SCOPE 5 - Environmental Impact Assessment

4 What are the Available Methods ?

4.1 THE PURPOSE OF THIS CHAPTER

The variety of methods used to assess impacts is very large, but we agree with Sorensen and Moss (1973) that the present diversity 'should be considered as a healthy condition in a newly formed and growing discipline'. In this chapter, we cannot attempt to include all the existing methods*. Instead, a few representative types are described. Other comparisons have been made by Warner (1973), Ortolano (1973), Canter (1977), Jain *et al*. (1977), and Solomon *et al*. (1977).

Section 4.2 lists the techniques available to the assessor and his staff, while Section 4.3 discusses the properties of desirable EIA methods. Section 4.4 describes some of the methods that may be used in connection with each of the following steps in the preparation of an EIA:

-Identification of effects
-Prediction of effects
-Interpretation of impacts
-Communication
-Inspection procedures

As illustrative examples, three general approaches to EIA are described and compared in Section 4.5.

In Section 4.6, some ideas concerning environmental uncertainty are introduced. A recommendation is made that EIA should not be a single 'event', but should be a process in which adaptive environmental management strategies are continually evolving to meet the challenges of the unexpected.

Finally, in Section 4.7, some practical advice is given on the resources that will be needed to carry out an EIA.

(*An annotated bibliography of methods is given in Appendix 4.)

4.2 THE ASSESSOR'S TOOLS

The assessor has a number of techniques that he may use for gathering and synthesizing information:

-Field surveys
-Monitoring
-Modelling
-Agency guidelines
-Literature searches
-Workshops
-Interviews with specialists
-Public opinion polls

These techniques can be used at almost every stage in the preparation of an EIA. There is no need for elaboration here because the techniques are described in various other sections throughout the book.

4.3 SOME DESIRABLE PROPERTIES OF EIA METHODS

In choosing a suitable EIA method, the following questions should be asked:

-Is the method *comprehensive*?

Sometimes a method is required that will detect the full range of important elements and combinations of elements, directing attention to novel or unsuspected effects or impacts, as well as to the expected ones.

-Is the method *selective*?

Sometimes a method is required that focuses attention on major factors. It is often desirable to eliminate as early as possible (i.e., during identification) un- important impacts that would dissipate effort if included in the final analysis. To some degree admittedly, screening at the identification stage requires a tentative pre-determination of the importance of an impact, and this may on occasion create subsequent bias.

One way to bound a complex problem of this sort has been discussed by Lindblom (1959), Beer (1967), and Holling (1978). The assessor should start with the most critical human concerns, for which he formulates initial sets of impact indicators and environmental effects. This small set can be partially analysed with relatively low expenditures of resources. By working with such a simple model (perhaps by analysis, perhaps by simulation), the assessor begins to learn, even at this coarse level, the factors that are relatively important and those that are not. Some will have an enormous effect: it is vital to know more about them. But as the assessor widens his horizons, his task becomes more and more complex; he must therefore be selective in his choice of additional factors to be included in the analysis. In this way, the assessment expands as time, money, and manpower permit.

-Is the method *mutually exclusive*?

The task of avoiding double counting of effects and impacts is difficult because of the many interrelationships existing in the environment. In practice, therefore, it is permissible to view a human concern from different perspectives, provided that the uniqueness of the phenomenon identified by each impact indicator is preserved. The point can be illustrated by noting that there could be several impacts of some action affecting recreation; the major human concern might be economic for those whose income is derived there from, social for those who use the area, and ecological for those concerned with the effects on wildlife.

-Does the method yield estimates of the *confidence limits* to be assigned to the predictions?

Subjective approaches to uncertainty are common in many existing methods and can sometimes lead to quite useful predictions. However, explicit procedures are generally more acceptable, as their internal assumptions are open to critical examination, analysis, and, if desirable, alteration. In statistical models, for example, measure of uncertainty is typically given as the standard deviation or standard error. Ideally, the measure of uncertainty should be in a form common to the discipline within which the prediction is made.

Having estimated the range of uncertainty, the assessor should undertake three separate analyses whenever possible, using the most likely, the greatest plausible (e.g., two standard deviations away from the mean), and the smallest plausible numerical values of the element being predicted. When the resulting range of predicted values proves to be unacceptably wide, the assessor is alerted to the need for further study and/or monitoring.

The ramifications of environmental uncertainty will be considered in more detail in Section 4.6 and in Chapter 5.

-Is the method *objective*?

This property is desirable to minimize the possibility that the predictions automatically support the preconceived notions of the promoter and/or assessor: these prejudgements are usually caused by a lack of knowledge of local conditions or an insensitivity to public opinion. A second reason is to ensure comparability of EIA predictions amongst similar types of actions. An ideal prediction method contains no bias.

-Does the method predict *interactions*?

Environmental, sociological, and economic processes often contain feedback mechanisms. A change in the magnitude of an environmental effect or impact indicator may then produce unsuspected amplifications or dampenings in other parts of the system. As an example, overgrazing of a semi-arid region causes a dusty and more stable atmosphere, reducing regional rainfall, and thus accelerating the destruction of vegetation (a positive feedback) (Bryson and Baerreis, 1967). As another example, populations of most large wild animals do not increase exponentially even during the most favourable environmental conditions, due to a number of negative feedbacks such as diminishing food supplies. Prediction methods should include a capability for identifying interactions and estimating their magnitudes.

4.4 A SURVEY OF METHODS

4.4.1 Methods for Identification of Effects and Impacts

There are three principal methods for identifying environmental effects and impacts (Sorensen and Moss, 1973; Warner and Preston, 1973).

Checklists: Checklists are comprehensive lists of environmental effects and impact indicators designed to stimulate the analyst to think broadly about possible consequences of contemplated actions. This strength can also be a weakness, however, because it may lead the analyst to ignore factors that are not on the lists ('tunnel vision'*). Checklists are found in one form or another in nearly all EIA methods. One of the most comprehensive is published in the United States (AEC, 1973).

Matrices: Matrices typically employ a list of human actions in addition to a list of impact indicators. The two are related in a matrix which can be used to identify (to a limited extent) cause-and-effect relationships. Published guidelines may specify these relationships or may simply list the range of possible actions and characteristics in an open matrix, which is to be completed by the analyst.

*Flow diagrams***. Flow diagrams are sometimes used to indentify action-effect- impact relationships. An example is given in Figure 4.1 (Sorensen, 1971), which shows the connection between a particular environmental impact (decrease in growth rate and size of commercial shellfish) and coastal urban development. The flow diagram permits the analyst to visualize the connection between action and impact. The method is best suited to single-project assessments, and is not recommended for large regional actions. In the latter case, the display may sometimes become so extensive that it will be of little practical value, particularly when several action alternatives must be examined. In the study by Sorensen and Moss (1973) of hydrologic impacts of coastal urban development, for example, an initial print-out of 350 pages was produced.

Overlays: See Section 4.5.3.

4.4.2 Methods for Prediction of Effects

Methods for prediction cover a wide spectrum and cannot readily be categorized. All predictions are based on conceptual models of how the universe functions; they range in complexity from those that are totally intuitive to those based on explicit assumptions concerning the nature of environmental processes. Provided that the problem is well formulated and not too complex, scientific methods can be used, to obtain useful predictions, particularly in the biogeophysical disciplines. For example, given the climate (particularly the wind) at a representative site, together with information on time of day, topography and chimney specifications, the patterns of ground level pollution concentrations around a chimney can be estimated (mean values for various averaging times, as well as frequency distributions).

Methods for predicting qualitative effects are difficult to find or to validate. In many cases, the prediction consists of indicating merely whether there will be degradation, no change, or enhancement of environmental quality. In other cases, qualitative ranking scales (from 1 to 5, 10 or 100) are used.

* This of course can become a weakness of any method.

**Moore et al. (1973) have used flow diagrams in a system for reviewing (as contrasted to preparing) impact statements.

Because some methods are better or more relevant than others, a listing of recommended methods for solving specific environmental problems would seem to be desirable. However, a compendium of methods, even with numerous footnotes and words of caution, is likely to be a snare for the unwary non-specialist. The environment is never as well behaved as assumed in models, and the assessor is to be discouraged from accepting off-the-shelf formulae. We have therefore limited ourselves to providing some general references in Appendix 4.

