Department of

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Environmental Impact Assessment -EIA-

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Chapter 3

Environmental Impact Assessment

Tools and Techniques

Desirable of EIA methodologies

EIA Methods based on equality, openness, cost-effectiveness and efficiency approach and should also be:

- ✓ **Comprehensive**: Recognize intricate systems and bound complex interrelationships;
- ✓ **Selective**: Pinpoint critical (significant) impacts and eliminate as early as possible unimportant impacts;

- ✓ **Comparative**: Determine environmental changes resulting from the project compared by that occur under existing conditions;

- ✓ **Objective**: Provide unbiased measurements free from political and external influences.

Commonly Used EIA Tools

- Checklists
- Matrices
- Networks
- Map overlays
- Geographic information systems (GIS)
- Task-specific computer modeling
- Expert systems

Successful utilization of analytical tools depends on:

- Nature of the project and competence of the users.

- Scale and scope of anticipated impacts

  For example, the use of costly GIS technology and expertise may not be justified for a small project of limited environmental scope.

Some simple EIA tools used for Scoping, Prediction and Evaluation

1- Checklists

Checklists Types:

- Simple Checklists
- Descriptive Checklists
- Questionnaire Checklists
- Threshold of Concern Checklists

What are Checklists?

- Structured list to identify relevant environmental factors for consideration in EIA,
- Encourage discussion during the early stages
- Represent the collective knowledge and judgment

=== Cont. What are Checklists?

- **Ensure nothing has been left out;**
- **Do not require the clear establishment of direct cause-effect links to project activities.**
- **Checklists *cannot* represent the interdependence, connectivity, or synergism between interacting environmental components.**

Checklists Advantages:

1. Can structure initial stages of assessment
2. Help to ensure that vital factors are not neglected
3. Easy to apply, particularly by non-experts

Simple checklists **: offers simplicity for gathering and classifying information, do not provide information on specific needs for data,**

Proposed Activities	
clearing	**X**
cut/fill	**X**
dredging	**X**
blasting	**-**
Environmental components:	
Physical	
air quality	**X**
water quality	**X**
water flow	**X**
Biological	
spawning habitat	**X**
rearing habitat	**X**
Socio-economic	
fishing	**X**

Descriptive checklists:

Give guidance how to assess impact

Table 4.3 Part of a descriptive checklist.

Data required	Information sources, predictive techniques
Nuisance	
Change in occurrence of odour, smoke, haze, etc., and number of people affected.	Expected industrial processes and traffic volumes, citizen surveys.
Water quality	
For each body of water, changes in water uses, and number of people affected.	Current water quality, current and expected effluent.
Noise	
Change in noise levels, frequency of occurrence, and number of people bothered.	Current noise levels, changes in traffic or other noise sources, changes in noise mitigation measures, noise propagation model, citizen surveys.

(Adapted from Schaenman 1976)

Questionnaire checklists:

Disease vectors

a) Are there known disease problems in the project area transmitted through vector species such as mosquitoes, flies, snails, etc. ?	yes	no	not known
b) Are these vector species associated with:			
– aquatic habitats?	yes	no	not known
– forest habitats?	yes	no	not known
– agricultural habitats?	yes	no	not known
. . .			
f) Will the project provide opportunities for vector control through improved standards of living?	yes	no	not known

Estimated impact on disease vectors?

high adverse ◄---------- insignificant ----------► high benefit

Figure 4.6 Part of a questionnaire checklist. Adapted from US Agency for International

Threshold of Concern (TOC) checklists:

Environmental component	Criterion	TOC	Alt X		Alt Y		Alt Z	
			Imp	Imp > TOC?	Imp	Imp > TOC?	Imp	Imp > TOC?
Air quality	emission standards	1	2C	yes	1C	no	2C	yes
Economics	benefit: cost ratio	1:1	3:1	no	4:1	no	2:1	no
Endangered species	no. pairs of spotted owls	35	50D	no	35D	no	20D	yes
Water quality	water quality standards	1	1C	no	2C	yes	2C	yes
Recreation	no. camping sites	5000	2800C	yes	5000C	no	3500C	yes

2- Matrices

Most Commonly used Method of Impact Identification

Matrices Types:

- Simple Matrices
- Time Dependent Matrices
- Magnitude Matrices
- Quantified Matrix (Leopold Matrix)
- Weighted Matrices

What are Matrices?

- Matrices are two-dimensional tables which facilitate the identification of impacts arising from the interaction between project activities and specific environmental components.
- The entries in the cell of the matrix can be either qualitative or quantitative estimates of impact.

Environmental Components	Phase I				Phase II	
	Project Activities					
Water Quality						
Air						
Biodiversity						
Standard of living						

Matrices advantages:

- Visually describe relationship between two sets of factors,
- Expanded or contracted to meet needs of the proposal being assessed,
- Identify impacts of different phases of project, construction, operation….
- Help separate site-specific impacts from impacts affecting region

1- Simple Matrices

Environmental component	Project action				
	Construction		Operation		
	Utilities	Residential and commercial buildings	Residential buildings	Commercial buildings	Parks and open spaces
Soil and geology	X	X			
Flora	X	X			X
Fauna	X	X			X
Air quality		—		X	
Water quality	X	X	X		
Population density			X	X	
Employment		X		X	
Traffic	X	X	X	X	
Housing			X		
Community structure		X	X		X

Figure 4.8 Part of a simple matrix.

