EIA Methodologies / techniques

developed to

identify, predict and value changes of

an

action

Methodologies for Impact identification in an EIA

- EIA should provide the decision makers and the population with all the necessary analytical data, for their information and awareness
- the assessment has to pinpoint the important parameters to be studied esp. for large projects
- methods available to guide the EIA author:
  - The check-list method,
    - The Battelle environmental evaluation system
  - The matrix method,

- networks;
- overlays and geographic information systems (GIS);
- expert systems and professional judgment
- Mathematical Simulation models
- Multi-criteria analysis
- Flowcharts and decision trees
- Contingency analysis
- Case studies
- Economics techniques

Methods for predicting the characteristics of impacts

- best estimate professional judgement;
- quantitative mathematical models;
- experiments and physical models; and
- case studies as analogues or points of reference.

Checklist

- list all possible impacts on environmental aspects
  - **Soil**
  - **Water**
  - **Atmosphere**
  - **Flora**
  - **Fauna**
  - **Resources**
  - **Recreation**
  - **Cultural**
- can vary in complexity and purpose: simple, descriptive, and questionnaires checklists

Example of a simple checklist

Impacts	Project Phase			
	Design	construction	operation	abandonment
1. On water -Pollution -Decrease -Change in use		X	X	X
2. On air -Pollution				
3. On Climate -				
4. On soil -				
5. On vegetation and fauna -				
6. On Population -				

Checklist: impact identification

Issue	Will the project:	Yes	May be	No	Observation
Noise	- increase existing noise levels?				
Vegetation	- Change the diversity or productivity of species or the number of any species (including trees, shrubs, aquatic plants, etc)				
Energy	- Use substantial amounts of energy?				
Transport and Traffic	- Generate additional traffic? - Have effects or increase demand on parking infrastructures?				
Public services	have effects on, or result in, need for new services or changes in the following areas: • Fire services?				
Public reaction	Potential controversies? Conflict with objectives in environmental plans locally adopted?				

Questionnaire checklist

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

Descriptive Checklist

Key criteria	Key Environmental sources
Air and climate changes	Air quality levels Sulfur dioxide levels CO_2 emission
Protected Areas	Designated areas (ha) under national or international protection (for example Natura 2000 – Special Conservation Areas and Special protection Areas
Natural resources	.....
Water	.....
Soil	.....
Landscape	.....
Noise	.....
Coastal areas	.....

Part of a descriptive Checklist

Data Required	Information Sources, predictive techniques
Nuisance Change in occurrence of oduor, 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

Threshold checklist

- Consist of a list of environmental components and, for each component, a threshold at which those assessing a proposal should become concerned with an impact.
- The implication of alternative proposals can be seen by examining the number of times that an alternative exceeds the threshold of concern.

Environmental Component	Criterion	TOC	Alt Imp	X Imp > TOC?	Alt Imp	Y Imp > TOC?	Alt Imp	Z 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
Endaged 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

Checklist characteristics

- structured list of key potential factors for analysis or key impacts
- often result from experts judgment published by public / international organizations;
- enable interdisciplinary discussions;
- preparatory stage for matrix assessment (checklist of actions /activities and checklist of environmental components);

Checklist cont'

- In the design of a checklist consider:
  - various sectors of activity (industries, forestry, agriculture…)
  - different types of areas affected (wetlands, tropical forests, coastal zones…)

Disadvantage

- Check-lists are good tools but they cannot take into consideration all particular cases that can be met during an EIA.
  - Guided tour - standard analysis, misses specific issues
- Generally sufficient for small scale projects.
- must be exhaustive if no serious impact is to be overlooked
- not as effective in identifying higher order impacts or the inter-relationships

Scaling Checklist

- rank the impact and alternatives according to their significance
- indicates relative importance of individual environmental aspect
- total ranking calculated for all versions of the project

Matrices method

- matrix serves as a checklist and a summary of the impact assessment
- they link a particular environmental aspect (effect) to a specific action (cause) of the development project
  - i.e. explain the nature of the impact
- Matrices provide a 2D matrix cross-referencing:
  - Project Activities (cause impacts on man or env.)
  - The existing Env. and social conditions (possibly affected by the project)

Matrices cont.'