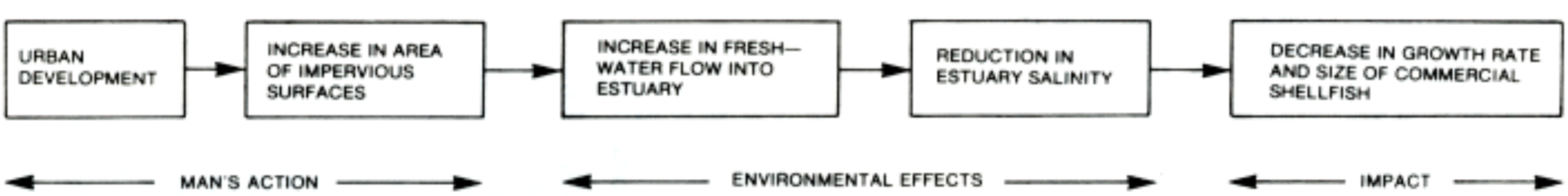


Figure 4.1 Example of a flow-chart used for impact identification (Sorensen, 1971)

4.4.3 Methods for Interpretation of Impacts

There are three methods for comparing impact indicators:

Display of Sets of Values of Individual Impact Indicators

One way to avoid the problem of synthesis is to display in a checklist or matrix all the impact indicators. For a relatively small set, and provided that some thought is given to a sensible grouping of similar kinds of indicators into sub-sets, a qualitative picture of the aggregate impact may become apparent by the clustering of checkmarks in the diagram.

This approach is used in numerous methods. Because the assessor wishes to be all-inclusive, however, the sets are usually much too large for visual comprehension. In the Leopold matrix, for example, 17,600 pieces of information are displayed. (See Section 4.5.2.) Such an array may confuse the decision-maker, particularly if a separate checklist or matrix is prepared for each alternative. Effort may be wasted if the assessor conscientiously tries to fill in a high proportion of the boxes, and he may be swamped with excessive information if he succeeds

Ranking of Alternatives within Impact Categories

A second and better method for estimating relative importance is to rank alternatives within groups of impact indicators. This permits the determination of alternatives that have the least adverse, or most beneficial, impact on the greatest number of impact indicators. No formal attempt is made to assign weights to the impact indicators; hence the total impacts of alternatives cannot be compared. An example of this approach is given in Table 4.1 (Hessel *et al*., 1972). Inspection of the table suggests that Plan IV is environmentally most acceptable, although construction costs are the highest.

Normalization and Mathematical Weighting

In order to compare indicators numerically and to obtain aggregate impacts for each alternative:

a. the impact indicator scales must be in comparable units;
b. an objective method for assigning numerical weights must be selected.

Various normalization techniques are available to achieve the first objective. In the Battelle system (Dee *et al*., 1972, 1973a), for example, environmental quality is scaled from 0 (very bad) to 1 (very good) by the use of 'value functions' (see Section 4.4.4). 'Very bad' and 'very good' can be defined in various ways. For a qualitative variable such as scenic beauty which has been ranked from 1 to 5 or from 1 to 10 by the assessor, the scales are simply transformed arithmetically to the range from 0 to 1. For quantitative variables such as water or air quality , 'very bad' could be the maximum permissible concentrations established by law, while 'very good' could be the background concentrations found at great distances from sources.

Table 4.1 Interpreting Impacts by Ranking of Alternatives for a Watershed Development (after Hessel *et al*., 1972)

	Ranking of Abatement Alternatives*				
Parameters	No Abatement	Plan I	Plan II	Plan III	Plan IV
Water quality					
Alkalinity-pH	5	2	3	4	1
Iron-manganese	5	2	3	4	1
Total hardness	2	5	4	4	1
Ecology					
Aquatic	5	2	3	4	1
Terrestrial	4	5	2	3	1
Aesthetics					
Land and terrestrial biota	4	5	2	3	1
Water and aquatic biota	5	4	2	3	1

Man-made structures	1	5	4	3	2
Economics					
Mix of economic activities	5	1	3	4	2
Capital formation	5	1	2	3	4
Incomes-employment	5	1	3	4	2
Property values	5	4	2	5	1
Social					
Individual services	5	4	2	3	1
Community services	1	3	4	5	2
Public cost					
Construction	1	4	3	2	5
Operation and maintenance	1	5	4	3	2

*Rankings range from 1 (most desirable) to 5 (least desirable).

Finally, a method of weighting may be required in order to obtain an aggregate index for comparing alternatives. This is undoubtedly a controversial part of the analysis.

The following schemes are listed in increasing order of complexity :

a. count the numbers of negative, insignificant, and positive impacts, and sum in each class;
b. when the impact indicators are in comparable units, assign equal weights;
c. weight according to the number of affected persons;
d. weight according to the relative importance of each impact indicator.

Scheme (a) is a special case of (b), both of which are to be discouraged. Scheme (d) may implicitly include (c). In either case, the criteria for weighting should be obtained from the decision-maker or from national goals. The number of weights will often be rather small, as few as two positive and two negative.

The use of weights is not perfect but it helps to quantify value judgements. The chief element of dispute is whether the task should be done by specialists or laymen. In the former case, the views may not reflect those of the public directly affected by the action. In the latter case, the non-specialist may not have sufficient factual information for impact assessment. For example, laymen have no basis for comparing the nutritional value of oranges, apples, and pears, although they could be asked quite appropriately to rank the flavours. Some of these problems and some partial solutions have been discussed by Dooley (1974).

The system described above also assumes that the numerical values of the individual impact indicators should indeed be aggregated into a single index. This has proved to be a controversial question. On the one hand,

> 'Because net environmental impact is expressed as a single value, it is easily compared to other alternatives to determine the most environmentally sound approach to development of a particular resource' (US Subcommittee, 1972).

Proponents of this point of view argue that an impact assessment should be in a form suitable for making a decision, and that decision-making is simplified if the major impacts are collapsed to a single number. Too often in the past a task force has prepared an impact assessment containing a catalogue of independent environmental concerns and impacts.

On the other hand, many are opposed to aggregation. Sorensen and Moss (1973) reason as follows:

> 'We believe that an evaluation framework should be organized to allow environmental impacts to be judged on an individual basis, or according to common categories (e.g., water quality , air quality). In this context, different units of measure which most accurately reflect the particular costs or benefits of an identified impact or type of impact could be used. The evaluation of individual impacts or impact groups permits more flexibility in decision-making. Rather than just

offering a "yes" or "no" choice, the evaluation of specific impacts allows and encourages alterations in particularly objectionable aspects of a project. A project could thus be approved on the condition that certain modifications or mitigation measures were incorporated in the design'.

Sorensen and Moss (1973) suggest in addition that aggregation may obscure a single major impact within an arithmetic average.

While recognizing that aggregation has some merit, we believe that it should only be used with caution and that:

1. the disaggregated values of the individual impact indicators should be given;
2. the procedure for aggregation should be clearly documented;
3. the procedure should include a provision for rejecting or flagging an unacceptable impact, e.g., a highway passing through an historic site.

4.4.4 Methods for Communication

Communication is sometimes the weakest component in the EIA process. The assessor may not have direct access to the decision-maker, in which case preparation of the EIA Executive Summary or Statement is probably the most important part of the EIA document. There and elsewhere, every effort should be made to avoid incomprehensibility and/or ambiguity, which may occur in several ways:

1. if scientific jargon is used without explanation;
2. if uncommon measurement units or scales are used to predict impacts;
3. if the explicit criteria and assumptions used in connection with value judgements and trade-offs are not given;
4. if the *affected parties* are not clearly indicated.

Efford (1975) quotes from an EIA for the expansion of Vancouver Airport on the west coast of Canada:

> 'Measurement of functional chlorophyll in the sediment of the Fraser River delta from January to March, 1974 gave a range of values from 4 to 225 mg chl a/m^2, with a mean of 70 mg/m^2 .These values are similar to those obtained during the summer of 1972 and to values of phytoplankton chlorophyll *a* obtained in moderately to highly productive oceanic and coastal waters."

Efford classifies this quotation as 'a particularly useless statement when it remains without interpretation or explanation'.

Affected parties should be clearly indicated. A good communication method should indicate the link in space and time between the expected impact and the affected parties. A poor system would leave one wondering, 'What effect does the impact have on me?' Most action proposals have beneficial impacts for some, but detrimental impacts for others. As noted by Biswas (1973) in connection with water-resource planning: 'benefits are estimated, but these analyses usually do not contain any information on the nature of the beneficiaries'. Some of the most strongly contested EIAs are associated with siting, in which there is no fundamental objection to a proposed development provided that it is sited somewhere else. This is a political rather than an environmental problem and should perhaps be excluded from the EIA process.

