

# Sustainable Engineering

## Module 3

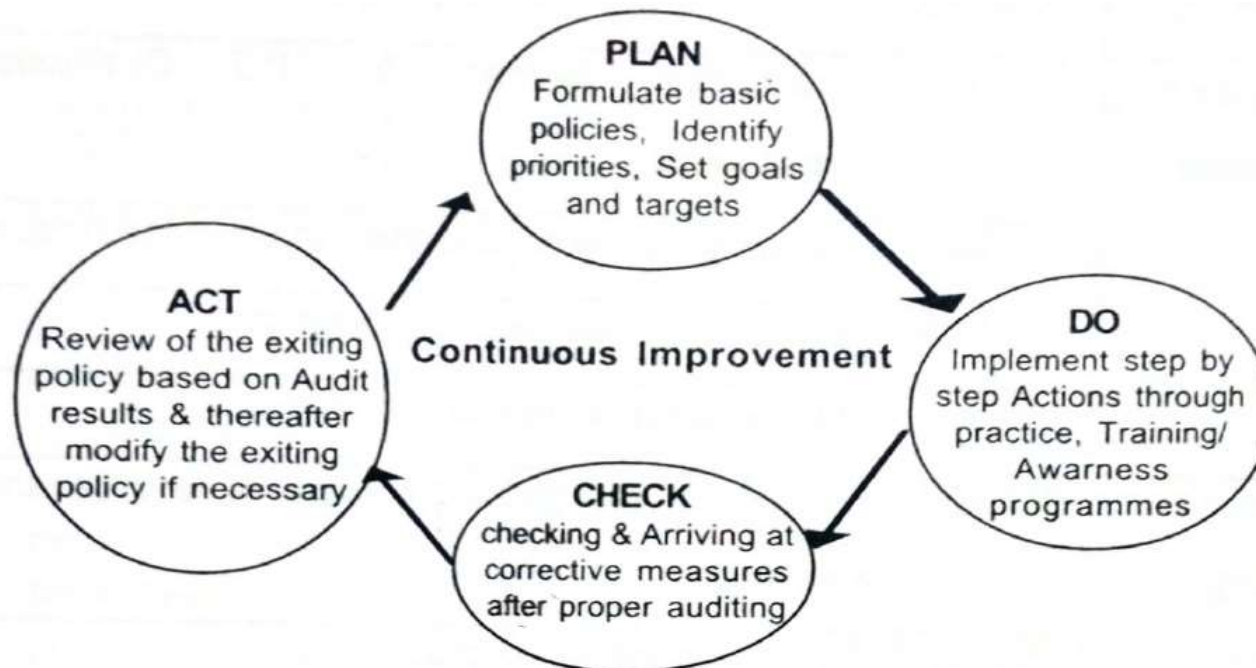
**Naveen Jacob**  
Associate Professor  
Dept. of ECE  
VJCET

## Environmental Management System & Standards (EMS)

- ❖ Harmony between man and environment is the essence of environmental management.
- ❖ Both economic development and conservation of our natural resources should go hand-in-hand.
- ❖ Proper planning right from the beginning can protect the environment in a sustainable way, which is the main intension behind implementation of Environmental Management Systems (EMS).
- ❖ EMS mainly serves the following functions:
  - i. Restricts over-exploitation of natural resources
  - ii. Improves environmental performance by the industry
  - iii. Meets regulatory and legislative requirements
  - iv. Focuses on continuous improvement of the system
  - v. Enhances employee morale
  - vi. Enhances image of organization among the public

## Basic EMS framework

- ❖ This follows Plan-Do-Check-Act (PDCA) cycle (also called Deming-Shewhart PDCA model).
- ❖ It is an iterative four step method used to identify a problem and solving it.



## ISO 14000 Series

- ❖ The International Organization for Standardization (ISO) (Headquarters in Geneva, Switzerland) developed a series of international recognized standards known as ISO 14000 to help organizations to meet their environmental performance
- ❖ ISO 14000 specifies only “how to achieve the goal” and not “what goal is to be achieved”
- ❖ Hence ISO 14001 has been introduced, which is the document containing requirements.
- ❖ Various standards in ISO 14000 series falls in to two major groups :
  - i. Organization based standards
    - Provides comprehensive guidance for the implementation and evaluation of the Environment Management System. ISO 14001 series, ISO 14010 series and ISO 14030 series are some of the standards which are included in this category.
  - ii. Product based standards
    - Provides comprehensive guidance for determining both the environmental impacts of products and services over their life cycle along with environmental labels. ISO 14020 series, ISO 14040 series and ISO 14060 series are some of the standards which are included in this category.