- A simple interaction matrix is formed where project actions are listed along one axis while Env. Conditions are listed along the other axis
- The environmental and social conditions are divided in 3 major groups:
  - physical conditions: soil, water, air…,
  - biological conditions: fauna, flora, ecosystems…,
  - social and cultural conditions: land use, historical and cultural issues, populations, economy

Impact identification matrix *(example)*

	ENVIRONMENTAL FACTORS	PROJECT ACTIONS HAVING THE POTENTIAL TO CAUSE AN IMPACT																		
		A1 Modification of industrial site	A2 Modification of industrial buildings	A3 Modification of property limits	A4 Demolition of buildings	A5 Construction of new buildings	A6 Landfills and earth movements	A7 Silting and drainage	A8 Recycling of wastes	A9 Transport of materials	A10 Handling of hazardous radioactive or toxic materials	A11 Emission of liquid and gaseous effluents	A12 Use of rubble tips or solid inert waste tips	A13 Storage of solid radioactive wastes	A14 Fires	A15 Releases or leakage of contaminating liquids or gases	A16 Operating failures	A17 Personnel accidents	A18 Structural failures due to external events	A19 Monitoring and control operations
PHYSICAL MEDIUM	E1 AIR				X	X	X			X		X			X	X			X	
	E2 LAND AND SOIL	X	X	X	X	X	X	X	X			X	X	X		X			X	
	E3 WATER							X				X	X	X		X			X	
	E4 FLORA											X	X	X		X			X	
	E5 FAUNA											X	X	X		X			X	
	E6 LANDSCAPE		X		X	X	X						X	X	X					
	E7 NOISE AND VIBRATION	X	X		X	X	X			X			X						X	
SOCIO-ECONOMIC MEDIUM	E8 LAND USE	X		X	X	X							X	X		X			X	
	E9 CULTURAL FACTORS	X																		
	E10 INFRASTRUCTURE									X										
	E11 HUMAN FACTORS				X	X	X			X	X	X	X	X	X	X	X	X	X	X
	E12 POPULATION AND ECONOMY	X							X										X	

- Entries are made in the cells to highlight impact severity or other features related to the nature of the impact:

- For instance:
  - ticks or symbols can identify impact type (such as direct, indirect, cumulative) pictorially;
  - numbers or a range of dot sizes can indicate scale; or
  - descriptive comments can be made

Sectoral Matrix Example

Valued Env. Component (VEC) / Development Projects	Surface Water Quality	Air Quality	Seismology/Geology	Erosion	Land Quality	Fisheries	Forests	Terrestrial Wildlife	Noise	Land Use	Aesthetics	Industries	Resettlement	Archaeological/Historical	Public Health	Socioeconomic
Ports and Harbours	●	●		●		●			●			●	○		○	●
Airports			●						●				●		○	●
Rapid Transit			○	●	○		●	●	●	●		●	●	●	○	●
Highways		●	●	●		●	●	●	●	●	○	○	●	○	○	●
Oil/Gas Pipelines			●	●	●	●	●	●	●	○	●	○	●		●	○	●

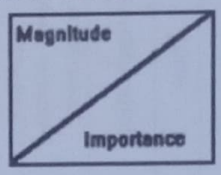
● Significant Impact ● Moderate - Significant Impact ○ Insignificant Impact

matrices

- Matrices can be used creatively to identify indirect impacts, cumulative impacts or contributions to mitigation measures
- A common matrix method is the Leopold matrix for predicting the impact of a project on the environment
- It proposes a 3 step process to estimate the impact:

Leopold Matrix steps

- **1st step** :
  - for all the interactions considered significant, the corresponding boxes in the matrix are marked with a diagonal line.
- **2nd Step:**
  - For each significant interaction, evaluation of the magnitude is done by applying a number from 1 (min) -10 (max), on the upper left hand corner.
  - It represents the scale of the action and its theoretical extent.
- **3rd Step:**
  - Involves marking the real importance of the phenomenon for the given project.
  - Values (from 1 to 10) are marked in the lower right hand corner, indicating the evaluation of the extent of the environmental impact according to the assessor's judgement.



Leopold matrix

- 100 causes per 100 effects.
- Magnitude (left-hand corner) and
- Importance or significance (right-hand corner). Scale 1 to 10.
- Values can still be signaled as positive ("+") or negative ("-").