A special difficulty with communication arises when public disclosure is required or when there is fear that the EIA will be 'leaked' to the news media. In such cases, the assessor may adopt one of the following protective mechanisms (Munn, 1977);

1. the encyclopaedic approach: the assessor mentions every possible impact, even those that are very unlikely to occur;
2. the circumspect approach: the assessor avoids mention of impacts that are controversial or could catch the attention of the news media.

Neither alternative is acceptable.

Table 4.2 Techniques for Communicating with the Public (Bishop, 1973)

Communication Characteristics				Water Resources Planning Objectives					
Level of Public Contact Achieved	Ability to Handle Specific Interest	Degree of 2-way Communication	Public Participation / Communication Techniques	Inform / Educate	Identify Problems / Values	Get ideas / Solve Problems	Feedback	Evaluate	Resolve Conflict / Consensus
2	1	1	Public hearings		x		x		
2	1	2	Public meetings	x	x		x		
1	2	3	Informal small group meetings	x	x	x	x	x	x
2	1	2	General public information meetings	x					
1	2	2	Presentations to community organizations	x	x		x		
1	3	3	Information coordination seminars	x			x		
1	2	1	Operating field offices		x	x	x	x	
1	3	3	Local planning visits		x		x	x	
1	3	1	Class action litigation	x		x	x		x
2	2	1	Information brochures and pamphlets	x					
1	3	3	Field trips and site visits	x	x				
3	1	2	Public displays	x		x	x		
2	1	2	Model demonstration projects	x			x	x	x
3	1	1	Material for mass media	x					
1	3	2	Response to public inquiries	x					
3	1	1	Press releases inviting comments	x			x		
1	3	1	Letter requests for comments			x	x		
1	3	3	Workshops		x	x	x	x	x
1	3	3	Advisory committees		x	x	x	x	
1	3	3	Task forces		x	x		x	

1	3	3	Employment of community residents		x	x			x
1	3	3	Community interest advocates			x		x	x
1	3	3	Ombudsman or representative		x	x	x	x	x
2	3	1	Environmental impact statement review by public	x			x	x	

1 = low, 2 = medium, 3 = high, x = capability.

Techniques for communicating with the public are summarized in Table 4.2 (Bishop, 1973). The table includes an indication of the effectiveness of each technique. As pointed out by Biswas (1973), however, 'it is virtually certain that some people or pressure groups will support a plan, and it is equally certain that some will oppose it'.

4.4.5 Methods for Determining Inspection Procedures

After an action has been completed, environmental quality may fall below design criteria because of:

a. an incorrect or incomplete impact assessment;
b. a rare environmental event or episode (e.g., an earthquake or drought);
c. an accident (e.g., a fire) or structural failure of a component (e.g., a pipeline rupture);
d. human error (e.g., an oil spill in coastal waters or misapplication of a pesticide).

The inspection procedures should take account of these four possibilities insofar as is practicable, and may include periodic examination of equipment and of safety procedures; in some cases, recommendations for regular monitoring programmes may be necessary.

The procedures to be followed in most cases can be derived from the predictions of effects and impacts that have already been made. An air pollution model, for example, will provide guidance on where to locate monitoring stations.

4.5 AN ANALYSIS OF THREE GENERAL APPROACHES TO ASSESSING IMPACTS

4.5.1 Introduction

Three general approaches, selected because they represent a range of options* for impact assessment, are discussed in this section:

-Leopold matrix
-Overlays
-Battelle environmental evaluation system

No connotation of endorsement is necessarily implied. Brief descriptions of some other approaches are to be found in Appendix 4.

4.5.2 The Leopold Matrix

4.5.2.1 Description

The pioneering approach to impact assessment, the Leopold matrix, was developed by Dr. Luna Leopold and others of the United States Geological Survey (Leopold *et. al.*, 1971). The matrix was designed for the assessment of impacts associated with almost any type of construction project. Its main strength is as a checklist that incorporates qualitative information on cause-and-effect relationships but it is also useful for communicating results.

The Leopold system is an open-cell matrix containing 100 project actions along the horizontal axis and 88 environmental 'characteristics' and 'conditions' along the vertical axis. These are listed in Table 4.3, while the accompanying instructions are reproduced in Figure 4.2.

The list of project actions in Table 4.3 is more comprehensive than that given in Table 3.1, Chapter 3, but the assessor will find that many of the cells will not be used in any individual case. The 'characteristics' and 'conditions' in Table 4.3 are a combination of environmental effects and impacts, using the definitions adopted in Section 1.1.

Figure 4.2 indicates that for each cell in the matrix, a ranking system (scaled from 1 to 10) is given for the *magnitude* and for the *importance* of each possible impact.

INSTRUCTIONS

1. Identify all actions (located across the top of the matrix) that are part of the proposed project.
2. Under each of the proposed actions, place a slash at the intersection with each item on the side of the matrix if an impact is possible.
3. Having completed the matrix, in the upper left-hand corner of each box with a slash, place a number from 1 to 10 which indicates the MAGNITUDE of the possible impact, 10 represents the greatest magnitude of impact and 1 the least (no zeroes). Before each number place + if the impact would be beneficial. In the lower right-hand corner of the box place a number from 1 to 10 which indicates the IMPORTANCE of the possible impact (e.g.,regional vs. local); 10 represents the greatest importance and 1 the least (no zeroes).
4. The text which accompanies the matrix should be a discussion of the significant impacts, those columns and rows with large numbers of boxes marked and individual boxes with the larger numbers.

SAMPLE MATRIX

	a	b	c	d	e
a		2/1			8/5
b		7/2	6/8	3/1	9/7

Figure 4.2 Instruction for using the Leopold Matrix (Leopold *et al*., 1971)

(*An additional option is simulation modelling, to be discussed in Chapter 5)

Table 4.3 The Leopold Matrix (Leopold *et al*., 1971). Part I Lists the Project Actions (Arranged Horizontally in the Matrix); Part 2 Lists the Environmental 'Characteristics' and 'Conditions' (Arranged Vertically in the Matrix)

PART 1: Project Actions

A. MODIFICATION OF REGIME
a) Exotic flora or fauna introduction
b) Biological Controls
c) Modification of habitat

E. LAND ALTERATION
a) Erosion control and terracing
b) Mine sealing and waste control
c) Strip mining rehabilitation

d) Alteration of ground cover
e) Alteration of ground-water hydrology
f) Alteration of drainage
g) River control and flow codification
h) Canalization
i) Irrigation
j) Weather modification
k) Burning
l) Surface or paving
m) Noise and vibration

B. LAND TRANSFORMATION AND CONSTRUCTION
a) Urbanization
b) Industrial sites and buildings
c) Airports
d) Highways and bridges
e) Roads and trails
f) Railroads
g) Cables and lifts
h) Transmission lines, pipelines and corridors
i) Barriers, including fencing
j) Channel dredging and straightening
k) Channel revetments
l) Canals
m) Dams and impoundments
n) Piers, seawalls, marinas, & sea terminals
o) Offshore structures
p) Recreational structures
q) Blasting and drilling
r) Cut and fill
s) Tunnels and underground structures

C. RESOURCE EXRACTTION
a) Blasting and drilling
b) Surface excavation
c) Sub-surface excavation and retorting
d) Well drilling and fluid removal
e) Dredging
f) Clear cutting and other lumbering
g) Commercial fishing and hunting

D. PROCESSING
a) Farming
b) Ranching and grazing
c) Feed lots
d) Dairying
e) Energy generation
f) Mineral processing
g) Metallurgical industry
h) Chemical industry
i) Textile industry
j) Automobile and aircraft
k) Oil refining
l) Food
m) Lumbering
n) Pulp and paper
d) Landscaping
e) Harbour dredging
f) Marsh fill and drainage

F. RESOURCE RENEWAL
a) Reforestation
b) Wildlife stocking and management
c) Ground-water recharge
d) Fertilization application
e) Waste recycling

G. CHANGES IN TRAFFIC
a) Railway
b) Automobile
c) Trucking
d) Shipping
e) Aircraft
f) River and Canal traffic
g) Pleasure boating
h) Trails
i) Cables and lifts
j) Communication
k) Pipeline