- ❖ An **EMS** is "a system and database which integrates procedures and processes for training of personnel, monitoring, summarizing, and reporting of specialized environmental performance information to internal and external stakeholders of a firm".
- ❖ **Environmental auditing** is essentially an environmental management tool for measuring the effects of certain activities on the environment against set criteria or standards. Depending on the types of standards and the focus of the audit, there are different types of environmental audit.
- ❖ "**Ecolabelling**" is a voluntary method of environmental performance certification and labelling that is practiced around the world. An ecolabel identifies products or services proven environmentally preferable overall, within a specific product or service category.



- ❖ **EPA** regulations cover a range of environmental and public health protection issues, from setting standards for clean water to specifying clean up levels for toxic waste sites to controlling air pollution from industry and other sources.

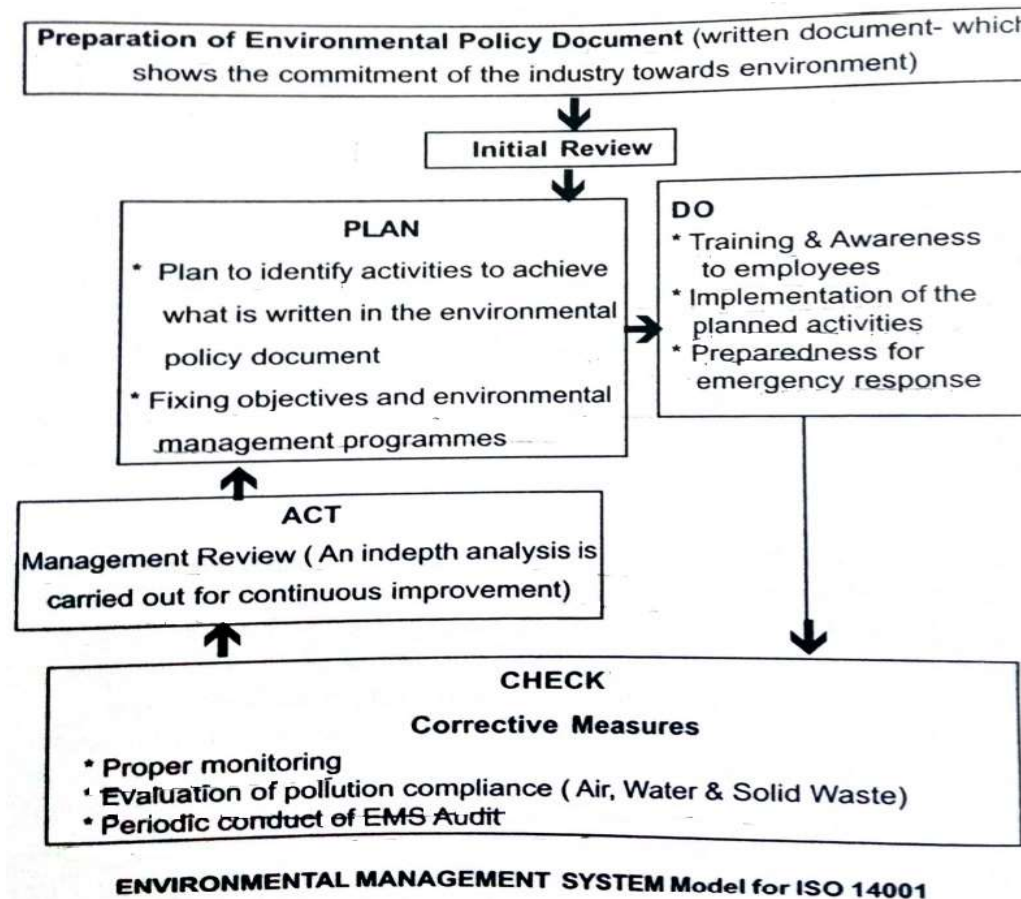
Category	Standard	Name of Document
Environment Management Systems	ISO 14001	Specification document for ISO Certification requirements
	ISO 14004	General guidelines on principles, system and techniques
	ISO 14006	Guidelines for incorporating eco-design
	ISO 14063	Environmental communication guidelines
Environment Auditing	ISO 14010	Guidelines and general principle of environmental auditing
	ISO 14011	Guidelines and auditing procedures
	ISO 14012	Qualification criteria for environmental auditors
	ISO 14015	Assessment of site and organizations
Environmental labelling	ISO 14020	General principles
	ISO 14021	Self declaration claims-terms and definitions
	ISO 14022	Self declaration claims- symbols
	ISO 14023	Testing and verification methodologies
	ISO 14024	Practitioner programmes- certification procedures
	ISO 14025	Environment information profiles
EPA*	ISO 14031	Guidelines

