In many cases, it will be the largest component of total cost.
3. ENVIRONMENTAL ECONOMICS EVALUATION

The methodologies and techniques for evaluating environmental consequences were explained by K.C. Sankaranarayanan and V. Karunakaran (1984). These are mentioned below.

1. Cost - Benefit Analysis (CBA)
2. Input - output Analysis
3. Multiple - Objective analysis (MOA)
4. Cost - Effectiveness Analysis (CEA)
5. Risk Benefit Analysis (RBA)
6. System Analysis and Optimization Models (SAOM)
7. Trade and Investment Models (TIM)

A brief description of the main characteristics of each type is given below.

3.1 Cost-Benefit Analysis (CBA)

Techniques of Cost-Benefit Analysis for evaluating development projects are not very old. (Nail K. Shatter 1991). These were used for the first time in 1930 in the USA for the implementation of water project planning programs. Since then these have been applied to a wider spectrum of projects, though the emphasis has been on schemes requiring a substantial amount of public investments like motor ways, airports, etc. In early years, these techniques have been widely used to evaluate projects whose outputs were designed to increase or improve a product. The classic example being irrigation projects designed to stimulate farm productivity. However, these techniques have limitations as they could suggest evaluation purely in monetary terms. In order to provide a holistic
approach for the project appraisal, an alternative technique termed as EIA has been deployed in the USA since 1970. Since then, EIA has superceded CBA as the principal advisory tool for decision-makers, but still there are many reasons to regard them as complementary.

3.1.1 Cost-Benefit Analysis Dimensions

Public investment commitment is a socio-ethical aspect, which is considered by planners, as well as policy makers in order to consider the economic viability of projects. Three important dimensions of CBA have been suggested as an important set of economic techniques.

(a) Projects are concerned with major resource development schemes, such as water supply reservoirs or electricity generating stations.

(b) Course of action is related to categorical and systematic programming, such as commitment to a major electric power programme, as part of an overall energy strategy.
(c) Policies, comprised of a definite programs to achieve socio-economic growth, for example, determination to make energy production self-financing and hence proposing removal of all subsidies from energy costs. Thus, the attempt of CBA procedure is to measure and compare all relevant gains (social benefits) and losses (social opportunity costs) which would result from a given project.

3.1.2 The Basic CBA Procedure

We can divide the basic CBA procedure in four steps:

(a) identification and listing of all the relevant social costs and benefits (project impacts) connected with the project or projects.

(b) collection of the data necessary to quantify the relevant costs and benefits.

(c) evaluation (in monetary terms) of the costs and benefits identified by the analysis.

(d) submission of the finished CBA report and results to the policy makers.

3.1.3 Economic Efficiency: An Important Factor

Consideration of economic efficiency enables any policy making and administrative machinery to judge project desirability, as well as to distinguish relevant costs and benefits. Economic efficiency is said to increase when a reallocation of resources (such as, building of a dam) stimulates an increase in the net value of social output and its associated social consumption. The latter would include, among others, the aesthetic and recreational benefits and also the life support benefits of the environment. The total social
costs of a given project must include all the private resource costs and that so-called external costs, which are imposed on people who are only indirectly concerned.

In any given project, the total social benefits should include all the direct, as well as indirect gains to users of its output. Dams are constructed primarily for irrigation benefits. They also yield secondary benefits and generate costs, which usually involve changes in some people’s well-being at the expense of others. In other words, they create redistribution effects and, if the strict efficiency approach to CBA is adhered to such benefits or costs should not be included in the analysis unless there are unemployed resources available.

3.1.4 Measurement of Cost and Benefits

There are two fundamental ethical postulates in relation to any project evaluation. First, it is assumed that only individual human beings matter and that the personal wants of individuals should guide the use of society’s resources. Further, it is conventionally assumed that the preferences of the present generation of individuals should dominate over the possible preferences of future generations. In this way, the analyst will be able to determine the effect of a given project on any individual’s level of welfare by understanding the individual’s own evaluation of wellbeing. Thus, the individual’s evaluation of any project’s benefits is measured in principle, by posing the question, “what would this beneficiary be willing to pay to acquire the benefits?” Project costs are valued by asking project losers what is the minimum sum of money they would require making them feel justifiably compensated for their losses. Any external costs induced by the project are valued at the minimum amount required by affected parties to compensate them.
for the imposition of the cost. Thus, the analyst's guiding principle is to value the welfare effect of the project on the individuals concerned as they would value it in monetary terms.