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

Leopold matrix

- Once the matrix is established the EIA gives a precise description of each important impact in the matrix
- Highlight columns and rows with large numbers of interaction
- show activities which are particularly significant or sensitive to the environment
- Need to develop a customized matrix for a project (not precise, too detailed)
- Example of a Leopold matrix (Pulp & paper industry)

				ACTION											
				raw material production	building Operations	water supply	energy supply	raw material preparation	Industrial processes	gaseous emissions	liquid effluents	cooling water discharges	Solid wastes treatment	transportation	Total
ENVIRONMENTAL / SOCIAL CONDITIONS	PHYSICAL	SOIL	Soil Quality												
			erosion												
			Geomorphology												
		WATER	Rivers												
			Coastal zone												
			Subsurface water												
			Sea Quality												
		AIR	Air Quality												
			Odours												
			Noise												
	BIOLOGICAL	FLORA	Forests												
			Crops												
			Wetlands												
			Sea-Grasses												
			River Flora												
		FAUNA	Mammals												
			Birds												
			Fish												
			Other Vertebrates												
			Invertebrates												
		ECOSYSTEMS	Ecosystems Quality												
			Ecosystems Destruction												

				ACTION											
				raw material production	building Operations	water supply	energy supply	raw material preparation	Industrial processes	gaseous emissions	liquid effluents	cooling water discharges	Solid wastes treatment	transportation	Total
ENVIRONMENTAL/ SOCIAL CONDITIONS	SOCIAL	LAND USES	Rural												
			Fisheries												
			Urban												
			Industrial												
			Recreational Uses												
		PATRIMONY	Landscape												
			Historical/ Cultural												
			Heritage												
			Wilderness Quality												
		SOCIAL	Population Density												
			Employment												
			Hazards												
	TOTAL														

Leopold matrix

- Once the matrix is established the EIA gives a precise description of each important impact in the matrix (with the larger numerical values for magnitude and importance).
- The discussion must also address columns and rows with large numbers of interactions.
  - They show activities, or elements, in connection with the environment which are particularly significant or sensitive.
- Is a comprehensive matrix; has 88 environmental characteristics along the top axis and 100 project actions in the left hand column
  - total entries = 8,800

Matrices (summary)

- Double entrance tables, permit establishment of relationships:

1. Project actions or activities (causes)
2. The environmental factors (effects)

Functions:

- Preliminary identification of impacts (scoping)
- Comparative analysis of alternatives
- Impact assessment
- Presentation of evaluation results

NB: the Leopold matrix proposes a framework for all developers, but there may be need to customize the matrix to suit a specific project

The Batelle Env. Evaluation method

- 1st designed for water resource development but adopted to other projects
- It splits the env. Impacts into 4 main categories:

Ecology
Species and populations,
Habitats and communities,
Ecosystems.

Human interest
Educational/scientific packages,
Historical packages,
Cultures,
Mood/atmosphere,
Life patterns,
Composition.

Pollution
Water pollution,
Air pollution,
Land pollution,
Noise pollution.

Aesthetics
Land,
Air,
Water,
Biota,
Man made objects,
Composition.

Steps in the Batelle Evaluation method

- 1st: Choice of environmental indicators for the thematic data e.g.
  - water pollution could be represented by: BOD, dissolved oxygen, faecal coliforms, inorganic carbon, pH, temperature, total dissolved solids, turbidity, etc.
- 2nd : transform environmental indicators into environmental quality
  - The notation table defines a number from 0 to 1 (0 for poor quality and 1 for good quality).
  - Thus it is possible to quantify evolution both in the wrong or right direction (environmental deterioration or improvement).

- 3rd: a total of a 1,000 points (or Parameter Importance Units : PIU) are shared among the indicators i.e.
  - They reflect the relative importance of each parameter.
- 4th: comparison between the situation with and without the project is done in Environmental Impact Units (EIU).
  - It can even reflect benefits or losses in terms of environmental conditions.

$$EIU = \sum_{i=1}^{m} (Vi)_1 w_i - (Vi)_2 w_i$$

- Where:
  - $(Vi)_1$ environmental quality for indicator "i" in the project conditions,
  - $(Vi)_2$ environmental quality for indicator "i" without the project,
  - w_i relative weight of the indicator "i" (PIU),
  - m total number of indicators.
- Adv. of this method:
  - it gives a comparative analysis between several situations, thus helps when effecting choices between alternatives.

