Overview on Environment Impact Assessment Concepts

by: Adnan Aqeel*

* Assistant Professor – Sana'a University, Yemen; email: ben_aqeel_2005@yahoo.com

INTRODUCTION

Environmental Impact Assessment (EIA) is a rapidly developing process which originated as a result of legislation in the US in the late 1960s. It was first introduced in the USA within the framework of the National Environment Policy Act (NEPA) in 1969 which became a law on Jan 1, 1971. Then, it was adopted by the European Commission (EC), now it is European Union (EU), in 1985 and then by the United Kingdom (UK) in 1988. EIA now forms an integral part of the planning process for many types of projects. It is therefore important to understand the nature of the EIA process and to be able to select, and use, suitable techniques.

In general, environment constitutes three main subsystems:

i. Physical Environment (geology, topology, climate, water, air).
ii. Biological Environment (terrestrial and aquatic communities, rare and endangered species, sensitive habitats, significant natural sites).
iii. Socio-cultural Environment (population, land use, development activities, goods and services, public health, recreation, cultural properties, customs, aspirations) [1].

Any man-made project has commonly an impact on the environment, which has to be addressed at early stage of that project planning and design. The question here is what we mean by saying "impact". Briefly, impact may be defined as the consequences of changes in the environment because of initiation of a new project. It is crucial to distinguish between impact and effect. For instance, the increasing of pollution in the air river due to initiation a cement factory is an effect; while, the consequences of that pollution on human health, flora, fauna, etc. is the impact. However, the process of assessing that impact is called assessment.

Assessment normally does not mean doing new science, but rather assembling, summarizing, organizing and interpreting pieces of existing knowledge, and communicating them so that an intelligent but inexpert policymaker will find them relevant and helpful in their deliberations [2].

Therefore, Environmental Impact Assessment can be defined as the systematic identification and evaluation of the potential impacts (negative and/or positive effects) of a proposed project plan, program, or legislative action relative to the physical – chemical, biological, cultural and socioeconomic components of the total environment [3]. In other words, it is simply a planning tool that provides decision makers with an objective basis for granting or denying approval for any proposed development project. Accordingly, EIA ensures that any potential problem is foreseen and addressed at an early stage in the project planning and design [4].

GENERAL PROCEDURES OF EIA

Environmental impact assessments should be an integral part of all planning for major actions, and should be carried out at the same time as engineering, economic, and socio-political assessments.

In order to provide guidelines for environmental impact assessments for community, national goals and policies should be established taking at the same time environmental considerations into account. Moreover, these goals and policies should be widely promulgated. Furthermore, The institutional arrangements for the process of environmental impact assessment should be determined and made public. It is essential that the roles of the various participants (decision-makers, assessors, proponents, reviewers, other expert advisors, the public, and international bodies) be designated. In addition, timetables for the impact assessment process have importantly be established, so that proposed actions are not held up unduly; and the assessors and the reviewers are not so pressed that they undertake only superficial analyses. The general procedures of conducting and achieving EIA process are briefly listed as follows:

1. An environmental impact assessment should contain the following:

    i. a description of the proposed action and of alternatives;
    ii. a prediction of the nature and magnitude of environmental effects (both positive and negative);
    iii. an identification of human concerns;
    iv. a listing of impact indicators as well as the methods used to determine their scales of magnitude and relative weights;
    v. a prediction of the magnitudes of the impact indicators and of the total impact, for the project and for alternatives;
    vi. recommendations for acceptance, remedial action, acceptance of one or more of the alternatives, or rejection;
    vii. recommendation for inspection procedures.

2. Environmental impact assessments should include study of all relevant physical, biological, economic, and social factors.
3. At a very early stage in the process of environmental impact assessment, inventories should be prepared of relevant sources of data and of technical expertise.
4. Environmental impact assessments should include study of alternatives, including that of no action .
5. Environmental impact assessments. should include a spatial frame of reference much larger than the area encompassed by the action, e.g., larger than the 'factory fence' in the case of an engineering project.
6. Environmental impact assessments should include both mid-term and long-term predictions of impacts. In the case of engineering projects, for example, the following time-frames should be covered:

i. during construction;
ii. immediately after completion of the project;
iii. two to three decades later.

7. Environmental impacts should be assessed as the difference between the future state of the environment if the action took place and the state if no action occurred.
8. Estimates of both the *magnitude* and the *importance* of environmental impacts should be obtained. (Some large effects may not be very important to society, and vice versa)
9. Methodologies for impact assessment should be selected which are appropriate to the nature of the action, the data base, and the geographic setting. Approaches which are too complicated or too simple should both be avoided.
10. The affected parties should be clearly identified, together with the major impacts for each party [5]

EIA METHODS

There are many EIA methods; however, in choosing a suitable EIA method, the following questions should be addressed first:

Is the selected method comprehensive?

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

Is the selected method selective?

Sometimes a method is to focus on major factors. It is often desirable to eliminate as early as possible (i.e., during identification) unimportant 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 [7 & 8]. The assessor should start with the most critical human concerns, for which he formulates initial sets of impact indicators and environmental effects. However, he must be selective in his choice of additional factors to be included in the analysis of the impact of those sets. In this way, the assessment expands as time, money, and manpower permit [9].