H. WASTE EMPLACEMENT AND TREATMENT
a) Ocean dumping
b) Landfill
c) Emplacement of tailings, spoil and overburden
d) Underground storage
e) Junk disposal
f) Oil-well flooding
g) Deep-well emplacement
h) Cooling-water discharge
i) Municipal waste discharge including spray irrigation
j) Liquid effluent discharge
k) Stabilization and oxidation ponds
l) Septic tanks, commercial &. domestic
m) Stack and exhaust emission
n) Spent lubricants

I. CHEMICAL TREATMENT
a) Fertilization
b) Chemical deicing of highways, etc.
c) Chemical stabilization of soil
d) Weed control
e) Insect control (pesticides)

J. ACCIDENTS
a) Explosions
b) Spills and leaks
c) Operational failure

OTHERS
a)
b)

o) Product storage

PART 2: Environmental 'Characteristics' and 'Conditions'

A. PHYSICAL AND CHEMICAL CHARACTERISTICS

1. *Earth*
a) Mineral resources
b) Construction material
c) Soils
d) Landform
e) Force fields & background radiation
f) Unique physica1 features

2. *Water*
1) Surface
b) Ocean
c) Underground
d) Qua1ity
e) Temperature
g) Snow, Ice, & permafrost

3. *Atmosphere*
a) Quality (gases, particulates)
b) Climate (micro, macro)
c) Temperature

4. *Processes*
a) Floods
b) Erosion
c) Deposition (sedimentation, precipitation)
d) Solution
e) Sorption (ion exchange, complexing)
f) Compaction and settling
g) Stability (slides, s1umps)
h) Stress-strain (earthquake)
f) Recharge
i) Air movements

B. BIOLOGICAL CONDITIONS

1. Flora
1) Trees
b) Shrubs
c) Grass
d) Crops
e) Microf1ora
f) Aquatic plants
g) Endangered species
h) Barriers
i) Corridors

2. Fauna
a) Birds
b) Land anirnals including reptiles
c) Fish & shellfish
d) Benthic organisms
e) Insects
f) Microfauna
g) Endangered species
h) Barriers
i) Corridors

C. CULTURAL FACTORS

1. Land use
a) Wildemess & open spaces
b) Wetlands
c) Forestry
d) Grazing
e) Agriculture
f) Residential
g) Commercial
h) Industrial
i) Mining & quarrying

2.*Recreation*
a) Hunting
b) Fishing
c) Boating
d) Swimming
e) Camping & hiking
f) Picnicing
g) Resorts

3. *Aesthetics & Human Interest*
a) Scenic views and vistas
d) Landscape design
e) Unique physical features
f) Parks & reserves
g) Monuments
h) Rare & unique species or ecosystems
i) Historical or archaeological sites and objects
j) Presence of misfits

4. *Cultural Status*
a) Cultural patterns (life style)
b) Health and safety
c) Employment
d) Population density

5. *Man-Made Facilities and Activities*
a) Structures
b) Transportation network (movement, access)
c) Utility networks
d) Waste disposal
e) Barriers

b) Wilderness qualities
c) Open space qualities

f) Corridors

D. ECOLOGICAL RELATIONSHIPS SUCH AS:

1) Salinization of water resources
b) Eutrophication
c) Disease-insect vectors
d) Food chains

e) Salinization of surficial material
f) Brush encroachment
g) Other

OTHERS
a)
b)

4.5.2.2 Identification

The Leopold matrix is comprehensive in covering both the physical-biological and the socio-economic environments. The list of 88 environmental characteristics is weak, however, from the point of view of *structural parallelism and balance*. For example, swimming (an activity) and water temperature (an indicator of state) are both included. In addition, the list is biased towards the physical-biological environment (67 entries).

The Leopold matrix is not *selective*, and includes no mechanism for focusing attention on the most critical human concerns. Related to this is the fact that the matrix does not distinguish between immediate and long-term impacts, although separate matrices could be prepared for each time period of interest.

The principle of a *mutually exclusive* method is not preserved in the Leopold matrix, and there is substantial opportunity for double counting. This is a fault of the Leopold matrix in particular rather than of matrices in general.

4.5.2.3 Prediction

The method can accommodate both quantitative and qualitative data. It does not, however, provide a means for discriminating between them. In addition, the magnitudes of the predictions are not related explicitly to the 'with-action' and 'without-action' future states.

Objectivity is not a strong feature of the Leopold matrix. Each assessor is free to develop his own ranking system on the numerical scale ranging from l to 10.

The Leopold matrix contains no provision for indicating *uncertainty* resulting from inadequate data or knowledge. All predictions are treated as if certain to occur. Similarly, there is no way of indicating environmental variability, including the possibility of *extremes* that would present unacceptable hazards if they did occur, nor are the associated probabilities indicated.

The Leopold matrix is not efficient in identifying *interactions*. However, because the results are summarized on a single diagram, interactions may be perceived by the reader in some cases.

4.5.2.4 Interpretation

The Leopold matrix employs weights to indicate relative importance of effects and impacts. A weakness of the system is that it does not provide explicit criteria for assigning numerical values to these weights.

Synthesis of the predictions into aggregate indices is not possible, because the results are summarized in an 8,800 (88 by 100) cell matrix, with two entries in each cell − one for magnitude and one for importance. Thus the decision maker could be presented with as many as 17,600 items for each alternative proposal for action.

4.5.2.5 Communication

By providing a visual display on a single diagram, the Leopold matrix may often be effective in communicating results. However, the matrix does not indicate the main issues or the groups of people most likely to be affected by the impact

4.5.2.6 Inspection Procedures

The matrix has no capability for making recommendations on inspection procedures to be followed after completion of the action.

4.5.2.7 Summary

Although the matrix approach has a number of limitations, it may often provide helpful initial guidance in designing further studies. In this connection, the assessor should feel free to modify the matrix to meet his particular needs. For initial screening of alternatives, we recommend that the number of cells be reduced, and that a series of matrices be prepared:

a. one set for environmental effects and another for impact indicators;
b. one set for each of two or three future times of interest;
c. one set for each of two or three alternatives.

Particular cells could be flagged if the assessor felt that an extreme condition might occur, even though the probability was very low, and footnotes could be used where appropriate.

A set of 8 or 12 such matrices might be a useful tool at the outset of an assessment, or whenever the resources of the assessor are limited.

4.5.3 Overlays

4.5.3.1 Description

The overlay approach to impact assessment was first suggested by Dr. Ian McHarg (1968, 1969) at the University of Pennsylvania. A series of transparencies is used to identify, predict, assign relative significance to, and communicate impacts in a geographical reference frame larger in scale than a localized action would require. The approach has been employed by Krauskopf and Bunde (1972) form selecting highway corridors, by Nehman *et al*. (1973) for evaluating development options in coastal areas, and in numerous other applications.

The study area is sub-divided into convenient geographical units, based on uniformly-spaced grid points, topographic features or differing land uses. Within each unit, the assessor collects information on environmental factors and human concerns, through aerial photography, topological and government land inventory maps, field observations, public meetings, discussions with local science specialists he and cultural groups, or by random sampling techniques (see Eckenrode, 1965, for example). The concerns are assembled into a set of factors, each having a common basis (i.e., not representing conflicting concerns). Regional maps (transparencies) are, drawn for each factor, the number of maps having a practical limitation of about 10. By a series of overlays, the land-use suitability, action compatibility, and engineering feasibility are evaluated visually, in order that the best combination may be identified.

A computer may be programmed to perform the tasks of aggregating the predicted impacts for each geographical sub-division and of searching for the areas least affected. Minshall *et al*. (1973), for example, have used computerized overlays in conjunction with a simulation model to assess trade-offs between economic growth and environmental quality in the state of Arizona. Procedures are also available for selecting sequences of unit areas for routing highways, pipelines and other corridors. The computer method is more expensive and requires more time to design than transparent overlays but is more flexible, an advantage whenever the reviewer suggests that the system of weights be changed.

The overlay approach can accommodate both qualitative and quantitative data, For example, water is often shaded blue while land elevation can be shown by contour lines. There are, however, limits to the number of different types of data that can be comprehended in one display. A computerized version thus has greater flexibility. Although in this case, too, the individual cartographic displays may be too complex to follow in sequence, the final maps (optimum corridors for each alternative, and comparisons amongst alternatives) are readily prepared and understood.