## **Benefits of Implementing EMS**

- ❖ **Improved environmental performance** : Enhances energy, waste reduction and pollution prevention.
- ❖ **Enhanced compliance** : Complying with existing environmental laws and legislations
- ❖ **Increased efficiency and reduced costs**
- ❖ **Competitive advantage in the global market** : Now a days consumers are giving preferences to products from environmentally responsible suppliers (ie; industries which have implemented EMS)
- ❖ **Improved image for organization among the public**
- ❖ **Enhanced employee morale**
- ❖ **Reduced risk potential**
- ❖ **Pollution reduction and resource conservation**

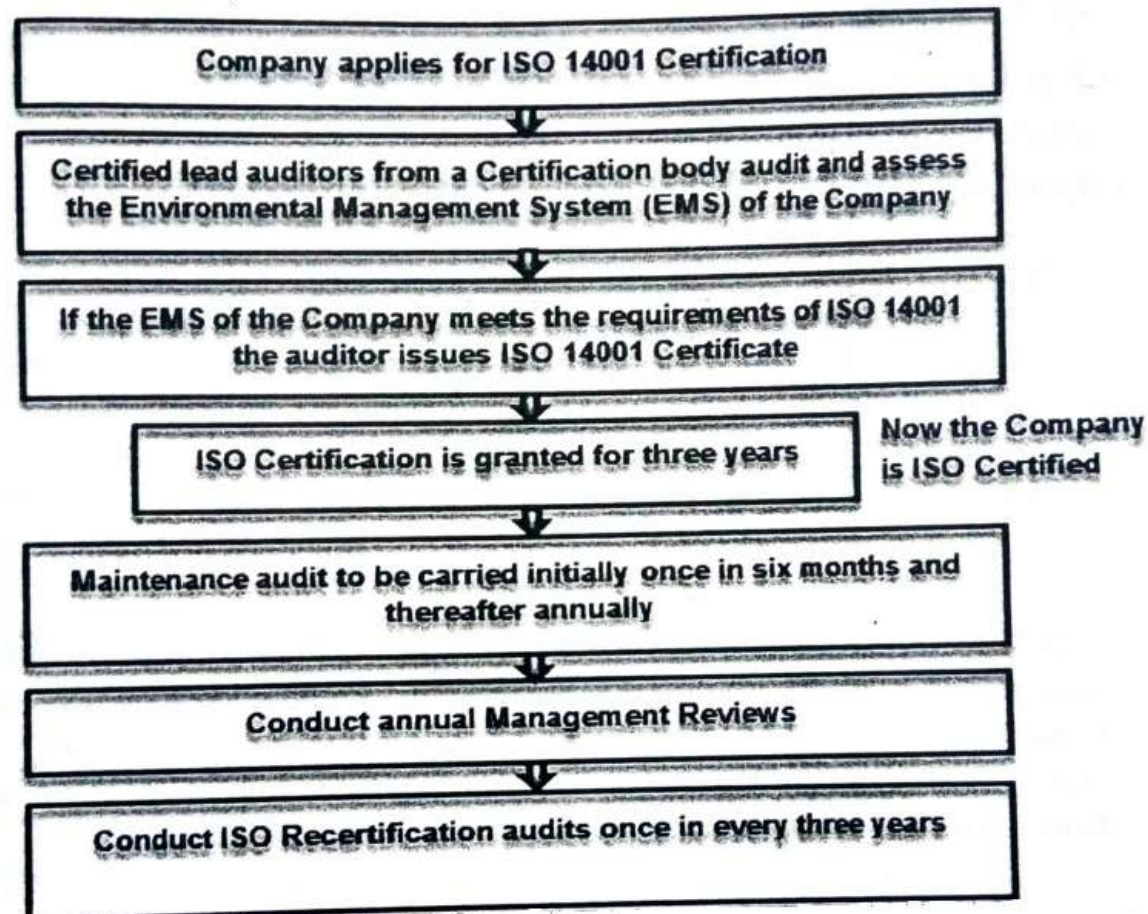
## ISO 14001

- ❖ ISO 14001 is the world's most widely used standard and contain the document for EMS with guidelines. It is auditable and also “voluntary” in nature (do not include legal requirements and comply with national laws).
- ❖ Typical EMS model for ISO 14001 is shown below :



## Certification for EMS

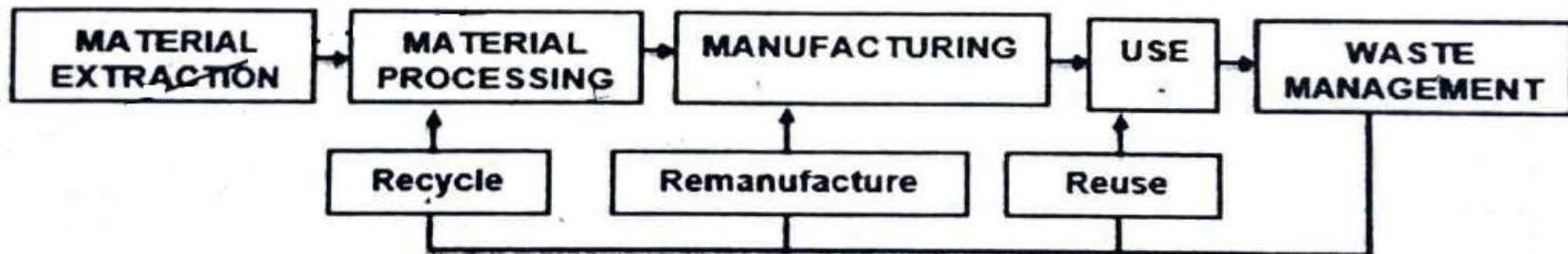
- ❖ ISO 14001 is the only standard in the series, by which organization can be certified by a third party.
- ❖ The procedure for getting EMS certification is given below:





## Life Cycle Analysis or Life Cycle Assessment (LCA)

- ❖ Life Cycle Assessment (LCA) is an environmental management tool which helps us to determine the environmental impacts of a product or proposed activity throughout its entire life cycle
- ❖ Life cycle of a product :
  - Raw material extraction
  - Raw material is processed and transported to manufacturing unit
  - Product is packed, transported and distributed to consumers
  - Consumer uses the product and once the useful life (after use, repair and maintenance), it is finally dispose off.
- ❖ Thus LCA can be defined as “the compilation and evaluation of the inputs, outputs and the potential impacts of a product or any activity throughout its life cycle.

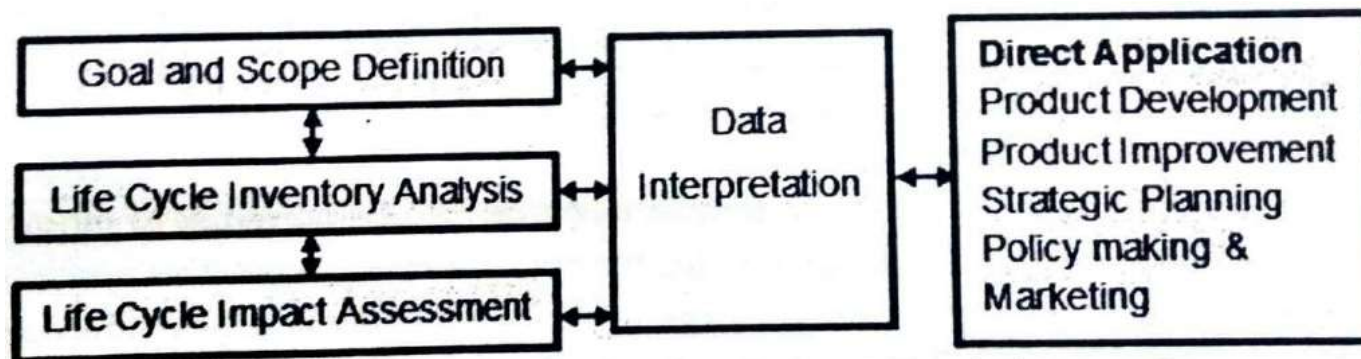


## Why conduct LCA?

- ❖ LCA of a product or activity helps us to identify, those stages in the life cycle, which causes harm to the environment.
- ❖ LCA can be used to compare the pollution potential of two products having same use in the market, thereby, decision can be taken by government to, either ban the product which causes maximum pollution to the environment or to promote the product which causes least harm to environment.