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 from there, social for those who use the area, and ecological for those who concerned with the effects on wildlife [9].

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 [9].

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 [9].

Three methods of EIA are commonly used:

1. Leopold matrix
2. Overlays
3. Battelle environmental evaluation system

1. The Leopold Matrix Method

The Leopold matrix was developed by Dr. Luna Leopold and others of the United States Geological Survey [10]. 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 (Table1). The Leopold matrix is comprehensive in covering both the physical-biological and the socio-economic environments. 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 [9].

In terms of prediction, The method can accommodate both quantitative and qualitative data but with no 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 [9].

In terms of 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 [9].

Table 1 The Leopold Matrix (Leopold *et al.*, 1971).

PART 1: Project Actions	
A. MODIFICATION OF REGIME	**E. LAND ALTERATION**
a) Exotic flora or fauna introduction	a) Erosion control and terracing
b) Biological Controls	b) Mine sealing and waste control
c) Modification of habitat	c) Strip mining rehabilitation
d) Alteration of ground cover	d) Landscaping
e) Alteration of ground-water hydrology	e) Harbour dredging
f) Alteration of drainage	f) Marsh fill and drainage
g) River control and flow codification	
h) Canalization	**F. RESOURCE RENEWAL**
i) Irrigation	a) Reforestation
j) Weather modification	b) Wildlife stocking and management
k) Burning	c) Ground-water recharge
l) Surface or paving	d) Fertilization application
m) Noise and vibration	e) Waste recycling
B. LAND TRANSFORMATION AND CONSTRUCTION	**G. CHANGES IN TRAFFIC**
a) Urbanization	a) Railway
b) Industrial sites and buildings	b) Automobile
c) Airports	c) Trucking
d) Highways and bridges	d) Shipping
e) Roads and trails	e) Aircraft
f) Railroads	f) River and Canal traffic
g) Cables and lifts	g) Pleasure boating
h) Transmission lines, pipelines and corridors	h) Trails
i) Barriers, including fencing	i) Cables and lifts
j) Channel dredging and straightening	j) Communication
k) Channel revetments	k) Pipeline
l) Canals	
m) Dams and impoundments	**H. WASTE EMPLACEMENT AND TREATMENT**
n) Piers, seawalls, marinas, & sea terminals	a) Ocean dumping
o) Offshore structures	b) Landfill
p) Recreational structures	c) Emplacement of tailings, spoil and overburden
q) Blasting and drilling	d) Underground storage
r) Cut and fill	e) Junk disposal
s) Tunnels and underground structures	f) Oil-well flooding
	g) Deep-well emplacement
C. RESOURCE EXRACTTION	h) Cooling-water discharge
a) Blasting and drilling	i) Municipal waste discharge including spray irrigation
b) Surface excavation	j) Liquid effluent discharge
c) Sub-surface excavation and retorting	k) Stabilization and oxidation ponds

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 o) Product storage	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**

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* a) 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 a) 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	d) Landscape design e) Unique physical features f) Parks & reserves g) Monuments h) Rare & unique species or ecosystems

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 b) Wilderness qualities c) Open space qualities	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 f) Corridors
D. ECOLOGICAL RELATIONSHIPS SUCH AS:	
1) Salinization of water resources a) Eutrophication b) Disease-insect vectors c) Food chains	d) Salinization of surficial material e) Brush encroachment f) Other

2. Overlays Method

The overlay method was first suggested by Dr. Ian McHarg (1968, 1969) **[11]** 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 was employed for selecting highway corridors, by Krauskopf and Bunde [12].

The study area is sub-divided into convenient geographical units, based on uniformly-spaced grid points, topographic features and/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 and cultural groups, and/or by random sampling techniques. The concerns are assembled into a set of factors, each having a common basis (i.e., not representing conflicting concerns). Regional maps, are limited by about 10 maps (transparencies), are drawn for each factor. The land-use suitability, action compatibility, and engineering feasibility are evaluated visually, and then by a series of overlays, the best combination can be identified. The overlay approach can accommodate both qualitative and quantitative data [9].

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 [9].

In terms of prediction, because predictions are made for each unit area, the overlay method is strong in predicting spatial patterns, although weak in estimating magnitudes. 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 [9].

In terms of interpretation, Two methods are used to obtain aggregate impacts from overlays: (a) Conventional weighting, the weights being a measure of relative importance; and (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.

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.

The Battelle Environmental Evaluation System Method

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, 1973) **[13 & 14]**. The human concerns are separated into four main categories (see Table 2):

i. Ecology
ii. Physical/chemical
iii. Aesthetics
iv. 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. 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 judgments, 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 2 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 [9].

This method 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) [9].

In terms of prediction, this 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 [9].

In terms of 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 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.

Table 2 The Battelle Environmental Classification

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

-Composite effect (15) -Unique composition (15)	-Employment opportunities (13) -Housing (13) -Social interactions (11)

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 [9 & 14]

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