Figure 4.3 provides a practical example of the overlay method, which in this case has been applied to the problem of selection of a corridor for a high voltage (550,000 volts) electric transmission line (Dooley and Newkirk, 1976). The study area is productive agricultural land interspersed with a number of small cities (up to 250,000 population) having industrial, commercial, and institutional importance, The area is approximately 250 x 100 km^2 and has fairly intense competition for land use.

The analysis was computerized using a unit square of 500 x 500 m^2. For each grid square, an inventory of information on a large number of variables was obtained. There were data, for example, on existing roads, pipelines, railways, airports, radio towers, major industries, residential areas, institutions, and commercial areas. Data were also obtained on crop yields, soil and wildlife capabilities, moisture regimes, landforms, historic sites, and recreational areas. This list is by no means complete, but indicates the complexity of land use. The areas of concern were as follows:

Economic system
- Agricultural operations
- Area utilities and industry
- Linear utilities (corridor users)

Social system
- Recreational, cultural, historical

Natural system
- Natural environment
- Natural landscape diversity
- Relative visibility of transmission line

For each factor and for each grid square, an impact rating was determined on a scale of 1 (low) to 5 (high) with 6 as a special rating denoting 'no go'. The numerical value to be used in each case was obtained with the aid of a computer programme, using a set of rules that had been developed for the study.

Computerized 'factor maps' were produced, light shading denoting low impact, dark shading high impact, and black denoting 'no go'. Township boundaries were included as a reference frame. Examples are given in Figure 4.3 (a,b,c), while a section of the composite impact map is shown in Figure 4.3 (d). It can be seen that corridors, say from A to B, that have low impact can readily be selected visually.

4.5.3.2 Identification

The approach is only moderately *comprehensive* because there is no mechanism that requires consideration of all potential impacts. When using overlays, the burden of ensuring comprehensiveness is largely on the analyst.

The approach is *selective* because there is a limit to the number of transparencies that can be viewed together.

Overlays may be *mutually exclusive* provided that checklists of concerns, effects, and impacts are prepared at the outset and a simplified matrix-type analysis is undertaken.

4.5.3.3 Prediction

Because predictions are made for each unit area, the overlay method is strong in predicting spatial patterns, although weak in estimating magnitudes: a rather elaborate set of rules is often required to reveal differences in severity of impacts from place to place.

In some regions, the assessor may be able to find cartographic charts of future environmental states, e.g., population or land-use projections, that have been prepared recently for some other purpose. The with-action and without-action conditions can then be readily compared.

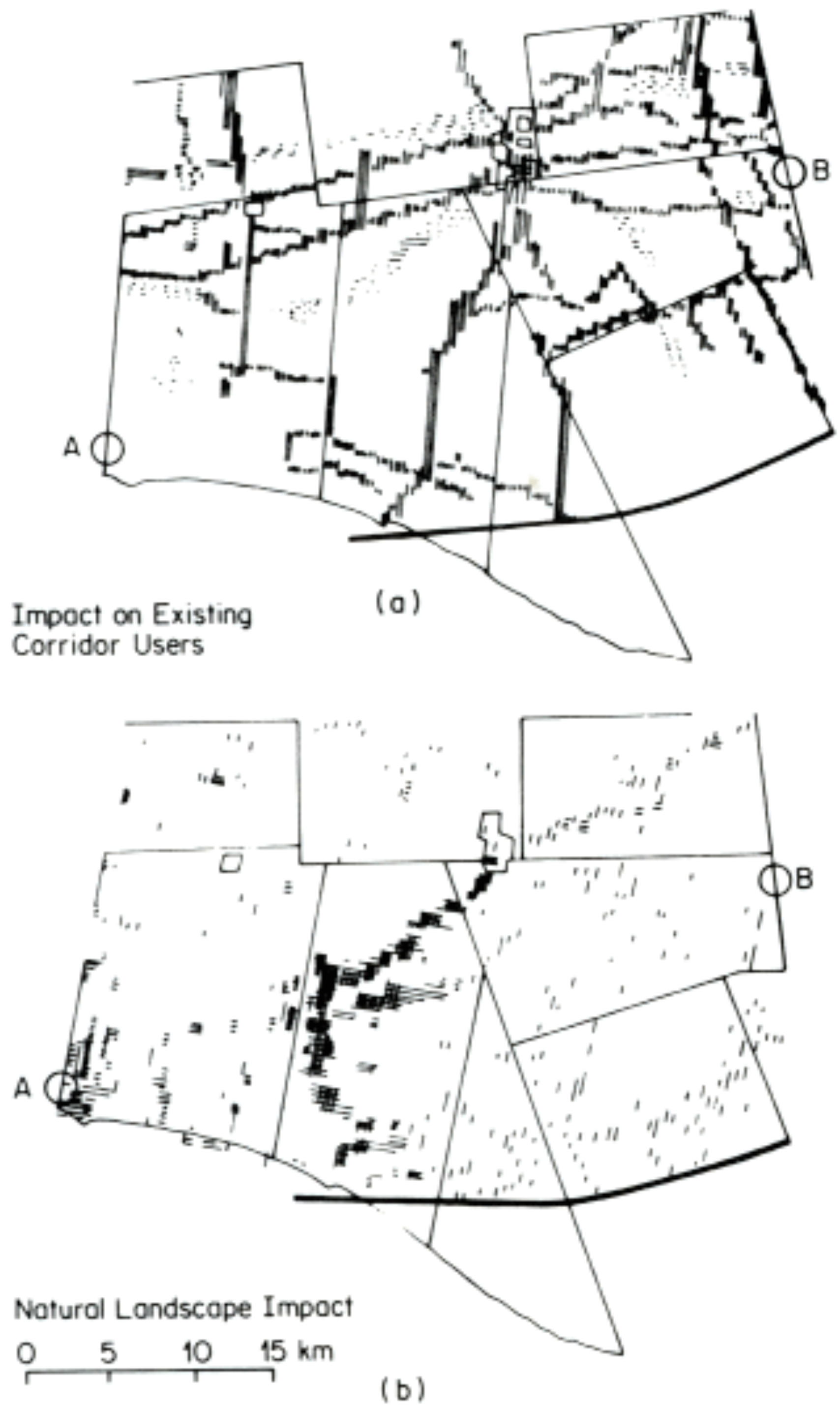
The *objectivity* of the overlay method is high with respect to the spatial positioning of effects and impacts (e.g., area of land to be flooded), but is otherwise low. Overlays are not effective in estimating or displaying *uncertainty* and *interactions*.

Extreme impacts with small probabilities of occurrence are not considered. A skilled assessor may indicate in a footnote or on a supplementary map, however, those areas near proposed corridors where there is a possibility of landslides, floods or other unacceptable risks.

4.5.3.4 Interpretation

Two methods are used to obtain aggregate impacts from overlays:

(a) Conventional weighting, the weights being a measure of relative importance;
(b) The threshold technique, in which a unit square is excluded from further consideration whenever a designated number of impacts is forecast to occur , or whenever an individual impact is unacceptably high.