Flowcharts (Impact trees, network diagrams)

- They enable the analysis of the inter-relationship between causes and effects,
  - hence enables the analysis of indirect and cumulative impacts.

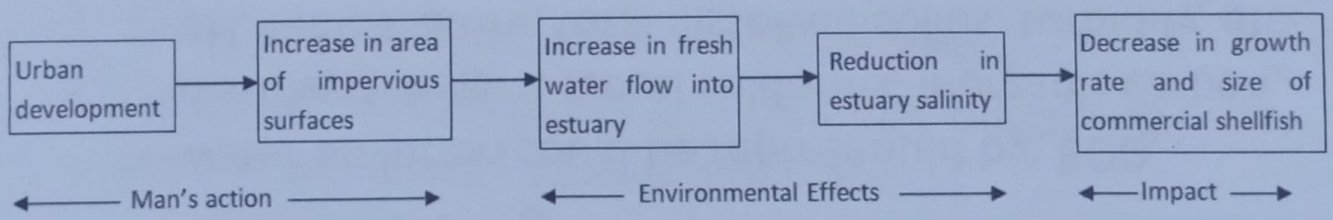
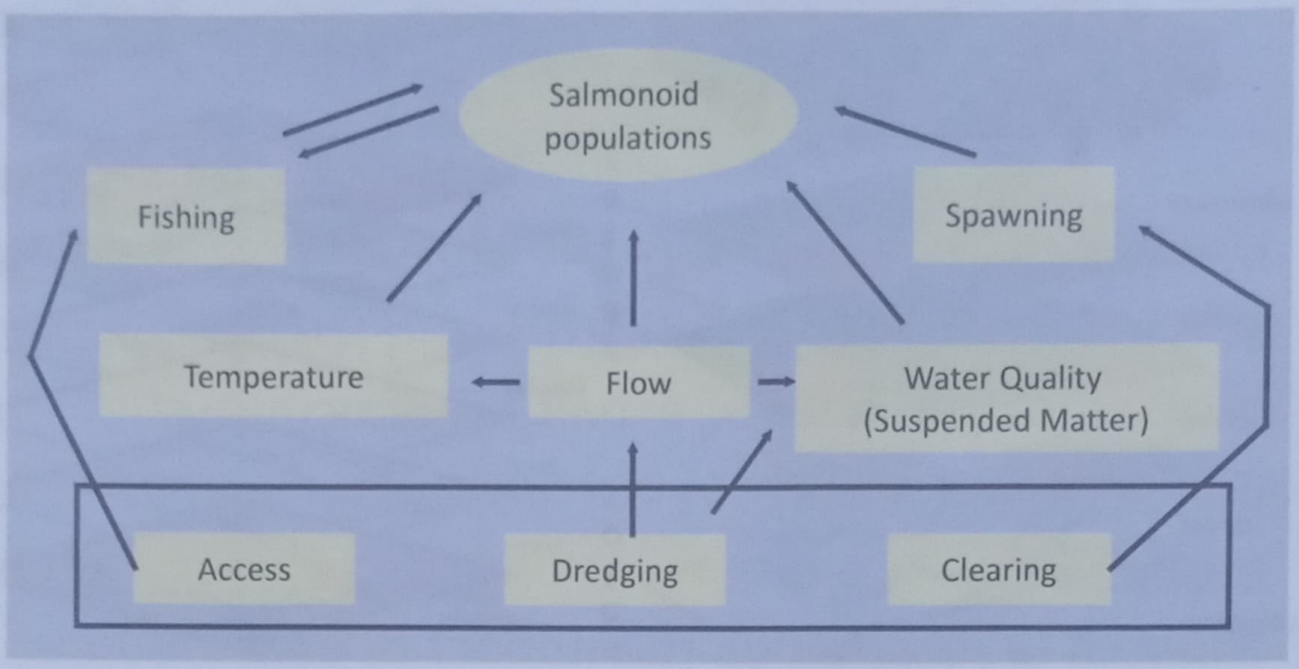


Figure: Flow-chart illustrating impact identification (source: Sorensen, 1971)

Example of a Network Analysis



Example 2: Network analysis

Flowcharts / networks analysis

Advantages:

- - integrated assessment, instead of discipline by discipline
- - inter-relations between causes and effects, including indirect impacts,
- - cumulative impact assessment
- - communication (when simple).