## Basic components (stages) in LCA process

- ❖ According to ISO 14040 series standards, LCA is carried out in 4 stages, shown below:

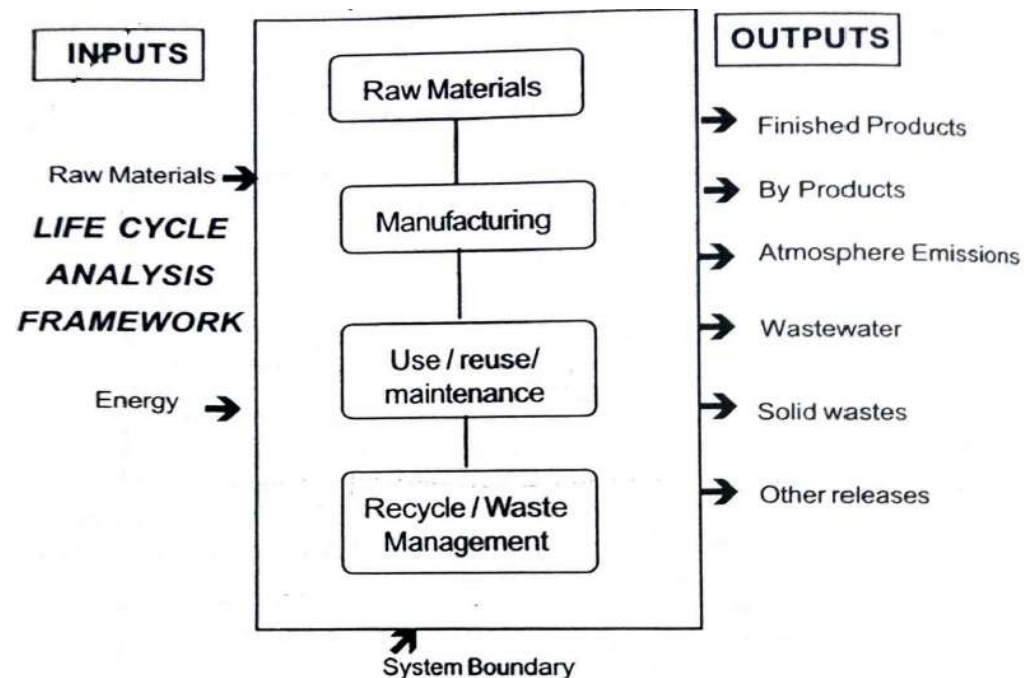


i. Goal and Scope definition

- ❖ This includes the technical details that guide subsequent work and also explains how and to whom the results of the study are to be communicated.

ii. Life Cycle Inventory (LCI) Analysis

- ❖ Heart of LCA method, which consists of “**data collection**” and develop a “**flow diagram**” that can map inputs (materials and energy consumed) and outputs, as shown below:



### iii. Life Cycle Impact Assessment (LCIA)

- ❖ In this step, the significance of potential impacts are evaluated with the help of Life Cycle Inventory flow results. Mandatory steps for assessing impacts are:
  - A. Selection of impact categories :
    - This includes identification of relevant environmental impacts such as global warming, ozone depletion, eutrophication, toxicity etc; on human health, ecological health resource depletion
  - B. Classification of impacts
    - Global impacts :- impacts in global scale such as, global warming, ozone depletion etc.
    - Regional impacts :- impacts in regional scale such as, photochemical smog formation, acid rain etc.
    - Local impacts :- impacts in local scale such as eutrophication, solid waste disposal problem, toxicity etc.
  - C. Impact characterization
    - It uses “**science based conversion factors**” to determine the overall harmful impact on environment. (eg: Global Warming Protocol (GWP) expressed in equivalents of CO<sub>2</sub>.)