The second assumption is related to the ethical postulate that the prevailing distribution of income in society, whatever it may be, is socially "just" and is, therefore, taken as given. The assumption is then made that all-individual gains and losses induced by a project can be valued equally, regardless of the income level of any individual concerned.

In environmental terms, this can be a very naive assumption, as monetary wealth tomorrow may not always provide solace for the irredeemable loss of quality of the landscapes and altered natural habitats caused by decisions made today.

In 1973 Joskov J. described the techniques of cost-benefit analysis. He has discussed, in detail, the problem of identifying costs (on whomsoever they fall). He also provided some advice regarding assigning monetary issues to environmental costs.

Roberts, H.A. and Sievering, H. (1976) provided some preliminary guidelines for conducting economic impact studies. They also suggested several improvements in the existing methods of evaluation.

3.2 Input-Output Analysis (IOA)

The first attempt to extend input-output analysis to environmental problems was made by the originator of input-output analysis, Leontief, (Leontief, 1970). Input-output analysis for an entire economy is based on the accounting of the flow of goods and services in monetary terms at a particular time. Part of this flow is an inter project flow.
foods transferred from the project to be used in the production processes of other projects, and the remainder flow to an exogenously defined "final demand" sector. This sector generally includes households, government, and foreign trade (often lumped together). For an n-industry economy the inter-industry input coefficients are arranged as a matrix $A = [a_{ij}]$. Such an arrangement is shown below.

<table>
<thead>
<tr>
<th>Input from industry</th>
<th>output of industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$a_{11}$ $a_{12}$ ... $a_{1n}$</td>
</tr>
<tr>
<td>2</td>
<td>$a_{21}$ $a_{22}$ ... $a_{2n}$</td>
</tr>
<tr>
<td>.</td>
<td>. . .</td>
</tr>
<tr>
<td>.</td>
<td>. . .</td>
</tr>
<tr>
<td>n</td>
<td>$a_{n1}$ $a_{n2}$ $a_{n3}$</td>
</tr>
</tbody>
</table>

The first column of this matrix explains that to produce a dollar's worth of commodity 1, inputs of $a_{11}$ units of commodity 1, $a_{12}$ units of commodity 2 etc. are needed. Frequently, the matrix is set up in such a way that no industry uses its own output. In that case, all the elements along the principal diagonal are zero.

If industry 1 is to produce an output just sufficient to meet the input requirements of the n industries as well as final demand of the open exogenous sector, its total output designated $x_1$ must satisfy the following equation:

$$x_1 = a_{11} - x_1 + a_{12} x_2 + \ldots + a_{1n} x_n + d_1$$

where $d_1$ is the final demand for the output of that industry. The equation can be rewritten as follows:
\((*)\)  \((1 - a_{11}) x_1 - a_{12} x_2 - ... - a_{1n} x_n = d_1\)

Except for the first coefficient \((1-a_{11})\), the others are the same as those in the first row of the \(A\) matrix (page 52), except they now have negative signs. Similarly, if we write the same type of equation for industry 2, it would have the same coefficients as in the second row of \(A\) (but with minus signs), except in position \(a_{22}\) where the coefficient would be \((1- a_{22})\). We can produce this same result in the whole matrix \(A\) if we subtract it from the identity matrix \(I\). Thus we can write:

\[
( I - A ) X = d
\]

where \(I\) is an \(n \times n\) identity matrix, \(A\) is the \(n \times n\) coefficients matrix, and \(x\) and \(d\) are both \(n \times 1\) vectors, \(X\) is the variable vector and \(d\) is the final demand vector. If \((I-A)\) has the rank \(n\) (i.e. is non-singular—meaning that the system of equations it represents has a unique solution), its inverse can be found and the system of \(n\) simultaneous equations represented by the above matrix equation will have the solution.

\[
X = (I - A)^{-1} d
\]