2- Time Dependent Matrices:

Environmental component	Project action				
	Construction (3 years)		Operation (25 years, evens out after 4 years)		
	Utilities	Residential and commercial buildings	Residential buildings	Commercial buildings	Parks and open spaces
Soil and geology	211	321	0000	0000	0001
Flora	221	422	1223	1111	1123
Fauna	221	311	1100	1100	1122
Air quality	000	000	0123	0034	0011
Water quality	010	022	1223	0111	0000
Population density	011	112	2344	0222	0011
Employment	120	342	1111	1334	1111
Traffic	220	332	2333	2333	1111
Housing	010	121	2344	0000	0000
Community structure	010	232	2344	1111	1233

3- Magnitude Matrices

No	Environmental Items	Rehabilitation of Wadi Gaza into a protected natural National Park *								Improvement of Agriculture Infrastructure in the Wadi Gaza Area **		
		1	2	3	4	5	6	7	8	9	10	11
. Historic and Cultural Heritage												
	Archaeological and cultural heritage sites		●	●	☺		☺	●	☺	●		●
. Human Health												
	Public and Local community health risks	☺	☺					☺				☺
	Workers health and safety	●	●	●				☺ ●		●		●
	Noise		●					●				●

Adverse Impact ●
Positive Impact ☺

3- Magnitude Matrices

Environmental component	Project action				
	Construction		Operation		
	Utilities	Residential and commercial buildings	Residential buildings	Commercial buildings	Parks and open spaces
Soil and geology	•	•			
Flora	•	●			○
Fauna	•	•			○
Air quality				•	
Water quality	○	•	•		
Population density			○	○	
Employment		○		○	
Traffic	•	•	•	●	
Housing			○		
Community structure		•	○		○

• = small negative impact
● = large negative impact
○ = small positive impact
○ = large positive impact

4- Quantified Matrix (Leopold Matrix):

Leopold Matrix lists 100 project actions and 88 environmental characteristics elements and conditions

(b)

Part 1. Project actions

A. Modification of regime
a) exotic flora or fauna introduction
b) Biological controls
c) Modification of habitat
d) Alteration of ground cover
e) Alteration of groundwater hydrology
f) Alteration of drainage
g) River control and flow modification
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, and sea terminals
o) Offshore structures
p) Recreational structures
q) Blasting and drilling
r) Cut and fill
s) Tunnels and underground structures

C. Resource extraction
a) Blasting and drilling
b) Surface excavation
c) Subsurface 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
o) Product storage

E. Land alteration
a) Erosion control and terracing
b) Mine sealing and waste control
c) Strip-mining rehabilitation
d) Landscaping
e) Harbour dredging
f) Marsh fill and drainage

F. Resource renewal
a) Reforestation
b) Wildlife stocking and management
c) Groundwater 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 and domestic
m) Stack and exhaust emission
n) Spent lubricants

I. Chemical treatment
a) Fertilization
b) Chemical de-icing 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. Natural and human environmental elements

A. Physical and chemical characteristics
1. Earth
a) Mineral resources
b) Construction material
c) Soils
d) Landform
e) Force fields and background radiation
f) Unique physical features
2. Water
a) Surface
b) Ocean
c) Underground
d) Quality
e) Temperature
f) Recharge
g) Snow, ice and 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, slumps)
h) Stress-strain (earthquakes)
i) Air movements

B. Biological conditions
1. Flora
a) Trees
b) Shrubs
c) Grass
d) Crops
e) Microflora
f) Aquatic plants
g) Endangered species
h) Barriers
i) Corridors
2. Fauna
a) Birds
b) Land animals, including reptiles
c) Fish and shellfish
d) Benthic organisms
e) Insects
f) Microfauna
g) Endangered species
h) Barriers
i) Corridors

C. Cultural factors
1. Land-use
a) Wilderness and open spaces
b) Wetlands
c) Forestry
d) Grazing
e) Agriculture
f) Residential
g) Commercial
h) Industrial
i) Mining and quarrying
2. Recreation
a) Hunting
b) Fishing
c) Boating
d) Swimming
e) Camping and hiking
f) Picnicking
g) Resorts
3. Aesthetics and human interest
a) Scenic views and vistas
b) Wilderness qualities
c) Open space qualities
d) Landscape design
e) Unique physical features
f) Parks and reserves
g) Monuments
h) Rare and unique species or ecosystems
i) Historical or archaeological sites and objects
j) Presence of misfits
4. Cultural status
a) Cultural patterns, lifestyle
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
a) Salinization of water resources
b) Eutrophication
c) Disease – insect vectors
d) Food chains
e) Salinization of surficial material
f) Brush encroachment
g) Other

Others

Figure 4.11 (a) Part of a Leopold Matrix; (b) Leopold Matrix elements.