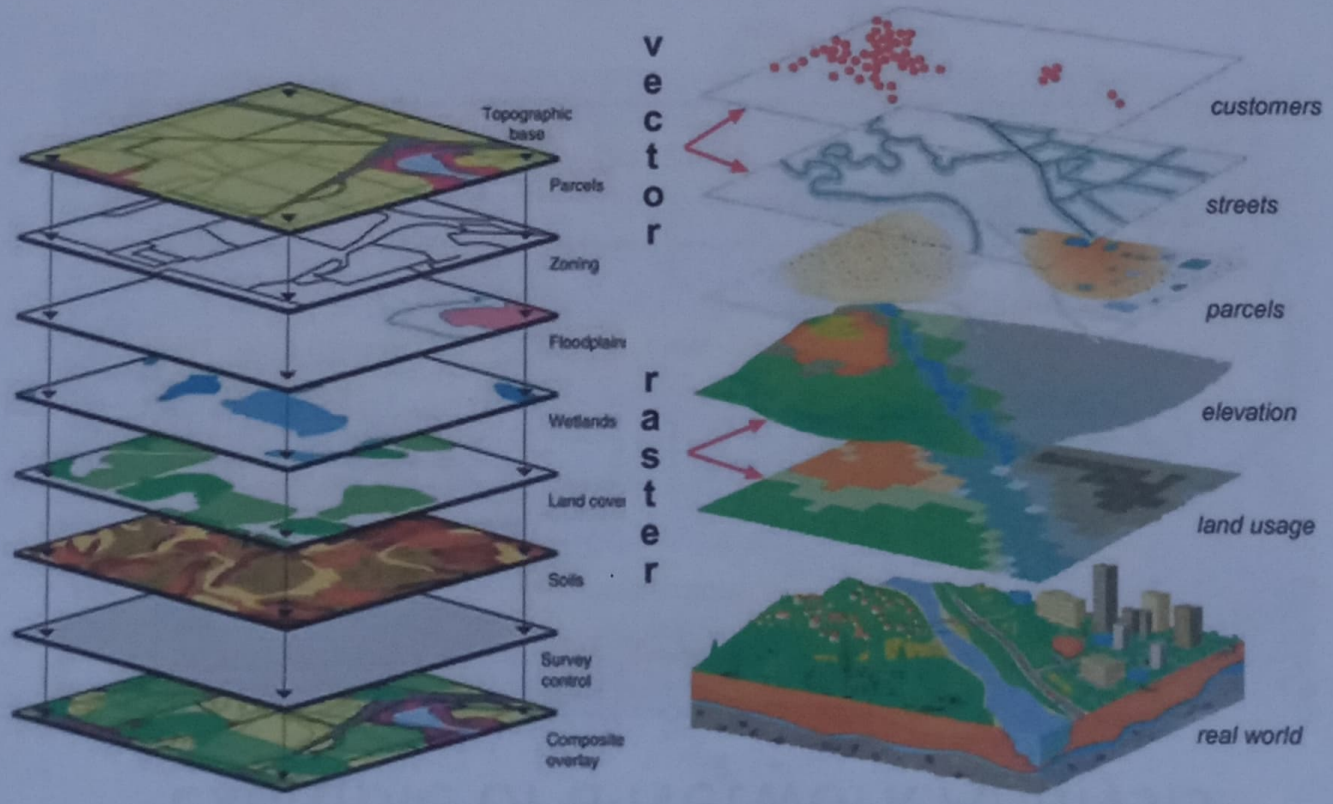
Disadvantages

- complexity (especially visually complex)
- - difficult to distinguish and quantify magnitudes (and importance) of different impacts

Overlays:-Mc Harg(1968,69)