Side A provides a solution for the \(n\) simultaneous equations, of which equation (1) is an example, representing commodity and service flow from industries to industries and the final demand. The inverse matrix \((I-A)^{-1}\) has great utility. Once it is available, this inverse and a new solution vector produced for the industry outputs \(X\), always on the assumption that the coefficients of \(A\) matrix have not changed, can premultiply \(d\). Since multiplying a matrix by a vector is a simple operation compared with getting entirely new solutions to simultaneous equations, this is a great advantage.
Applying the Input-Output Model to Environmental Problems

A few years ago, Leontief proposed an extension of the basic national open I-O model, which would permit forecasting of residual emissions and at least, have gross effects on certain types of policy measured with respect to them. The input-output balance of pollutants included in the system is shown by the matrix equation as following:

\[
\begin{bmatrix}
1-A_{11} & -A_{12} \\
A_{21} & 1-A_{22}
\end{bmatrix}
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix}
=
\begin{bmatrix}
Y_1 \\
Y_2
\end{bmatrix}
\]

for final demand

\[
A X = \text{produced residuals}
\]

ordinary goods

ordinary goods, or industries, are indexed as follows

1, 2, ..., i, ..., m | (m + 1), ..., k, ..., 1, ..., n

We have m ordinary goods and n-m pollutants, making a total of n inputs and outputs.

Each of the A matrixes is a matrix of input-output coefficients. For example:

\[a_{ij}\] is the amount of the kth ordinary input required per unit of the kth ordinary output (sub matrix \(a_{11}\))
$a_{ik}$ is the amount of the $i$th ordinary input required to produce a unit of the $k$th residuals reduction output (sub-matrix $a_{12}$).

$d_{ji}$ is the amount of the $j$th residual resulting from producing a unit of the $i$th ordinary output (sub-matrix $a_{21}$).

$a_{ki}$ is the amount of the $k$th residual produced as a result of a unit reduction in the $i$th residual (sub-matrix $a_{22}$).

To see what is involved in this system of equations, assume that we have three ordinary commodities as two pollutant equation activities, making a total of five outputs, or "inputs", in all. Take, for example, the first equation which is formed by multiplying each member of the first row of $A^*$ by the corresponding members of the $X$ vector of industry outputs. Add these products together, thereby obtaining the first member, $Y_1$, of the vector of final outputs, $Y$:

$$
egin{bmatrix}
1 & -a_{12} & -a_{13} & -a_{14} & -a_{15}
\end{bmatrix}
\begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
x_4 \\
x_5
\end{bmatrix}
= Y_1
$$

or,

$$
x_1 - a_{12} x_2 - a_{13} x_3 - a_{14} x_4 - a_{15} x_5 = Y_1
$$

Note that in the matrices of input-output coefficients $a_{ij}$ and $a_{kj}$ are regarded as zero so that industry output is always net of its one output that it uses itself.

This equation simply says that the total output of the first commodity minus the amount used in the production of $x_2$, $x_3$, $x_4$, and $x_5$ is equal to the amount of the first
commodity, $Y_1$ going to final demanders. The last four terms account for all of the $x_i$ used in production, whether for ordinary goods or residual reduction.

Now consider an equation in the bottom part of the square matrix, $A^*$, say the last one for the $n$th commodity, which is a residual. Note that since the output of the residuals processing industry here is measured as residual reduction, the sign of the elements in the two lower quadrants are reversed from those in the two upper:

\[
\begin{bmatrix}
  x_1 \\
  x_2 \\
  x_3 \\
  x_4 \\
  x_5
\end{bmatrix}
= Y_5
\]

\[
a_{51} x_1 + a_{52} x_2 + a_{53} x_3 + a_{54} x_4 - x_5 = Y_5
\]

This says that the residual which is commodity number five. That is generated in the production of $x_1$, $x_2$, $x_3$ and $x_4$ minus the amount by which this residual is reduced equals the amount which goes to final demanders.

Thus, in abbreviated matrix form, the input-output balance is $A^* X = Y$, where $X$ and $Y$ are vectors of industry outputs and deliveries of final goods, respectively. Industry outputs include residual reduction, and final goods include residuals received.