Leopold Matrix

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 large numbers

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

Sample matrix

		Proposed actions	a. Exotic flora or fauna introduction	b. Biological controls	c. Modification of habitat	d. Alteration of ground cover	e. Alteration of ground water hydrology	f. Alteration of drainage	g. River control and flow modification	h. Canalization	i. Irrigation	j. Weather modification	k. Burning	l. Surface or paving	m. Noise and vibration	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, corridors	i. Barriers including fencing	j. Channel dredging and straightening	k. Channel revetments	l. Canals	m. Dams and impoundments	n. Piers, seawall, marinas and sea terminals	o. Offshore structures	p. Recreational structures	q. Blasting and drilling	r. Cut and fill	s. Tunnels and underground structures	a. Blasting and drilling	b. Surface excavation	c. Subsurface excavation and retorting	d. Well drilling and fluid removal	e. Dredging	f. Clear cutting and other lumbering	g. Commercial fishing and hunting
			A. Modification of regime													B. Land transformation and construction																			C. Resource extraction						
CHEMICAL CHARACTERISTICS	1. Earth	a. Mineral resources																																						
		b. Construction material																																						
		c. Soils																																						
		d. Land form																																						
		e. Force fields and background radiation																																						
		f. Unique features																																						
	2. Water	a. Surface																																						
		b. Ocean																																						
		c. Underground																																						
		d. Quality																																						
		e. Temperature																																						
		f. Recharge																																						
		g. Snow, ice and permafrost																																						

How to use a Leopold Matrix:

- ✓ **Identify all actions that are part of the proposed project**
- ✓ **Under each of the proposed actions, place a slash at the inter- section with each item on the side 0f the matrix if an impact is possible**

	a	b	c	d
a				
a				
c				

How to use a Leopold 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 IMPORT ANCE of the possible impact (e.g. regional vs. local); 10 represents the greatest': importance and 1 the least (no zeroes)

	a	b	c	d
a	- 1 / 3	+ 5 / 8		
b				
c				

5- Weighted Matrices

Environmental component	(a)	Alternative sites					
		Site A		Site B		Site C	
		(c)	(axc)	(c)	(axc)	(c)	(axc)
Air quality	21	3	63	5	105	3	63
Water quality	42	6	252	2	84	5	210
Noise	9	5	45	7	63	9	81
Ecosystem	28	5	140	4	112	3	84
Total	100		500		364		438

(a) = relative weighting of environmental component (total 100)

(c) = impact of project at particular site on environmental component (0–10)

Figure 4.12 A weighted matrix: alternative project sites.

=== cont. Weighted Matrices

	Importance weighting (a)	Treatment plant	Pumping station	Interceptor	Outfall	Total
Air quality	21	10(b)	0	50	40	15,750
		8(c)	–	7	8	
Water quality	42	100	0	0	0	37,800
		9	–	–	–	
Noise	9	0	100	0	0	2700
		–	3	–	–	
Ecosystem	28	10	20	40	30	19,320
		5	4	8	8	
Total	100					75,570

(a) = relative weighting of environmental component (total 100)
(b) = relative weighting of project component (total 100)
(c) = impact of project on environmental component (0–10)

Figure 4.13 A weighted matrix: weighted project components. Based on Wenger & Rhyner (1972).

3- Networks

- **Matrices are limited to identifying cause-effect linkages (direct impact). Network diagram visually describes these linkages, providing some indication of how an ecosystem operates.**
- **Different levels of information can be displayed in a network diagram to study the.**

===*Cont. Networks*

- **"Holistic" characteristic approach of network is to recognize series of impacts may be activated by a single project action.**
- **This method provides a guide to identification of second and third-order effects (indirect impact).**

