Journal of Theoretics Vol.3-5

DEVELOPMENT OF A COMPUTER-AIDED SYSTEM FOR ENVIRONMENTAL COMPLIANCE AUDITING

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ABSTRACT: In Malaysia, at present, 19 different category projects require Environmental Impact Assessment (EIA) reports duly approved by Department of Environment (DOE) before their implementation. Predictions on environmental impacts made during EIA for major development projects are hypotheses about such responses, which can be tested with data collected from environmental monitoring programs. The systematic comparison of predicted and actual impact has been termed as compliance audit. Integration of geographic Information System (GIS), Statistical and Database software packages have been conceptualized in order to design an integrated monitoring system and for compliance audit.

Keywords: Expert System, Computer Aided Compliance, Environmental Impact Assessment, and Environmental Monitoring System.

INTRODUCTION

Environmental Quality order 1987, Malaysia, implies that every development project having some potential environmental impact requires a duly approved Environmental Impact Assessment (EIA) report before implementation of that project. Present Environmental Impact Assessment guidelines of Department of Environment (DOE) Malaysia recommend that a matrix be used to relate the different project activities at different phases of the project such as exploration, development, operation, and rehabilitation etc. to the physio-chemical, Biological, and Human or Socio-economic environment. Once the possible environmental impacts are assessed, the project initiator must identify and indicate the possible mitigation measures to be taken with a view towards keeping the environmental pollution within the standard limits. While the project is under implementation, compliance auditing comes into picture to check whether and how far the project is complying with environmental protection and standards. In fact, an environmental compliance audit is a management tool comprising the systematic, documented, periodic and objective examinations of how well environmental organization management and equipment are performing, with the aim of helping to safeguard the environment by 1) facilitating management control of environment practice and 2) assessing compliance with the company policies which would include meeting regulatory requirements. So, compliance auditing plays a vital role in environmental management. Development of an expert system for compliance auditing might help in improving the management efficiency in manifolds.

OBJECTIVE OF THE STUDY

The main objective of the proposed research study is to develop a computer-aided system (specially an expert system) for environmental compliance auditing.

Other objectives to be achieved in this regard include:

1. Designing of an cost effective integrated environmental monitoring systems for EIA projects.

2. Developing an environmental database management system.

METHODOLOGY

The proposed research study methodology will mainly be based on the secondary data available from the DOE regarding the existing environmental management systems, monitoring system, and compliance auditing system. All the available data will be analyzed to design the environmental database management system. Geographic Information Systems (GIS), Expert Systems, and some other statistical packages and database software and microcomputers will be used to achieve the proposed objectives. A field study will also be conducted to explore real world data, to check its validity, analysis, and also to test the main hypothesis of the study on improving the management efficiency and cost effectiveness.

PROJECTS UNDER ENVIRONMENTAL COMPLIANCE AUDITING COVERAGE

Department of Environment (DOE), Malaysia, has identified the following projects of different capacities under different sector and sub-sectors which requires mandatory Environmental Impact Assessment (EIA) reports before going into implementation:

1. Agriculture (land development, agriculture program, agriculture estate)
2. Airport (airport constructional, air strip development etc.)
3. Drainage & Irrigation (irrigation scheme, construction of dams, drainage, etc.)
4. Land reclamation (coastal reclamation)
5. Fisheries (construction of fishing harbors, harbor expansion, agricultural projects, etc.)
6. Forestry (logging, land use project conversion of mangrove swamp etc.)
7. Housing.
8. Industry (chemical, petro-chemicals, non-metal, non-ferrous, iron and steel, shipyard, pulp and paper, etc.)
9. Infrastructure (construction of hospitals, express highway, national highway, new township, industrial estate development, etc.)
10. Port (construction of ports, expansion of ports, etc.)
11. Mining (mining of minerals, ore processing, sand dredging, etc.)
12. Petroleum (oil & gas field development, on-shore & off-shore oil and gas exploration, storage depot for petroleum products, etc.)
13. Power generation and transmission (construction of power stations, nuclear fuelled stations, etc.)
14. Quarries (quarries of aggregate, limestone, quartzite, sandstone, and marble, etc.)
15. Railways (construction of new rail way lines and branch lines, etc.)
16 Transportation (Construction of mass rapid transport)
17. Resort and recreation development (construction of coastal resorts, hill station resort, development of tourist facilities, etc.)
18. Water supplies (construction of dams, ground water development, etc.)
19. Waste treatment and disposal (construction incineration plant, recovery plant, waste treatment plant, land fill, composting plant, storage facility, etc.)