The system of equations, $A^* X = Y$, can be solved for the vector $X$, industry outputs, by pre-multiplying each side by the inverse of the matrix, $A^{*-1} Y$. Thus, if $A^{*-1}$ has been calculated for a given industrial structure the industry output $X$ would be
associated with the specified bill of final goods $Y$ as I indicated in the general discussion of input-output scheme. The main one is that the input coefficients, the $a$'s, are fixed no matter what the size of an industry's output. That is, as also pointed out previously, there is only one way to produce an output, a way that is completely described by one column of coefficients. It is this assumption that facilitates calculations of wide economy effects as a result of certain policy changes on each in final demanders.

### 3.3 Multi-Objective Analysis

Multi-objective analysis is composed of a wide field of operations research. Often, it consists of a direct, clear-cut application of mathematical programming to actual problems. These problems may vary from industrial, architectural and environmental design to production, organizational or strategic planning. They may also be very personal, such as choosing a place to live, selecting job opportunities, or purchasing a vacuum cleaner, Rietveld, (1980), which define the role of the decision maker who wishes to make a decision in order to solve a problem.

Multi-objective optimization models are formal models. In a mathematical model they describe how a series of objectives is influenced through a number of decision variable. In its most essential form, this can be represented by:

$$\text{Max } w_1(x), \ldots, w_n(x) \quad \text{ s.t.  } \begin{align*}
g_1(x) &\leq 0 \\
\vdots &
\end{align*}$$

$$\begin{align*}
g_i &\leq 0 \\
g_m &\leq 0
\end{align*}$$

and $x \in \sum A \subset \mathbb{R}^k$

$m, n, k \sum n$
where \( x \) is the vector of decision variables, \( g_i(x) \) are constraints on \( x \). \( W_i(x) \) are objective functions, determined by \( x \). A unique optimum for \( x \) is generally not found. This is where multi-objective optimization methods come in. These methods allow for the calculation of an optimum or a set of optimal solutions, all depending on when and how the decision maker assign priorities to the various objectives.

Multi-objective modeling encompasses an enormous variety of techniques, mathematical representations, computational procedures, etc. Here, we shall treat the characteristics of multi-objective models while distinguishing between the:

a. Decision space, in which a decision is made under varying circumstances;
b. Objective spaces, in which results of the decision are measured;
c. Preference structures, which contains an ordaining in objective space;
d. Optimization procedure, which describes a procedure for finding a set of optimal solution.

Keeney and Raiffa (1976), use the term “Objective” to indicate the direction of improvement on a certain aspect of decision-making. They use the term “attribute” to denote the dimension in which an objective is measured.

From the basics of multi-objective analysis, we could make a distinction between choice processes with a limited number of alternatives and choice processes with a continuous set of alternative. The latter category applies to the choice problem that exists when economic, employment and environment policies can be utilized to influence such objectives as economic growth, employment and environmental quality.
Multi-objective analysis provides us with a number of methods which help a decision-maker that is faced with a difficult problem. In such a situation, it may be troublesome for an analyst to assess the preference and make the best choice. It may then be helpful to trace a decision-maker's preferences and his best choice within one and the same interactive procedure. Therefore, we explored the possibilities of a choice method called the "Ideal Point Method".

3.4 Cost-Effectiveness Analysis (CEA)

Cost-Effectiveness Analysis is useful in cases where benefits cannot be readily monitored. This suggests that it may be widely useful for natural resource and environmental problems (K.C. Sankaranarayanan and V. Karunakaran, 1984).

In the general formulation of a cost effectiveness problem, one seeks models of the form by Alfred Blumstein (1971):

\[ E = f(X, Y) \]

Where

- \( E \) = measure of effectiveness, typically a vector with at least two components, cost (\( E_c \)), and one or more effectiveness components
- \( X \) = set of alternative systems
- \( Y \) = set of uncontrollable or exogenous variables affecting the effectiveness measures associated with the system alternatives
Moreover, the objective or standard can be varied and another least-cost estimates can be made. The cost curve for pollution abatement leaves and is traced even though an "optimal" level of abatement is not a product of the analysis.

Also, the mere fact that benefits cannot be assessed in monetary terms does not mean that the standards are arbitrary. Standards may be set on the basis of either minimum health levels or on the basis of the judgement of experts.

Cost may be especially difficult to analyze because of distortion in market prices. But economists are now well acquainted with shadow pricing techniques for domestic capital, foreign exchange, labour and income distribution effects.

CEA appears most relevant in the areas of health, air quality and water quality. Protection of endangered species may be another area of application.