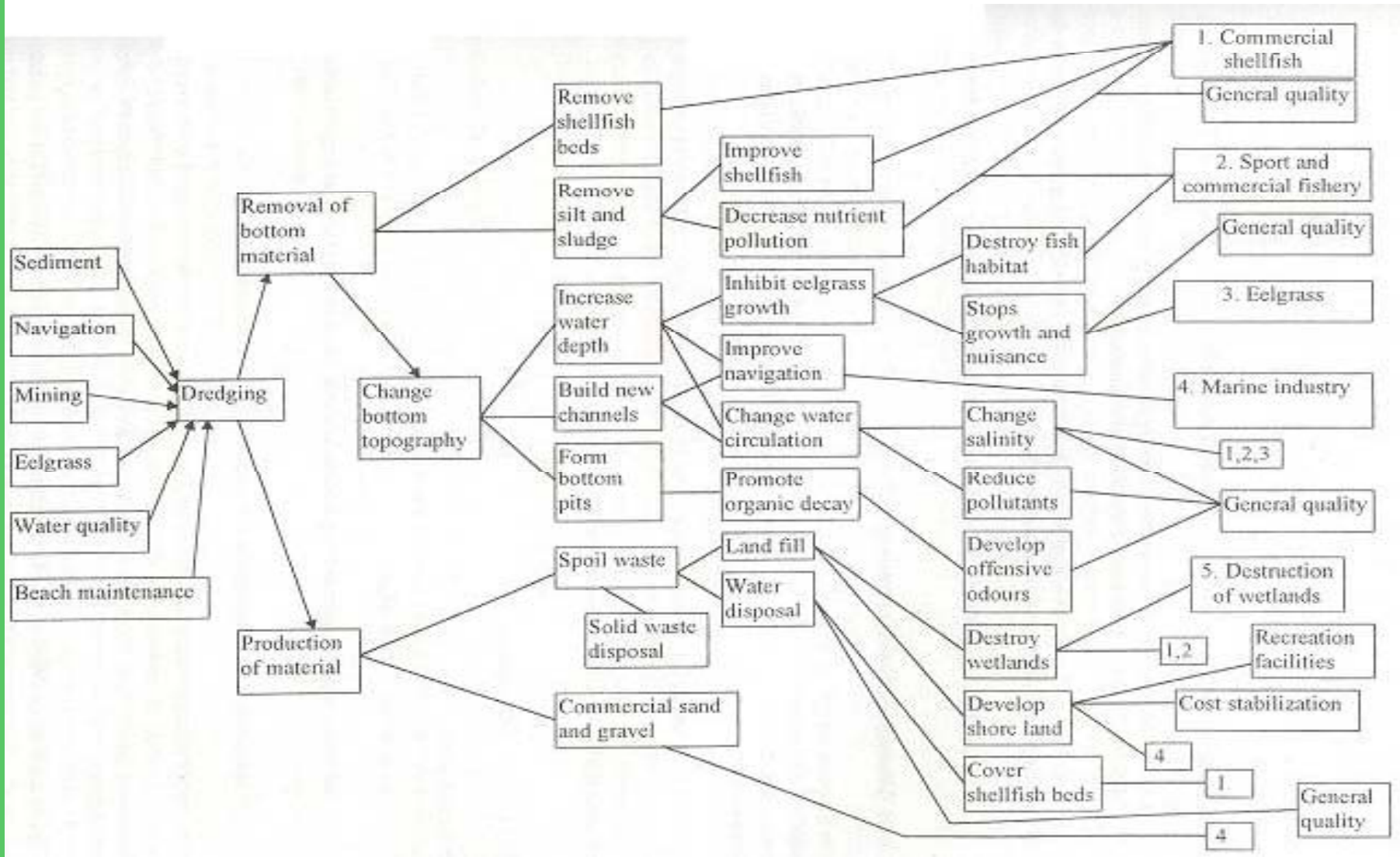
Limitations of Networks

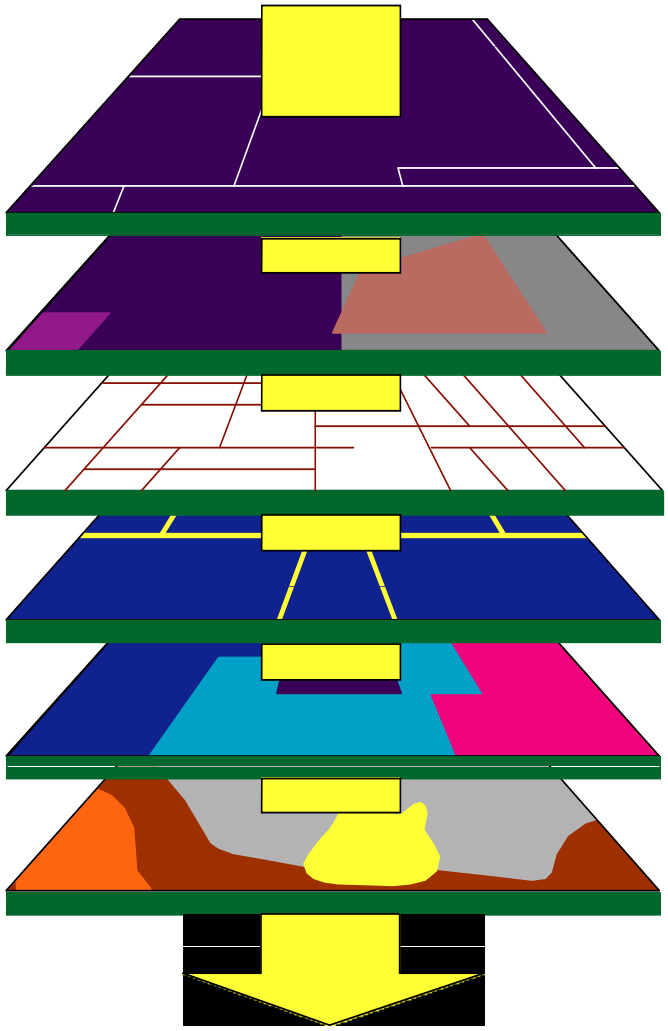
- A network may be an unnecessary and generalization of reality unless relationships between individual ecosystem components are adequately understood.
- Individual ecosystem or social system elements may not be easily recognized or found in the diagram, especially as the level of detail increases.
- Networks cannot describe temporal aspects of ecosystem dynamics.