- ❖ Other mandatory steps for assessing impacts are :
  - a) **Normalization** : Impact indicator data is expressed in such a way that, it can be compared among impact categories
  - b) **Grouping** : It consists of sorting /ranking in the order of high, medium or low.
  - c) **Weighting** : Different environmental impacts are weighted relative to each other, so that they can be summed to get the total environmental impact in terms of a single number.

#### iv. Data Interpretation

- ❖ It is a systematic process to identify, quantify, check and evaluate the results from the Life Cycle Inventory and Life Cycle Impact Assessment studies.

## **Benefits of LCA**

- ❖ Evaluation of key environmental impacts associated with a given product to select more ecofriendly product in market among competing products.
- ❖ LCA enables companies to limit harmful environmental releases to air, water and land
- ❖ Independent third party certification can assess the company's dedication to produce safer and ecofriendly products.

## **Limitations of LCA**

- ❖ Analysis is costly and large resource consuming
- ❖ Life Cycle boundaries are not clearly defined
- ❖ Depends upon accuracy of data.

## Different types of LCA

- ❖ **Cradle-to-grave** : Full “life cycle assessment” starts from raw material extraction from nature (known as cradle) to disposal phase (known as grave).
- ❖ **Cradle-to-cradle (closed loop)**: Here the end of disposal step for the product, is a recycling process.
- ❖ **Cradle-to-gate** : Partial “life cycle assessment “ starts from raw material extraction from nature (cradle) to the factory gate (gate; ie; before the product is transported to customer.). Here, consuming phase and disposal phase of the product are omitted
- ❖ **Gate-to-gate** : It focusses only on value added process in the entire production chain.
- ❖ **Well-to-wheel** : Used in transportation sector (type of vehicle and fuel), to evaluate their energy consumption and emission impacts

## Assignment

1. **Life Cycle Analysis - Case Study :-** Life Cycle Analysis of plastic pet bottles
2. **Circular Economy**
3. **Industrial Ecology & Industrial Symbiosis**



## Biomimicking

- ❖ The term “Biomimicking” was first introduced by Janine M. Benyus, in 1997, in her book “Biomimicry - Innovations Inspired by Nature”. Bio = life & Mimicry = copying or emulating.
- ❖ Biomimicking can be defined as a methodology to observe, inspire and value nature to learn from it and find long lasting solutions to the problems of mankind.
- ❖ 9 basic laws underpinning the concept of biomimicry are :
  - i. Nature runs on sunlight
  - ii. Nature fits form to function
  - iii. Nature rewards cooperation
  - iv. Nature demands local expertise
  - v. Nature taps the power of limits
  - vi. Nature uses only the energy it needs
  - vii. Nature banks (stores) on diversity
  - viii. Nature controls excesses from within
  - ix. Nature recycles everything
- ❖ Organisms in nature faces the same challenges we do, but they meet them sustainably. Hence we have to look at the nature as a **model, measure and mentor**.
- ❖ Different systems working in nature can be studied and copied for developing technologies towards sustainable development.

## ❖ Some examples:-

- ❖ **Self cleaning paints and surfaces :-** The hydrophobic surface structure of **lotus leaf** became inspiration. Lotus has tiny spikes on the surface of leaves. When liquid drops on lotus leaf, it rolls down and cleans the surface without wetting the surface.
- ❖ **Shinkansen Bullet Train :-** The front end of the train is designed keeping “**Kingfisher beak**” as the model to reduce the huge noise produced due to pressure variation when coming out of tunnel.
- ❖ **Passive cooling in buildings :-** Building construction adopt natural ventilation system to resist towards hot climate. One of such method is inspired from “**termite mounds**” which maintains uniform temperature inside its home.
- ❖ **Gecko tape :-** This is type of adhesive which mimics the mechanism used by the **Gecko Lizard** to walk on the surface. It contains millions of tiny plastic fibers, which are similar to natural hairs covering the Gecko’s feet, which generates aerodynamic adhesion at a microscopic level.
- ❖ **Bionic Car concept :-** Mercedes-Benz, for their bionic car, adapted the aerodynamic shape of the “**box fish**”, which reduces the drag coefficient, thereby increasing fuel efficiency.
- ❖ **Ships hull design :-** It is adapted from the “**skin surface of sharks**”, which has special pattern of lines that enables them to move fast in water.