Major activities and actions related to all of the above mentioned projects at their different phases of implementations includes as below (Errickson A. Paul, 1994):

No	Phases of development	Activities and action involved	Possible Environmental impact on
1.	Pre-construction phase	i. On-ground preliminary reconnaissance of surveying of site. ii. Collection of land ownership records. iii. Taking of test boring within a proposed right of ways. iv. Appraisal of real property. v. Negotiation with landowners. vi. Relocation of disposed persons. vii. Securing of physical access to site. viii. Demolition and disposal of exciting structures.	Air, Water, Soil, Human and plant & wild life etc.

2.	Construction phase	i. Excavation ii. Pre-blasting iii. Dredging iv. Transport and placement of borrow v. Clear cutting and disposal of vegetation. vi. On-site transport and storage of material & supplies. vii. Dewatering viii. On-site material processing ix. Land clearing x. Lighting xi. Structural fabrication and placement xii. Controlling run-off xiii. Dust suppression xiv. Landscape engineering and plantation.	Air, Water, Soil, Noise & Human habitat, Plant life etc.
3.	Post-construction phase	i. Selective cutting and disposal of vegetarian. ii. Application of preservatives iii. Application of pesticides iv. Disposal of run-off v. Waste generation, storage and disposal vi. Resource utilization vii. Process chemistry and other risk management.	Air, Water, Soil, Noise, Biota, Human habitat etc.

		viii. Management of by products.	

PROCEDURE OF ENVIRONMENTAL IMPACT ASSESSMENT COMPLIANCE AUDITING

As discussed above, the project requiring Environmental Impact Assessment approval includes activities and actions which have got impact either direct or indirect or both on the physio-chemical, biological and human environment. These impacts may have localized or global affects. Usually, initial impact on the environment by the activities of an individual project are on the project locality, but subsequently such impacts of the similar or other types of projects are accumulated and may spread over with global impacts with synergic affects. So, perspective of the environmental compliance auditing would not remain with the particular projects but it has to be considered both at micro level (individual project) and macro level (cumulative effects of different projects on the whole environmental system). Again, compliance auditing is not a one-time job, rather it is to be a regular phenomenon where different environmental parameters have to be monitored regularly to provide necessary information for compliance auditing. A simplified overview of the compliance auditing process is shown in Fig. 5.1:

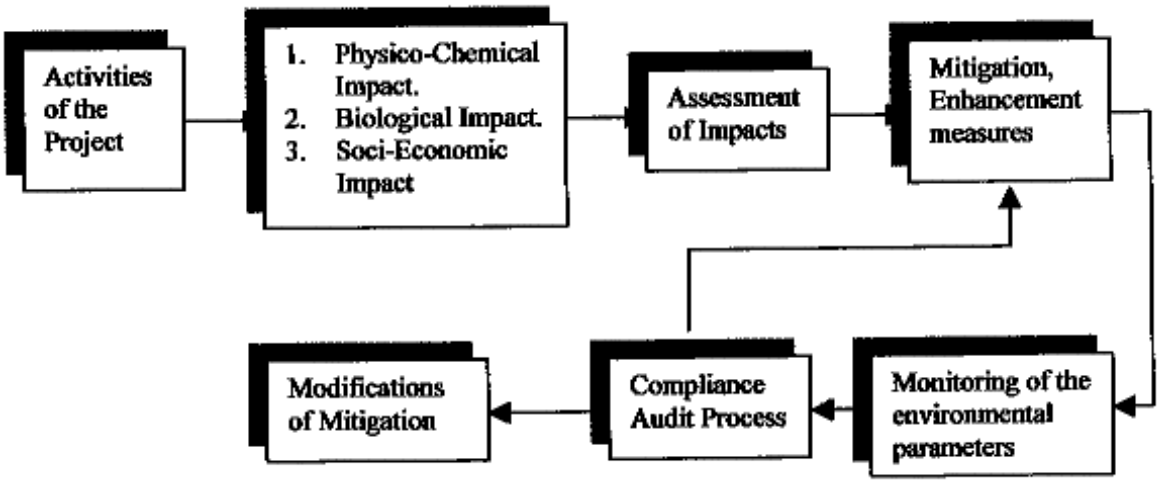

Figure.5.1: Overview of the monitoring and compliance auditing process.