Additionally, CEA appears well suited to a wide range of natural resources and environmental problems in developing countries, even though it does not give "optimal" solutions in the sense of optimizing social welfare.

It is important to bear in mind that the EIA would be pointless and even disfunctional if it identified only the negative impacts and, then, does nothing about minimizing them by modifying the project or by substituting it with a project of lower negative impact.

3.5 **System Analysis and Optimization Models (SAOM)**

System Analysis is best viewed as a process in which data and information are gathered, organized, analyzed and presented in an impact comprehensible format, useful in
decision making. A simple schematic of system analysis consists of the following five steps (K.C. Sankaranarayanan and V. Karunakaran, 1984).

1. Problem identification and formulation.
2. Selection of solution techniques.
3. Data collection.
4. Analysis; and
5. Review and presentation of results for final decision.

In system analysis, mathematical models provide for more rigorous treatment of data. Commonly used mathematical solution techniques include linear and non-linear programming, dynamic programming, integer programming and optimal control algorithms. Mathematical simulations are non-optimization models used to identify and predict problems and opportunities and to analyze alternative plans.

Linear programming is the most common technique for the maximization of an objective function subject to a set of constraints. Linear programming format can be programmed easily on computers and can be widely used among policy makers. More specialized techniques are available to solve these problems when the co-efficient of the variables are non-linear.

Application of systems analysis to large, complex problems has the following advantages:

1. It provides a way of putting problems into perspective in a compact form, thus enabling analysts and planners to get a balanced view of the total system.
(2) Since systems analysis emphasizes the use of interdisciplinary study teams, the task of each discipline can be specified explicitly and interaction among disciplines can be made more systematic and effective.

(3) It provides a means of identifying gaps and overlaps of information.

(4) It provides systematic means of synthesizing information and enables rigorous treatment of data on system components, and interactions.

The system analysis is not free from defects. The major drawback of this method are given below:

(1) In order to complete the entire process and achieve the objectives, system analysis requires a vast amount of good quality data. In many instances, systems analysis has been misused because theoretically sophisticated models were built on insufficient data basis and tenuous assumption. Because of these abuses, many decision-makers remain sceptical about the credibility of the approach.

(2) Full-scale application of systems analysis demands a great deal of time, financial resources and technical inputs.

(3) Numerical solutions may be given more credence than they deserve, given the assumption and quality of data employed. Because of these difficulties systems analysis should be used selectively to deal with large and complex problems where many sectors and disciplines are involved and the interrelationship among those sectors are of crucial importance.
3.6 Risk-Benefit Analysis (RBA)

Risk Benefit Analysis is a comparatively new technique developed mainly to assist in decisions about alternative energy systems involving different types of risk. For example, although the probability of a nuclear accident may be very low, it could lead to extensive damage. In contrast, the use of coal tends to involve low level of damage, but damage may occur fairly regularly. RBA requires the estimation of beneficial functions, usually a straightforward task since the main benefit is the economic value of the output. However, a risk function is substituted for, or, preferably incorporated in, the cost function. But if the public’s perception of risk is different from the decision-maker’s “objective” determination of risk, this method may fail.

Cicehethi and Freeman, (1974) have given the uncertainty in either demand or supply. Suppose a public agency has under review an activity which would result in irreversible distraction of an environmental resource. Therefore, it would foreclose the option to consume the “amenity” services provided by the resource, in the future. That is, the activity causes a loss of opportunity to the individual, which is in addition to the loss of expected consumer’s surplus from the “amenity” of risk bearing service. The opportunity loss, in fact, is equivalent to the cost.

3.7 Trade and Investment Models (TIM)

TIM is useful in tracing the environmental impact. It could be used to calculate the export and trade balance consequences of alternative pollution abatement standards for industrial pollution in developing countries. Given the required data on environmental control cost, trade values and import elasticity, these models could be used to evaluate the
external cost of alternative pollution abatement levels within the country. Also an input-output model (IOM) could be combined with a TIM to estimate the pollution levels associated with different trade bundles.

An example of the use of TIM is the projection of global supply and demand for renewable and non-renewable raw materials. Each level of consumption implies certain demands on the raw material extraction activities of developing countries, and some likely set of environmental consequences for the raw material extraction, processing and consumption for developing and developed countries.