## **Environmental Impact Assessment (EIA)**

- ❖ Recently environmental deterioration become alarming and hence legislations were made all over the world to limit negative environmental impacts. Environmental Impact Assessment (EIA) is one of the tool implemented to attain the above mentioned aim.
- ❖ EIA is defined as “a planning tool used for identification, evaluation and mitigation of potential impacts (positive and negative) on proposed project on, biological, social, cultural and economic factors, before decision making”.
- ❖ Main objectives are :
  - Predict environmental impacts of projects
  - Find methods to reduce adverse impacts
  - Refine the project to suit the local environment
  - Present the predictions and options before decision makers

### **Global Evolution of EIA**

- ❖ First introduced in US (1969) in the form of United States National Environmental Policy Act (USNEPA)

## Evolution of EIA in India

- ❖ First initiated with the examination of environmental impacts with river valley projects, based on **Technical feasibility and Cost-Benefit analysis**. This assessment was purely on the basis of economy.
- ❖ In 1986, under Environmental Protection Act (EPA) notification issued to list the projects in different “**schedules**”. In 1997, the Union Ministry of Environmental and Forests amended this act and notified that “**public hearing**” made mandatory for the environmental clearance.
  - **Schedule I** : - List of projects requiring environmental clearance from the central government. This list includes Nuclear Power projects, River Valley projects, Petroleum Refineries, Ports, Harbors etc.
  - **Schedule II** : - Industry shall submit an application form for environmental clearance to the Union Ministry of Environment and Forests
  - **Schedule III** : - Composition of expert committee from various disciplines such as air pollution, water pollution, social science etc. are constituted for giving environmental clearance.
  - **Schedule IV** : - Procedure for public hearing. ie; state pollution control board will inform the public regarding the proposed development.

## Procedures of EIA in India

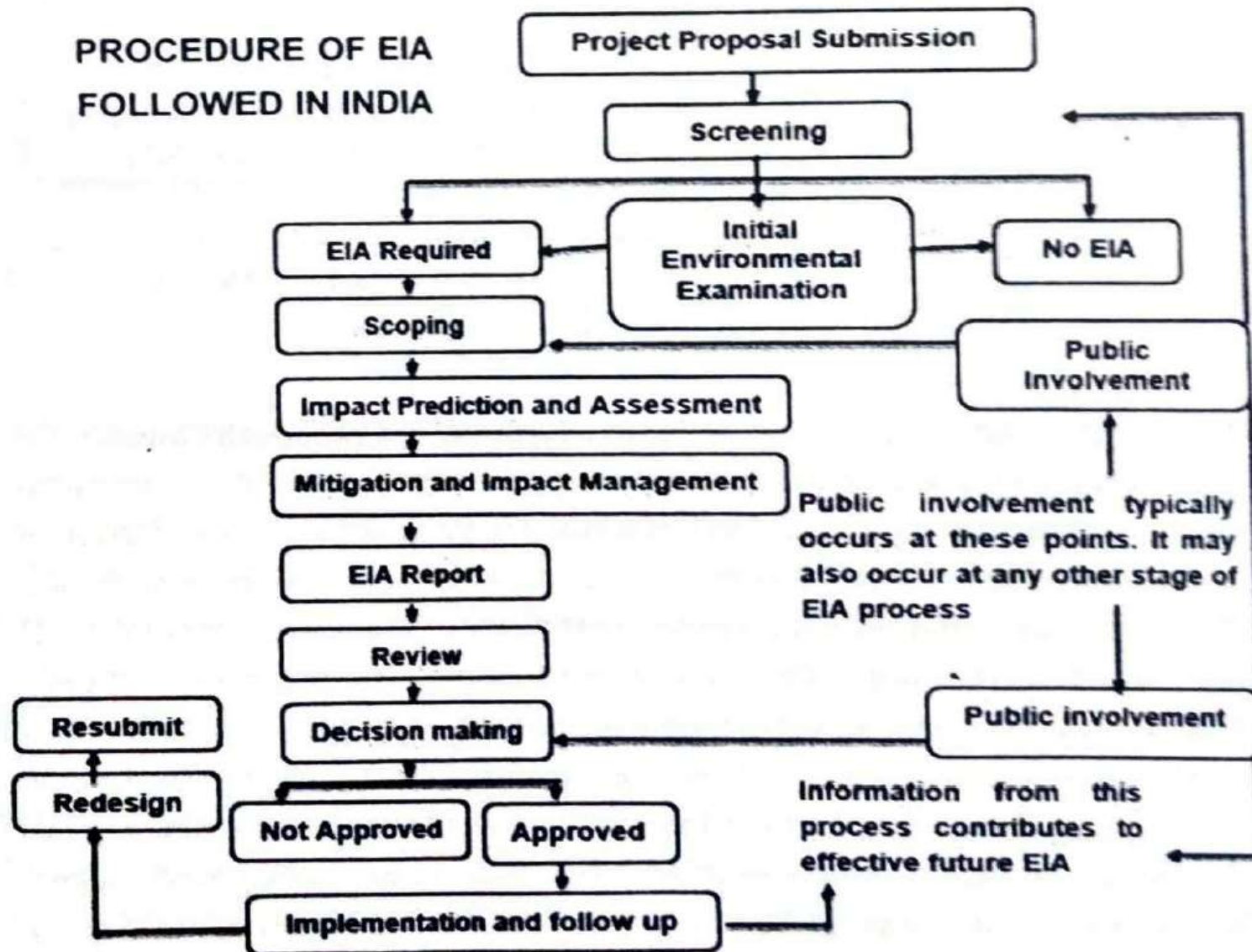
❖ The processes involved in EIA followed in our country are given below:-