Sorensen Network as an Example

- Sorensen network is probably the best known approach for investigating higher order impacts.
- It identifies feasible mitigation measures. Structure/ content of the network must be predefined for a particular EIA.
- Its application is limited by adequate data availability and reference networks relevant to the local environment

A Network Analysis of Dredging

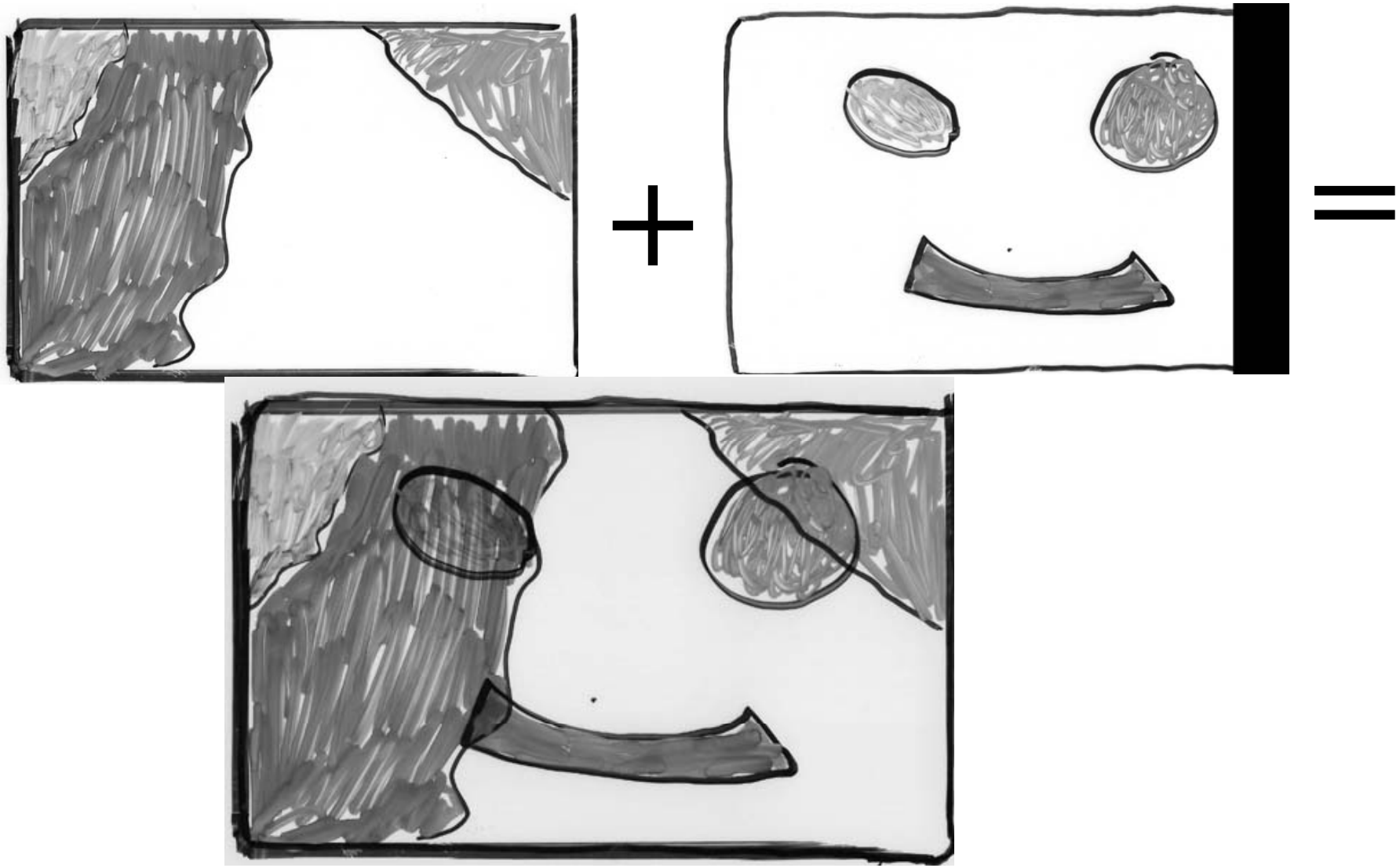




4- Map Overlays (Overlay Maps)

- An effective visual aid,
- Useful as documentation of environmental conditions existing before project implementation
- May describe both biophysical and social aspects of area under study.

Sample photo overlay



The overlay method is effective in considering:

- Sensitive lands, requiring protection from human activity (e.g., shorelines, wetlands, etc.),
- Hazard lands, requiring protection from the environment (e.g., floodplains, unstable slopes, volcanic slopes, etc.),
- Renewable resource areas, where the environment needs to be protected from human activities (e.g., aquifer recharge zones, , fish and wildlife habitat, etc.),
- Cultural heritage (areas of scientific/ educational value, historical, architectural resources).

Limitations of Map overlays:

- Maps tend to oversimplify.
- Specific interrelationships between environmental factors are not readily obtainable.
- Although "before" and "after" conditions is possible, it cannot describe ecosystem dynamics through time.