At present about 14 different organizations including University Putra Malaysia (UPM), Department of Environment (DOE), Malaysian Meteorological Services (MMS), Malaysian Agricultural Research & Development Institute (MARDI), Palm Oil Research Institute Malaysia (PORIM), Petroleum National (PETRONAS), University Malaya (UM), University Technology Malaysia (UTM) are involved in monitoring of various components of the environment. But the main problem of this domain is in the scattered monitoring of different environmental components and parameters by different organizations. So, it is essential to find out a cost-effective and integrated monitoring system in order to aid in efficient compliance auditing. Introduction of internal compliance auditing by the individual project owner and also voluntary involvement of NGOs, local environmentalists & social workers, methods of monitoring, choice of technology etc. may be the options to be considered in this regard.

Since the monitoring work would constitute the major cost component and effort for compliance auditing, careful design of the monitoring system would be emphasized. A well-designed monitoring system must have clearly defined objectives on such as:

I. Classification of Resources.
II. Collecting base line data.
III. Environmental Quality surveillance
IV. Investigation of pollution incidents and
V. Surveys for predictive modeling.

The careful choice of the objectives will normally be followed by a number of decisions relating to the monitoring program itself as shown below (Sham, et al, 1988):

1. Determination of objectives

2. Allocation of Resources

3. Choice of monitoring parameters
a. Determinants to measure
b. Precision and accuracy required
c. Most appropriate techniques.

4. Choice of sampling strategies
a. Where the measure
b. How to collect sample
c. How frequently to sample

5. Analysis of data

a. Manpower allocation & training
b. Statistical approach
c. Data logging & Storage

The monitoring system will provide the crucial base line and sample data for compliance auditing purposes which require the comparison of existing environmental data with the standard guideline data or related indices on a particular environmental parameters. Different steps of the monitoring system including data collection, data validation, data analysis, data interpretation and decision on compliance etc. has been shown in figure 5.2:

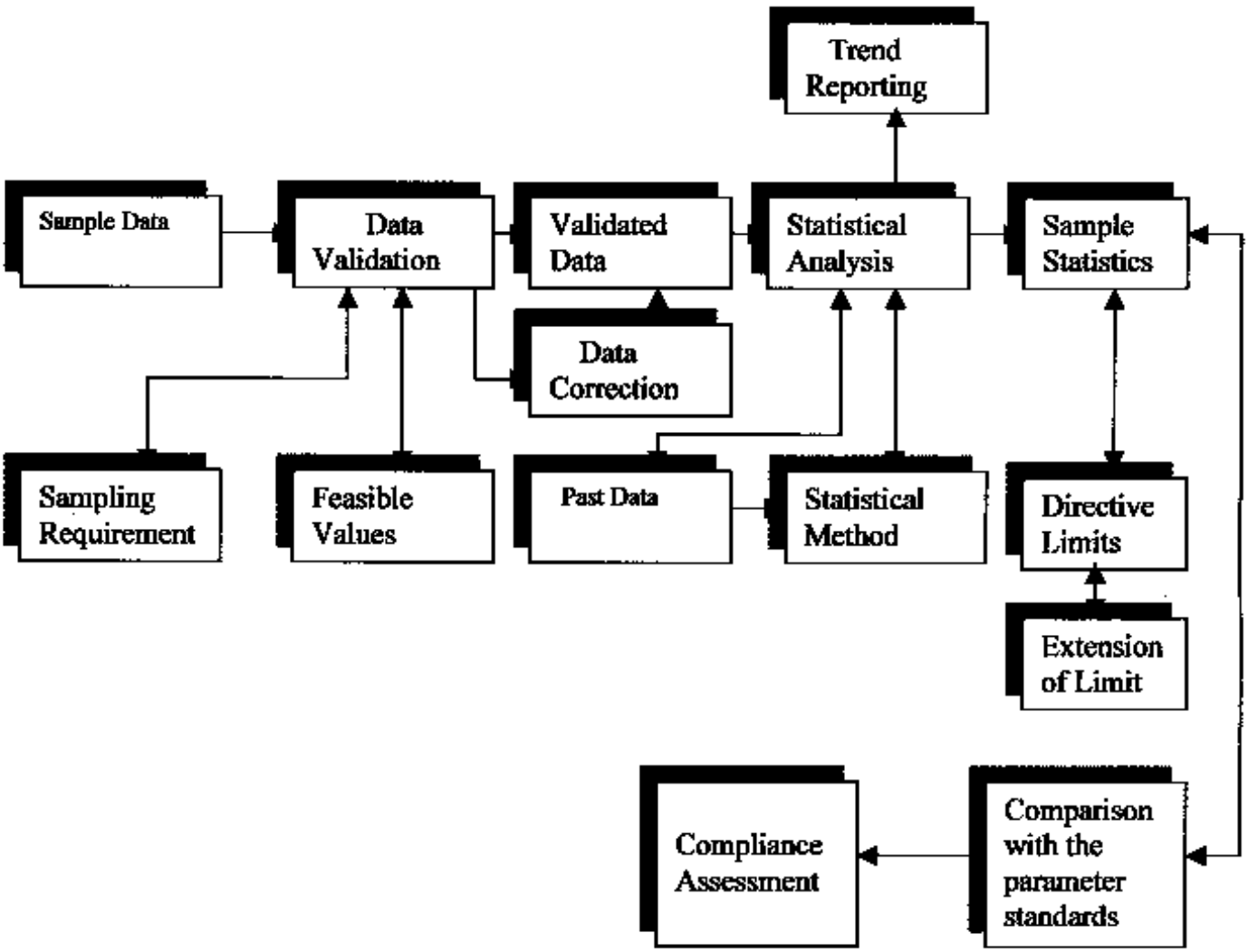

Figure 5.2: Steps of environmental data monitoring and compliance assessing

The individual project owners internally do it compliance auditing whether or eternally done by DOE through environmental auditors, the process requires a standard for each of the environmental parameters to be monitored. Fixation of the standards also depends on the purposes of health, safety and welfare of the public, quality of the environment and demands of the situation. Following are the major parameters and criteria, which needs to be considered while setting the standards for environmental monitoring program (Errickson A. Paul, 1994):

Environmental issues of concern	**Relevant parameters and Criteria**
Air Quality	i. Kinds and concentration of chemicals ii. Public health iii. Vegetation and wild life iv. Corrosion of structural materials v. Acid deposition vi. Social equity
Water Quality	i. Physical, Chemical and Biological Factors ii. Human health iii. Agriculture and Industry iv. Wildlife habitat v. Ecological Stability and Diversity vi. Bio Accumulation
Noise	i. Amplitude, Frequency, and duration ii. Temporal and spatial variation iii. Physiological and Psychological responses iv. Vibration effects on unconsolidated soils v. Wild life vi. Social Equity

Soil Quality	i. Physical, Chemical, Biological factors ii. Vegetation and wildlife
Historic Sites	i. Age ii. Historic events/persons iii. Architectural significance iv. Educational Opportunity
Pesticides	i. Lethality for target species ii. Lethality for non-target species iii. Persistence in environment iv. Degradation products v. Social Equity
Radiation	i. Types and levels ii. Effects on vegetation and wildlife iii. Acute and chronic effect on human iv. Social Equity
Hazardous Waste	i. Amount and type ii. Health and safety hazards iii. Discharge of leaches or combustion products into surface and ground water iv. Effects on vegetation and wildlife v. Efforts of generation to reduce waste vi. Social Equity

Resource Use Planning	i. Critical areas / resources ii. Multipurpose use of resources iii. Sustainability

However, development of environmental indices on the mentioned environmental components based on the major criteria and standards would ease the compliance auditing process.

DEVELOPING ENVIRONMENTAL DATABASES

A carefully designed monitoring program would provide the necessary base line data and other environmental data on individual projects and also on global level. These data bases will be then be aggregated for a specific areas, over a given time period and by groups exhibiting synergic effects. These data bases will later on be linked up with Geographic Information Systems (GIS) for environmental modeling and further analysis on spatial & time dimensions, and with the proposed expert system where the data would be compared with the generally accepted limits / or standard, set by the competent authority, of the individual stress factors with global stresses produced by synergic effects of individual parameters, and with an acceptable environmental indicators to give a more or less complete environmental assessment of the situation for decision making and environmental management.

USE OF GIS TO SUPPORT INTEGRATIVE MODELING AND SPATIAL ANALYSIS OF ENVIRONMENTAL DATA

GIS is a technology designed to capture, store, manipulate, analyze, and visualize diverse set of spatially referenced data. GIS would use spatial data that are available from the monitoring program for spatial processes operating at multiple time and pace scales, and also for environmental modeling. Attempts will also be taken for flexible scaling, parameterization and reclassification for statistical analysis, creating variable grid cell resolutions, aggregation and integration of spatial data from disparate sources with potentially different data models, monitoring the changes at a range scale, and for visual presentation of modeling results in a policy-supportive, decision-making environment.

DEVELOPMENT OF AN EXPERT SYSTEM FOR ENVIRONMENTAL DATA MANAGEMENT FOR COMPLIANCE AUDITING

The most important part of the proposes compliance auditing system is to provide necessary information to the decision makers about the existing environmental conditions of a particular project or a locality and also about the changes in the environmental condition over time in order to facilitate them in the management of the environment.

Any successful decision-making is strongly dependent upon various capabilities that include the effective acquisition, storage, distribution, and sophisticated use of the knowledge of the human experts in the field. In the context of computer-aided systems for monitoring and information processing, these capabilities would be achieved through developing an expert system.