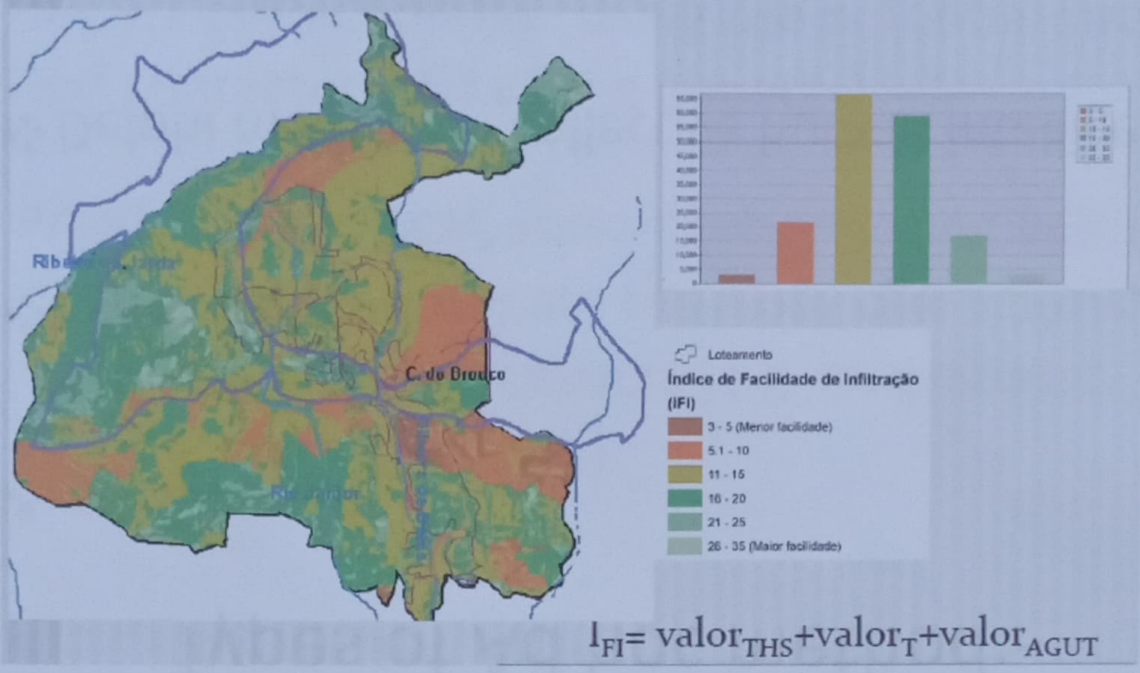
- Rely on a set of maps of a project area's environmental characteristics covering physical , social, ecological, aesthetic aspects.
- Separate mapping of critical environmental features at the same scale as project's site plan
  - e.g. wetlands, steep slopes, soils, floodplains, bedrock outcrops, wildlife habitats, vegetative communities, and cultural resources...
- Older Technique: environmental features are mapped on transparent plastic in different colors.
- Newer Technique: Geographic Information Systems (GIS).

Overlays and GIS



GIS impact identification/analysis

Definition of areas of maximum infiltration



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Specialized software e.g. "Ecozone"

- suitable in forecasting the impact of development projects
- It allows the analysis of possible impacts of a project for 5 groups of activities: agriculture, aquaculture, forestry, livestock and H_2O resources
- Follows FAO classification for ecozones:

- Upland humid,	Upland arid,
- Lowland humid,	Lowland arid,
- Coastal humid,	Coastal arid.

Ad hoc Method:-

- Simple method based on subjective environmental impacts on broad aspects.
- Ad hoc method is useful when time constraints and lack of information require that the EIA must rely exclusively on expert opinion.
- It provides minimal guidance for total impact assessment while suggesting the broad areas of possible impacts and the general nature of these possible impacts.
- When more scientific methods are available, it is not recommended.

Types of Ad hoc method:-

- Opinion polls.
- Experts opinion.
- Delphi methods – collective human intelligence

Impact Analysis/Prediction

- Impact identification stage provides data for impact prediction (i.e. using the potential size and characteristics of the impacts)
- Physical, biological, socio-economic and cultural data is used to estimate the likely characteristics and parameters of impacts (e.g. magnitude, spatial occurrence, etc.)

Impact prediction

- A range of methods and techniques may be employed: simple to complex mathematical models

Type of methods:

- Experts opinion
- Case comparison
- Use of models e.g. ecological, hydrological, air dispersion models
- Experiments

Prediction of impacts - models

- **Physical models** – representation of the reality in a reduced scale, simulating processes. (Exs. Wind tunnels or coastal area physical models that simulate waves)
- **Visual models** – elaboration of images that represent the environment before and after the development of a project and its alternatives. It can also address the timing dimension (*e.g.*, seasonal changes, vegetation growth).
- **Mathematic models**- maths or statistic simulations applied to the deterministic or probabilistic calculation, based on quantitative values.
- **Cartographic models**- representation of reality that will be affected by the project through maps or charts. Cartographic overlaps enable impact preditions.