In the past, manual overlay techniques have been applied and continue to be used for analyzing small projects. For large projects, geographic information systems GIS are currently favored

5- Quantitative methods,

Advanced analytical tools

- These tools are useful in early stages for identification environmental factors and processes to be included in more advanced analysis.
- As Example, Battelle Environmental Evaluation system was designed to assess the impacts of water resource developments, water quality management plans, highways, nuclear power plats and other projects.
- The system is sophisticated checklist.

Major concerns are separated into four categories:

1- Ecology

2- Physical/ Chemical

3- Aesthetics

4- Human interest and social.

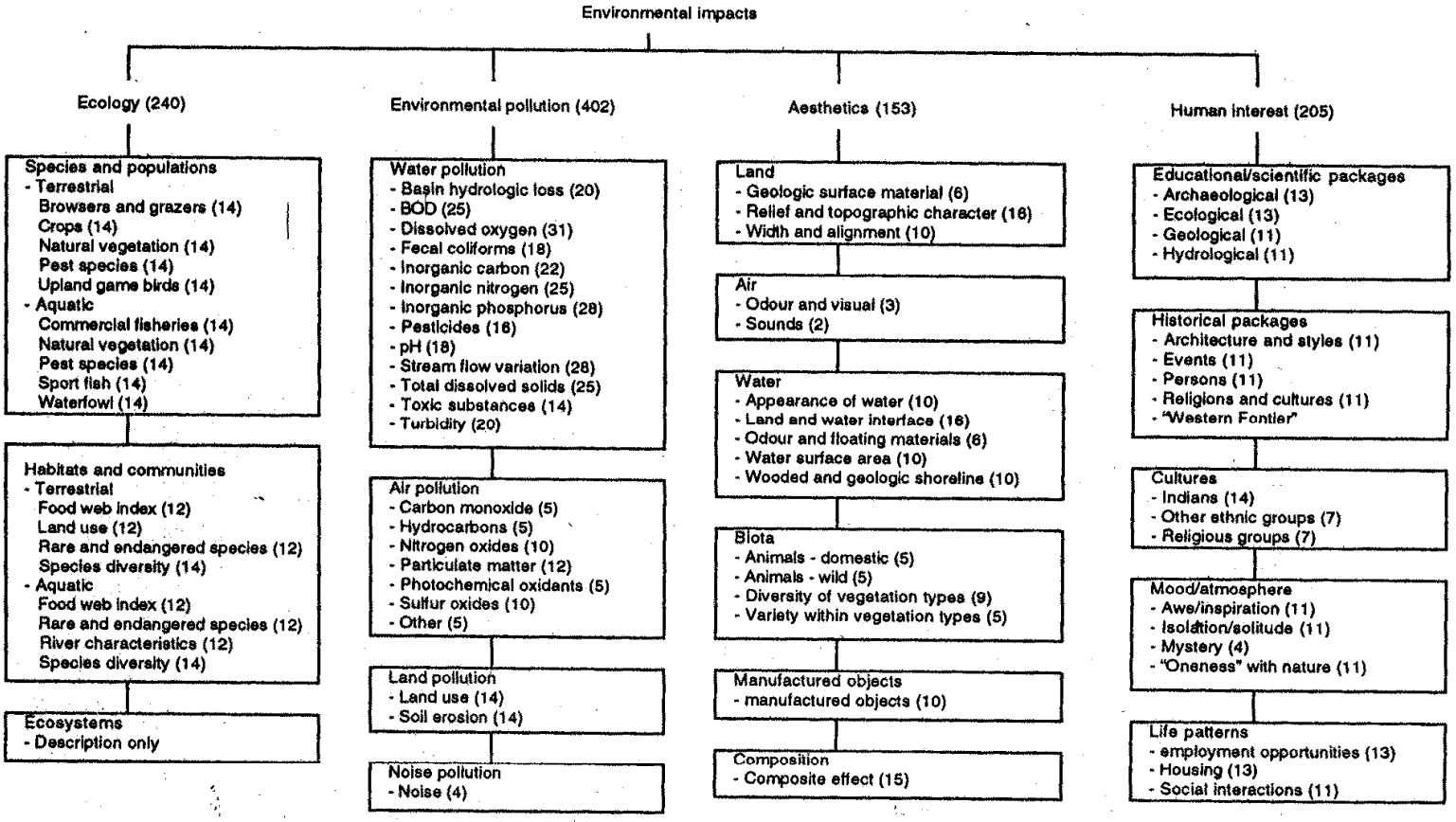


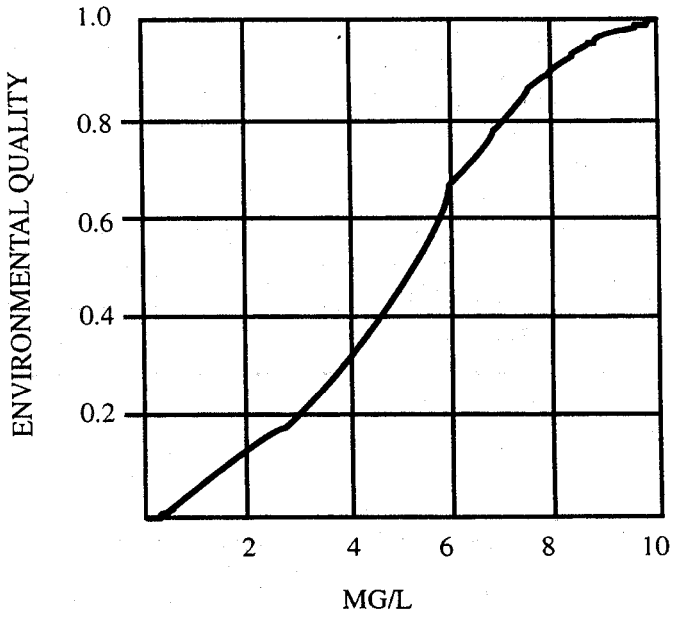
Figure 4.14 Framework for the Battelle Environmental Evaluation system. (*Source:* Dee et al. 1973.)