Attempts will be taken to link the GIS models and with the proposed experts system for in-depth analysis and explanation of an environmental situation. The GIS would supply out from functions for spatial analysis of environmental parameters, image processing functions, and uncertainty measures. The expert routines and the data base would provide the vehicles for transferring information between goal list and the GIS functions in the form of sub-goals, function parameters, and variable values. The proposed expert system will also be linked with database and statistical software for time series and other statistical analysis of data. There will also be a need for transfer of knowledge bases between different systems. A skeleton structure of the proposed expert system is shown below (Fig.8.1):

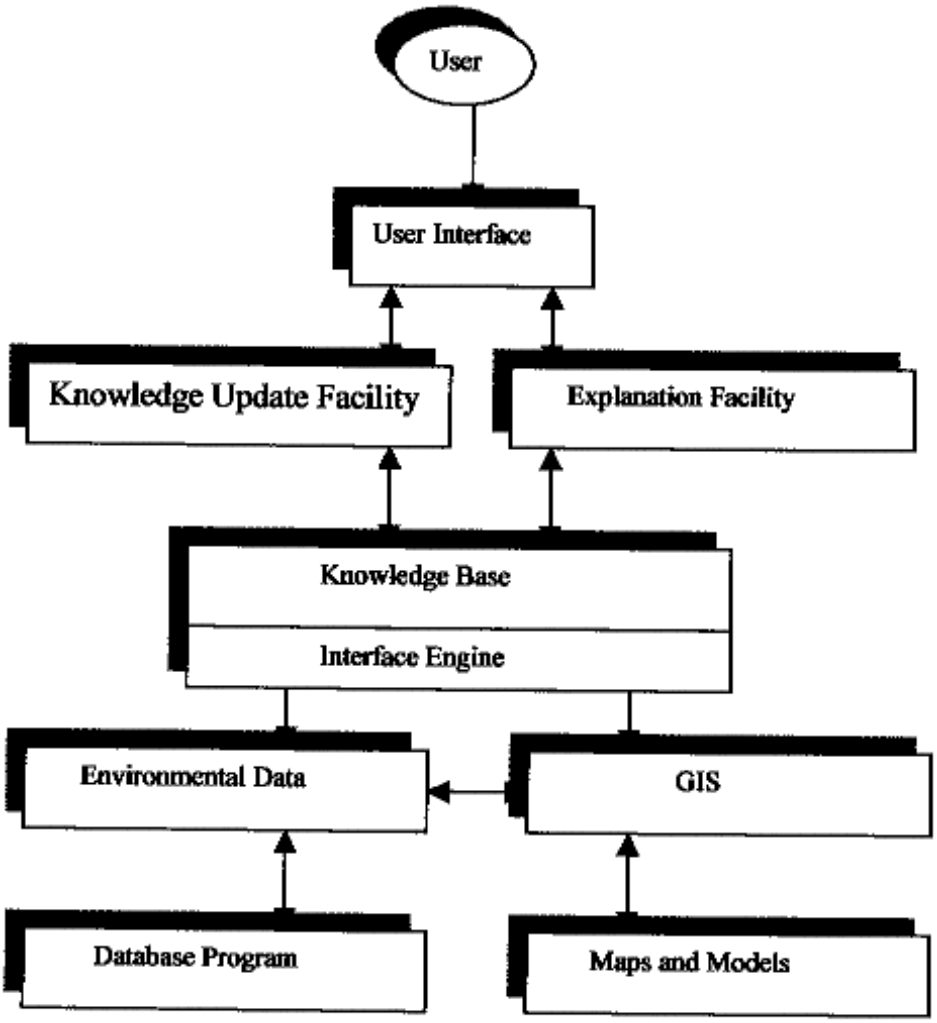

Figure 8.1 A skeleton Structure of the components of the proposed Expert System

CONCLUSION

The proposed computer aided environmental compliance auditing system includes four major components such as:

a) Designing of an integrated monitoring system
b) Developing an environmental database management system
c) Environmental modeling and spatial analysis of environmental data
d) Developing an expert system for judgmental decisions on environmental compliance

The proposed expert system would provide two main tasks. First, the system would assist in obtaining the values on environmental parameters on the basis of aggregation on for a specific area, over a given time period etc. Further on, the system would provide comparison of individual values with the limits generally stated by law and states' environmental policy as well as with the specific local authority regulations of the area. The complete set of values would also be compared with the actual environmental indicators of the area with a view to provide judgmental decisions for the management use.

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