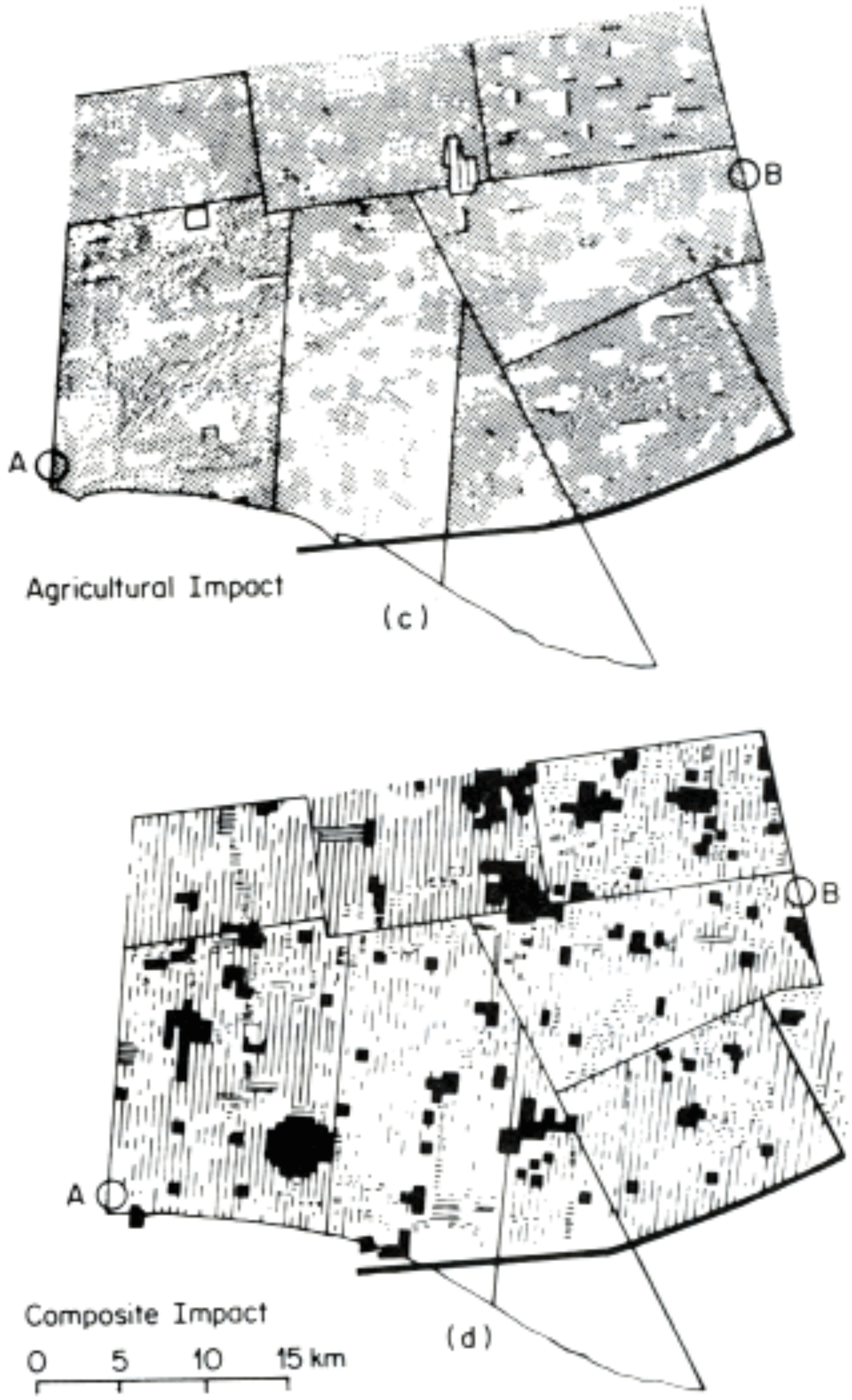


Figure 4.3 Example of the overlay method as applied to the selection of a corridor for an electrical transmission line. The four parts of the figure represent relative impacts (indicated by the intensity of shading) for three separate impact indicators (a, b, c) and for a composite of eight indicators (d), The solid lines are jurisdictional boundaries (Dooley and Newkirk, 1976)

A weighted average tends to give too little emphasis to impacts that are extreme for only a few people; the decision-maker may wish to be alerted to these extremes, and may wish to receive recommendations for remedial actions, e.g., financial compensation to property owners for land expropriation.

Overlays are strong in synthesis and in indicating trade-offs whenever spatial relationships are important. Although the analysis is limited to the total area represented by the transparencies, several levels of detail may be examined by preparing:

a. a set of overlays for a geographical scale much larger than the area covered by the action and in only modest detail;
b. a set of overlays for part of the region on an expanded scale and in much greater detail than the other set.

4.5.3.5 Communication

The overlay approach can be used to communicate clearly where the types and number of affected parties are to be found. Other advantages include:

a. the possibility of displaying magnitudes by colour, coding or shading;
b. the ease with which the system can be programmed on a computer to provide composite charts that can be readily understood.

4.5.3.6 Inspection Procedures

The overlay method provides guidance on the spatial design of inspection procedures to be followed.

4.5.3.7 Summary

The overlay system cannot be considered ideal, but despite its limitations it u valuable in illuminating complex spatial relations. It is recommended for large regional developments and corridor selection problems, provided that the assessor views his analysis with at least a modest degree of scepticism.

4.5.4 The Battelle Environmental Evaluation System

4.5.4.1 Description

The environmental evaluation system was designed by the Battelle Columbus Laboratories in the United States to assess impacts of water-resource developments, water-quality management plans, highways, nuclear power plants, and other projects (Dee et al., 1972, 1973a, b).

Table 4.4 The Battelle Environmental Classification for Water-Resource Development Projects (Dee *et al*., 1973a). The Bracketed Numbers are RelativeWeights

ECOLOGY	PHYSICAL/CHEMICAL
Terrestrial Species & Populations	Water Quality
-Browsers and grazers (14)	-Basin hydrologic loss (20)
-Crops (14)	-Biochemical oxygen demand (25)
-Natural vegetation (14)	-Dissolved oxygen (31)
-Pest species (14)	-Fecal coliforms (18)
-Upland game birds (14)	-Inorganic carbon (22)
	-Inorganic nitrogen (25)
Aquatic Species & Populations	-Inorganic phosphate (28)
-Commercia1 fisheries (14)	-Pesticides (16)
-Natural vegetation (14)	-pH (18)
-Pest species (14)	-Streamflow variation (28)
-Sport fish (14)	-Temperature (28)
-Water fowl (14)	-Total dissolved solids (25)
	-Toxic substances (14)
Terrestrial Habitats & Communities	-Turbidity (20)
-Food web index (12)	
-Land use (12)	Air Quality
-Rare & endangered species (12)	-Carbon monoxide (5)
-Species diversity (14)	-Hydrocarbons (5)
	-Nitrogen oxides (10)
Aquatic Habitats & Communities	-Particulate matter (12)
-Food web index (12)	-Photochemical oxidants (5)
-Rare & endangered species (12)	-Sulphur oxides (10)
-River characteristics (12)	-Other (5)
-Species diversity (14)	
	Land Pollution
Ecosystems	-Land use (14)
	-Soil erosion (14)
	Noise Pollution
	-Noise (4)
AESTHETICS	HUMAN INTEREST /SOCIAL
Land	Education/Scientific
-Geologic surface material (6)	-Archeological (13)
-Relief & topographic character (16)	-Ecological (13)
-Width and alignment (10)	-Geological (11)

Air -Odour and visual (3) -Sounds (2) Water -Appearance of water (10) -Land & water interface (16) -Odour and floating material (6) -Water surface area (10) -Wooded and geologic shoreline (10) Biota -Animals -domestic (5) -Animals -wild (5) -Diversity of vegetation types (9) -Variety within vegetation types (5) Man-Made Objects -Man made objects (10) Composition -Composite effect (15) -Unique composition (15)	-Hydrological (11) Historical -Architecture and styles (11) -Events (11) -Persons (11) -Religions and cultures (11) -'Western Frontier' (11) Cultures -Indians (14) -Other ethnic groups (7) -Religious groups (7) Mood/ Atmosphere -Awe/inspiration (11) -Isolation/solitude (11) - Mystery (4) -'Oneness' with nature (11) Life Patterns -Employment opportunities (13) -Housing (13) -Social interactions (11)

The human concerns are separated into four main categories (see Table 4.4):

-Ecology
-Physical/chemical
-Aesthetics
-Human interest/social

Each category contains a number of components that have been selected specifically for use in all U.S. Bureau of Reclamation water-resource development project.

For each component, Battelle has developed an index of environmental quality, normalized to a scale ranging from 0 to 1, using a value function method. Each impact indicator is then given as the difference in environmental quality between the states with and without action.

Two examples of Battelle 'value functions' are given in Figure 4.4. The rationale for Part (a) of the diagram is as follows. In the western United States, optimum populations of livestock and/or wild herbivores such as deer and elk are such that about 50 to 60% of the net annual above-ground production of plants is consumed; When this percentage is exceeded, the stability of the system is disturbed (overgrazing); when it is not reached, the full potential of the system for grazing is not being used. In Part (b) of Figure 4.4, a value function is given for dissolved oxygen, which is a commonly used index of water quality. Dee *et al*. (1972) recommend the following procedure for determining value functions:

Step 1: Obtain information on the relationship between the parameter and the quality of the environment.

Step 2: Order the parameter scale (abscissa) so that the lowest value is zero.

Step 3: Divide the quality scale (ordinate) into equal intervals between 0 to 1, and determine the appropriate value of the parameter for each interval. Continue the process until a curve can be drawn.