1. **Project description** : - It is the condensed description of all aspects of the project showing all project details and its boundary.
2. **Screening** : - This is the process of scrutinizing the application submitted by the industry seeking whether that project requires environmental clearance.
3. **Scoping** : - This stage identifies the important environmental impacts that can occur due to the implantation of project. This is called **ToR (Terms of Reference)**. This may vary from project to project. For eg; impact on environment due to pulp & paper mill will bring water pollution where as a cement factory results in air pollution.
4. **Consideration of alternatives** : - In this step all the available options/alternatives should be considered with respect to the process and technology involved in the project in order to reduce its adverse impact on environment.
5. **Baseline data collection** :- Data has to be collected on the existing condition of environmental factors before commencement of project.

Existing Surface Water Quality	Existing Ground Water Quality	Existing Air Quality	Land use pattern & Soil	Flora	Fauna
Social aspect	Aesthetics	Cultural aspects	Noise level	Health	Economic aspects

6. **Impact prediction and assessment** : - Here all the significant environmental impacts (positive and negative) are identified and suitable methods are used to assess the magnitude of the identified impacts and expressed either quantitatively or qualitatively.
7. **Mitigation measures** : - A detailed plan called “**Environmental Management Plan (EMP)**” has to be organized and documented to decide about the actions to be taken to mitigate the potentially adverse environmental impacts.
8. **Preparation of EIA report** : - All the details, including EMP, in connection with the implementation of project should be documented and made into a report format.
9. **Public hearing** : - After the completion of EIA report, the public must be informed about the details of project and their views are to be considered before issuing environmental clearance.
10. **Reviewing the EIA report and decision making** :- This is carried out by Expert Appraisal Committee (EAC) of the Union Minister of Environment and Forest, Government of India.

**PROCEDURE OF EIA  
FOLLOWED IN INDIA**



## EIA Methodologies for impact prediction

- ❖ To predict and assess the impacts of developmental projects, various methodologies are adopted by EIA, as given below:-
  - i. **Checklist Method** : - Complete list of environmental factors, potentially affected by the project.
  - ii. **Matrix Method** : - Here we use an interaction matrix between causes (project activities) and effects (environmental pollution). Most common matrix used is “Leopold Matrix”, is a qualitative environmental impact assessment method. It consists of a matrix with rows representing various activities of the project in the order of its significance and columns representing the magnitude of various environmental factors to be considered. The intersection are filled in, to indicate the magnitude (from -10 to +10) and the importance of the impact (1 to 10) of each activity on each environmental factor.
  - iii. **Overlay Method** : - It consists of using a base map of the project area and overlaying on this map, different impact characteristics of the proposed project of the same area. Today, Geographical Information System (GIS), technique is commonly used for overlaying number of impact maps to produce a composite map.
  - iv. **Network Method** : - Here a network is drawn with project activities along with corresponding “causes” and “effects”.
  - v. **Expert Opinion (Ad-hoc Method)** :- In case, if the time and information required for analysis is limited, then we go for expert opinion to assess the impacts.