How to use Battelle system:

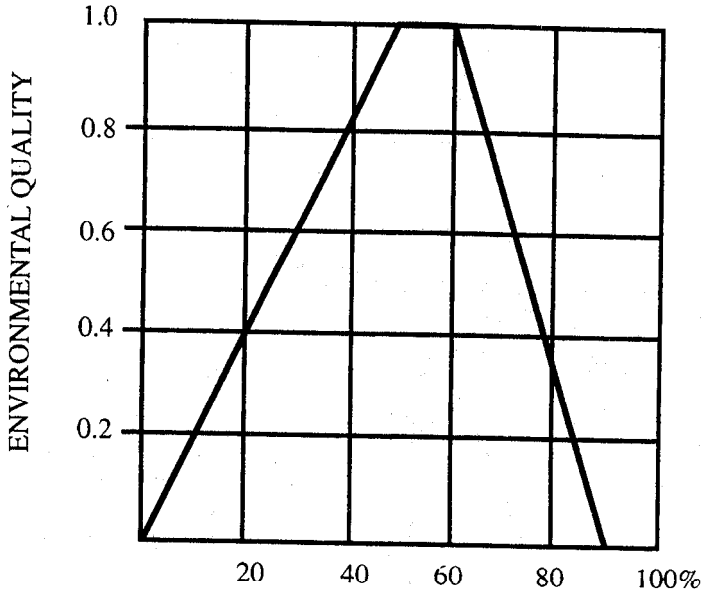
- Each category is broken down into number of environmental components.
- For each component an index of environmental quality, normalized to a scale ranging from 1 to 10 is developed.
- Environmental indicator defined as difference in environmental quality between "before" and "after" impact states.
- Each environmental component has weighting factor (relative importance).

===*Cont.* How to use Battelle system*:*

- Weights are fixed and overall impact of project alternative is calculated by summing the weighted impact indicators.



(b) Dissolved oxygen.



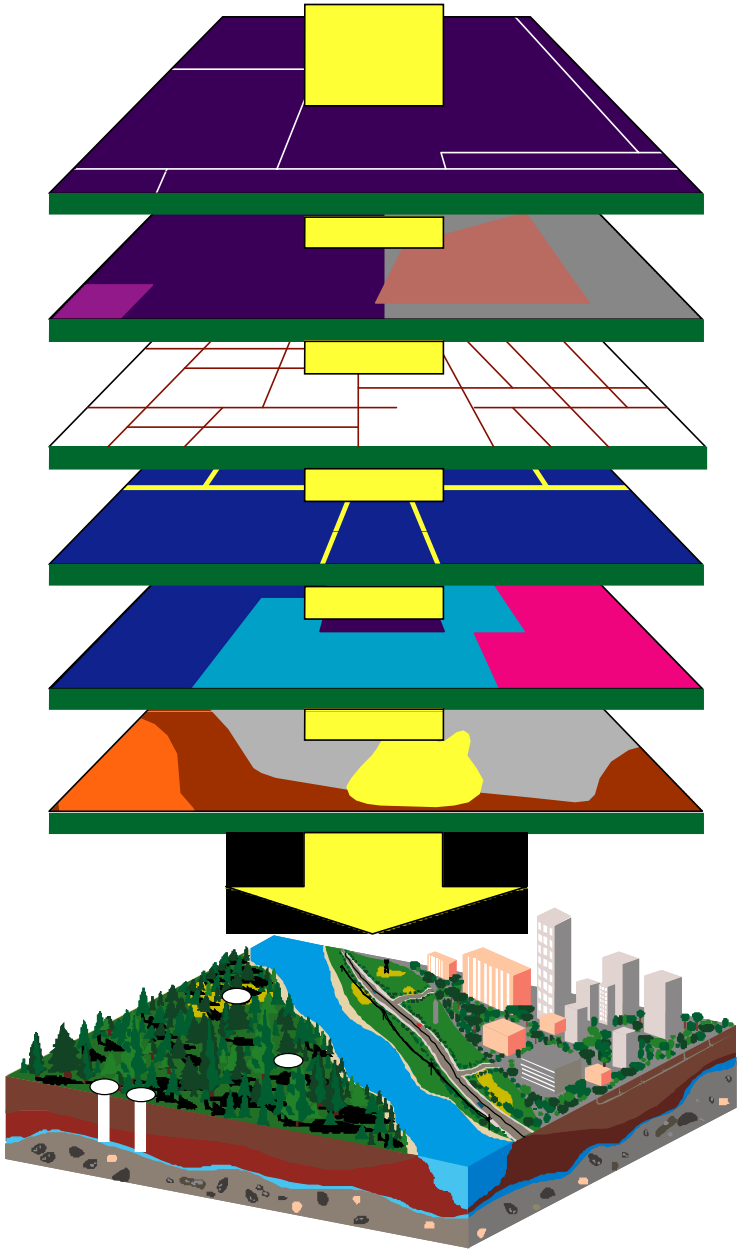
(a) Browsers and grazers

Battelle system advantages:

- Has high capability for identification and prediction of impacts and good replicability of results.
- Provides high level of detail for assessment and documentation purposes.
- Basis for the development of environmental indicators and associated weights is fully documented.

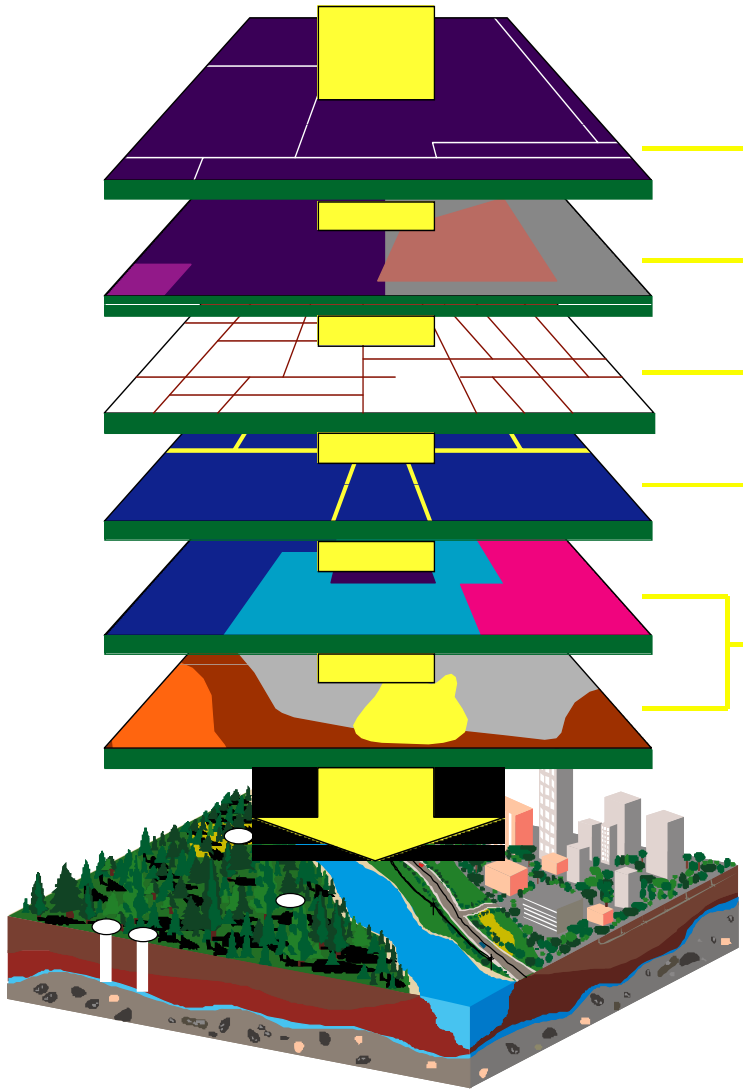
Limitations of Battelle System:

- System is applicable only to projects for which was designed; development additional indicators is demanding.
- System has no mechanism for estimating or displaying interactions between environmental components.
- System does not link impacts to affected parties or to dominant issues.
- The system has very high resource requirements (money, time, manpower skills).



6- Geographic information systems (GIS)

GIS is computer-based system incorporating collection, storage, recovery, transformation and display of spatial data



Social Factors

Biodiversity

Engineering

Land Use

Environmental Considerations

Data Layers Store Information

Geographic information systems (GIS)

1. Have potential for storing and accessing large data,
2. Can combine data from many different sources for use in geographic analysis,
3. Are efficient at performing multiple map overlays
4. Can generate descriptive and analytical statistics
5. Allow number of different scenarios to be investigated quickly and efficiently
6. Can generate maps for output

Limitations of geographic information systems in EIA:

- Many commercial GISs are expensive and require highly trained personnel
- GISs are not specifically structured for EIA
- Digital data is costly and often difficult to acquire
- A full-scale GIS is likely to contain many expensive analysis capabilities

7- Task-specific computer models

- Computer model is designed for a specific purpose. This type of modeling is most effective when environmental factors are easily quantifiable.
- While it is possible to develop such a model within a GIS, it may be more cost effective to adopt the task -specific modeling approach.

8- Expert systems

1. Expert systems are also task-specific. They may not be computer based. Expert systems incorporate the knowledge and experience of experts from relevant disciplines into a structured decision-making analytical tool.
2. In this respect expert systems attempt to mimic the human decision-making process, in which decisions must often be made on the basis of incomplete information.