Step 4: Ask several different specialists to repeat Steps 1 to 3 independently. Average the curves to obtain a group curve. (For parameters based solely on value judgements, use a representative cross-section of the population.)

Step 5: Show curves to all participants, and ask for a review if there are large variations. Modify the group curve as appropriate.

Step 6: Repeat Steps 1-5 with a separate group of specialists, to test for reproducibility.

Step 7: Repeat Steps 1-6 for all the selected parameters.

The bracketed number that follows each entry in Table 4.4 is the relative weight assigned to each impact indicator. The weights are fixed for all similar types of projects. Given the value of each impact indicator and the associated weight, the overall impact of each project alternative may then be calculated by taking, weighted sums.

The system also incorporates a warning system, a series of red flags used to indicate that:

a. the value of an impact indicator cannot be estimated because of inadequate data; or
b. the value of a particular impact indicator is unacceptable, even though the weighted index suggests that the project may be given approval to proceed on environmental grounds.

Red flags indicate areas where further studies are needed.

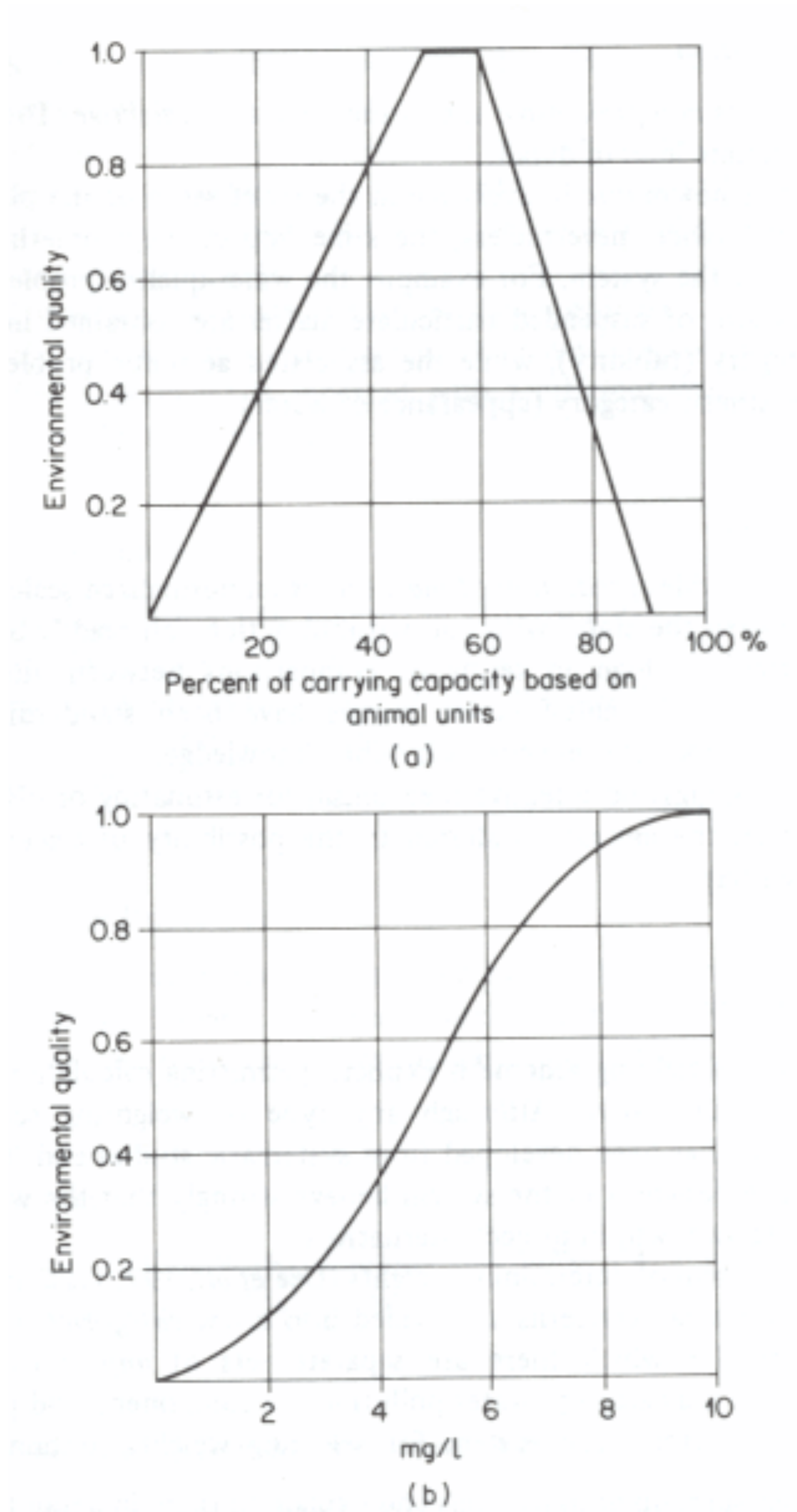


Figure 4.4 Exampes of environmental value functions: (a) terrestrial carrying capacity for browsers and grazers; (b) disso1ved oxygen (Dee *et al*., 1972)

4.5.4.2 Identification

The approach is *comprehensive* and at the same time *selective*. The assessor may select an appropriate level of detail.

The system is not *mutually exclusive* in the strict sense of the phrase. Impacts are not counted twice; nevertheless, the same impact may sometimes appear in different parts of the system. For example, the water-quality problems caused by high concentrations of suspended particulate matter are contained in the physical/ chemistry category (turbidity), while the associated aesthetic problems are to be found in the aesthetic category (appearance of water).

4.5.4.3 Prediction

The method provides *prediction on magnitudes* on normalized scales, from which differences between the states with and without action can readily be determined.

The *objectivity* is high in terms of comparisons between alternatives and between projects. The value-function curves have been standardized, and the rationale for the shapes of these curves is public knowledge.

The system contains no effective mechanism for estimating or displaying *interactions*. However, the assessor is alerted to the possibility of *uncertainty* and of *extremes* by red flags.

4.5.4.4 Interpretation

The numerical weighting scheme is explicit, permitting calculation of a project impact for each alternative. Although any type of weighting scheme is controversial, this one has been developed from systematic studies and its rationale documented. The designers of the system believe strongly that the weights should not be allowed to vary within project alternatives.

The Battelle system of determining weights (Dee *et al*., 1972) is a useful example to describe. The human concerns are divided into a few *categories*, each of which has *components*, for which there are separate sets of *impact indicators*. For example, pollution is a category , water pollution is a component, and pH is one of a set of impact indicators. The system for selecting weights contains nine steps:

Step 1: Select a group of individuals and explain to them in detail the weighting concept and the use of their rankings and weights.

Step 2: List the categories, components, and impact indicators, and ask each individual independently to rank each member of each set in decreasing order of importance.

Step 3: Each individual assigns a value of I to the first category on his list, and then decides how much the second is worth compared to the first, expressing his estimate as a decimal between 0 an 1.

Step 4: Each individual makes similar comparisons for all consecutive pairs of categories.

Step 5: Steps 3 and 4 are repeated for the sets of components and impact indicators.

Step 6: Averages are computed over all individuals for all categories, components, and indicators, the weights being adjusted in the cases of components and indicators to take account of the weights obtained for the larger groupings.

Step 7: The group results are revealed to the individuals.

Step 8: The experiment is repeated with the same group of individuals.

Step 9: The experiment is repeated with a different group of individuals to check for reproducibility .

4.5.4.5 Communication

The approach does not link impacts to *affected parties* or to *dominant issues*. However, the system is effective in its *summary format*, which is usually a table listing individual and aggregate impacts as well as flagging impacts in need of future study. The summary format is designed for the specialist and may sometimes require explanation.

4.5.4.6 Inspection Procedures

The approach provides modest guidance on the development of future inspection procedures. Particularly for value functions that are related to national standards or criteria, the system indicates the parameters that will require monitoring.

4.5.4.7 Summary

The Batteile methodology, although not ideal, has much to recommend it wherever the assessor has sufficient resources.

4.5.5 Some Concluding Remarks on General Approaches

Table 4.5 summarizes the strengths and weaknesses of the three general approaches selected for study. The assessor may, in fact, have difficulty in choosing from amongst the range of approaches and of methods. The choice win depend upon the nature of the action and upon the available resources. Indeed, the assessor may sometimes wish to use more than one approach, either:

a. *consecutively* at different stages and levels of detail of the assessment; or
b. *concurrently* at a single stage. In the latter case, the assessor may wish to test whether two approaches yield the same results.

Table 4.5 Comparison of Three General Approaches

		Leopold	Overlay	Batelle
Capability	Identification	Medium	Medium	High
	Prediction	Low	Low	High
	Interpretation	Low	Low-Medium	High
	Commumcation	Low	High	Low-Medium
	Inspection procedures	Low	Medium	Low-Medium
Action complexity capability		Incremental alternatives	Fundamental and incremental alternatives	Incremental alternatives
Risk assessment capability		Nil	Nil	Nil
Capability for flagging extremes		Low	Low	Medium
Replicability of results		Low	Low-Medium	High
Level of detail	Screening of alternatives	Incremental	Fundamental and incremental	Incremental
	Detailed assessment	Yes	Yes	Yes
	Documentation stage	Yes	Yes	Yes
	Money	Low	Maps low; computer high	High

Resource requirements	Time	Low	Maps low; computer high	High
	Skilled manpower	Medium	High	High
	Computational	Low	Maps low; computer high	Medium
	Knowledge	Medium	Medium	Medium

4.6 THE PROBLEM OF UNCERTAINTY*

An EIA contains four kinds of uncertainty, due to:

1. the natural variability of the environment, particularly the occurrence of rare events such as floods and earthquakes;
2. inadequate understanding of the behaviour of the environment;
3. inadequate data for the region or country being assessed;
4. socio-economic uncertainties (inadequate understanding and inadequate data).

(*Risk assessment is one of the major SCOPE programmes; see, for example, SCOPE 10 (1977, pp. 124-127) and SCOPE 8 (1978).)

Methods are available for predicting the first kind of uncertainty. Frequency distributions of the numerical values of physical and biological elements can be estimated in many cases, and can be used to predict the probabilities of rare events. Engineers use these methods in the design of flood-control systems, tall buildings, and so forth. Although prediction of the exact date of occurrence of a rare event is not possible, the engineer can design a structure so that its risk of failure is smaller than any value specified in national building codes, standard or the like. For very large projects, Mark and Stuart-Alexander (1977) believe that the expected costs of low-probability disasters should be evaluated. They estimate a dam failure rate of the order of 10^{-4} per dam-year, and they assert that in urban areas the relative damage costs (i.e., the costs weighted by the probability of occurrence) could be comparable to project benefits.

The second and third types of uncertainty are more difficult to manage. The degree of knowledge and data varies from discipline to discipline, and this leads to mismatches, not only in the confidence to be placed in a prediction but also in the philosophies advocated by members of the assessment team. On the one hand, there are those who believe that EIAs should focus on impacts that can be estimated with reasonable assurance; see, for example, Hall (1977). On the other hand, there are those who believe that EIAs should focus on impacts whose magnitudes and frequencies of occurrence cannot be determined with any exactitude; thus, because a chimney can be designed so that emission controls and air-quality standards can be met, some environmentalists assert that the engineering calculations should not be an integral part of an EIA, but should be considered separately in relation to existing laws or regulations.

The fourth kind of uncertainty − socio-economic − is the most difficult to quantify. Externalities such as wars, currency devaluations, and changes in international trade relations are impossible to predict. But even when national and international conditions remain relatively stable, the construction of a highway or dam may sometimes produce unexpected adjustments by the local population; for example, there is always uncertainty in predicting the ways in which a community will respond after a highway has been constructed: in terms of employment, housing, recreational, and other kinds of patterns. Furthermore, the strong feed-back loops between socio-economic and biophysical impacts can result in corresponding uncertainty in the long-term biophysical impacts.

A related problem is due to the fact that uncertainty increases as a prediction is made for times further and further into the future. In some cases, predictions of long term consequences may be so uncertain that the decision-maker has no option but to make a decision on the expected short-term impacts.

For these reasons, Holling (1978) has urged that an EIA should be considered as an *investigation into*, rather than a *determination of impacts*. At present, an EIA is one of several considerations leading to a decision to implement a proposed action. Once the decision has been taken, however, the EIA is generally filed, and the assessment team is disbanded. A modest monitoring programme may be established by the proponent or by a designated government agency. But what happens if the EIA predictions begin to go seriously wrong? Walters (1975) has emphasized that a development pattern, once established, is difficult if not impossible to terminate or to change radically. What happens more often than not is that the decision-maker takes a number of small corrective actions as the situation develops, leading to an ultimate blurring of the original goals and a worsening of the long-term impacts.

Holling (1978) therefore recommends a policy of *adaptive environmental impact assessment,* in which the EIA process continues long after the proposed action has been implemented. The EIA is then an essential component of a long-term environmental management strategy .Referring back to Figure 1.1 , the environmental condition 'with action' (the lower curve in that diagram) becomes known up to the time of the EIA update. Because the equivalent section of the upper curve (environmental condition 'without action') in Figure 1.1 cannot readily be estimated, there is still the problem of determining the net effect of the action so far. Nevertheless, periodic reviews of the EIA after the action has been taken force the assessor to reevaluate the EIA in a holistic and non-crisis way.

One reason why EIA predictions go wrong is the fact that socio-economic values change with time. For example, the role of the automobile as a status symbol is changing in some countries.

4.7 RESOURCES AVAILABLE TO THE ASSESSOR

Of pragmatic importance is the question of the resources available to the assessor. Generally in the past, quantitative and comprehensive analyses have demanded substantial resources. In this connection, two points of view have been expressed. On the one hand, there have been occasions when a project has been over-assessed, when the analysis has included either irrelevancies (in terms of the real needs of the decision-maker) or predictions that are more detailed than warranted by the quantity and quality of the available data sets. On the other hand, White (1972) has suggested that because of the complexity of the environment, assessors have sometimes tended to fasten on to simplified approaches and methods, which may obscure the real issues or impacts. He fears that the impact statement may become a new genre of scientific fiction which could submerge bureaucratic decisions in an avalanche of obfuscating paper'. Schindler (1976) has expressed similar concerns, noting furthermore that an EIA is seldom refereed and rarely receives 'the hard scrutiny that follows the publication of scientific findings in a reputable scientific journal'. While recognizing the possibility that charlatans and hucksters may operate within the EIA system, this book is based on the premise that the assessor and the environmental scientists who assist him have a genuine desire to produce the best possible EIA within the constraints of current knowledge of environmental processes.

Any discussion of resources must recognize the two very real dangers described above: *over-complexity and over-simplicity*. Between these two undesirable extremes, there is undoubtedly a useful working range of options for selecting an approach that matches resources. The most important considerations are as follows:

-Money
-Manpower
-Time
-Knowledge
-Computational facilities

Money. Assessment costs money, but the costs of environmental assessment should not be viewed as a no-return investment. Precise details on costs are not available, even in the United States where environmental assessment has been practised extensively for some years; however, it is likely that the preparation of an Environmental Impact Statement probably absorbs about 0.1% of the capital cost of a project. This figure does not inc1ude the costs of environmental analysis at the 'screening of alternatives' and design stages. By contrast, engineering feasibility and design studies may cost as much as 10% of project capital cost.

Manpower. Environmental impact assessments are not very feasible without staff support. According to the complexity and nature of the project, the assessor should be able to draw upon the skil1s of specialists in the physical, behavioural, social, and life sciences.

Time. In some cases, analyses of sub-systems cannot be undertaken in parallel; the output from one component may be input to another. In other cases, sub- systems may require common data sets ('massaged' in different ways). These examples suggest that economies in time and money can be achieved by coordinated scheduling within the assessment team.

Knowledge. Some approaches are not suitable unless extensive data sets are available. This constraint must be recognized, as well as the cost of collection, retrieval, and quality control of existing data.

Another form of knowledge is familiarity with the environment of the action area and with the availability and quality of relevant environmental data. As a general rule, subjective approaches and methods should not be used without familiarity with local environmental conditions. Where knowledge is dispersed through many agencies and institutes, inventories of data sources and of specialist skills should be prepared at an early stage of the assessment process.

Computational facilities. The need for computational facilities will vary widely according to the nature of the proposed action and the approach adopted. Digital (and to some extent analogue) computers are almost mandatory if large data bases or simulation models are to be used. But much can be accomplished with facilities such as simple electronic or mechanical calculators and slide rules. The selected approach is, however, dependent to a certain extent upon the available computational resources.

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