Predictive Techniques Audit

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Abstract- The challenges of how to respond to climate change and ensure sustainable development are currently high on the political agenda among the world's leading nations. The Predictive Techniques in Environmental Impact assessment is a part of the global carbon market, developing rapidly as a result of the Kyoto response towards mitigation of global warming. One of the aims of Predictive Techniques in Environmental Impact assessment is to achieve sustainable development in developing countries, but uncertainty prevails as to whether the Predictive Techniques in Environmental Impact assessment is doing what it promises to do. Close to 200 studies on the Predictive Techniques in Environmental Impact assessment have been carried out since its birth in 1997 including peer-reviewed articles and reports from the grey literature. However, no overview of the different debates and key issues in the Predictive Techniques in Environmental Impact assessment exists. This paper attempts to assess the state of knowledge on how the Predictive Techniques in Environmental Impact assessment contributes towards pollution control and sustainable development.

Keywords – Physical Models, Mathematical Modeling, Adhoc Model, Predictive Techniques

I. INTRODUCTION

Environment Impact Assessment or EIA can be defined as the study to predict the effect of a proposed activity/project on the environment. A decision making tool, EIA compares various alternatives for a project and seeks to identify the one which represents the best combination of economic and environmental costs and benefits.

The environment impact process was introduced with the purpose of identifying /evaluating the potential beneficial and adverse impacts of development projects on the environment, taking in to account environmental, social, cultural and aesthetic considerations. All of these considerations are critical to determine the viability of a project and to decide if a project should be granted environmental clearance.

The aim of prediction in EIA is to describe how the environment is likely to change as a result of implementing an activity.
In order to do this, it may be necessary:

- To describe the state of the present environment using **monitoring and survey methods** (these methods are required to provide the starting point for prediction) ;
- To predict the future situation in the environment using **predictive methods;**
- To value subjectively the condition of the environment, either in the present or in the future, using **valuation methods**.

Predictive Techniques

In order to predict, the environment must be modeled and tested. The possibilities for modeling depend on the complexity of the problem, the number of different factors involved, the nature of the relationships between them, and on how well the system (i.e. that part of the environment being modeled) is understood.
Environmental systems can be modeled in more or less formal ways by:

- mathematical modeling
- physical modeling
- experimental modeling

Where it is impossible or impracticable to construct or use formal models of environmental systems, they can also be modeled informally.

In each case the models can be characterized in terms of their representation of the environment:

- The nature and size of the environmental system they represent and the conditions in which they can be applied
- The nature of the process or processes occurring within that system which are (or are not) simulated within the model
- The degree to which the model simplifies the behavior of the real system

And in terms of the outputs they are designed to generate:

- The types of effect which can be predicted (change in concentration of a pollutant, in productivity of an ecosystem, in physical characteristics – flow, slope, density, etc,) ;
- The type of outcome which can be described (long term, short term, local, long distance; averages, instantaneous values etc.);
- And the form in which the output is presented (raw data, analyzed data, graphs, maps, pictures etc.)

1.1 Mathematical Models

In mathematical models, the behavior of environmental systems is represented by mathematical expressions of the relationships between variables.

In general, the output variable (X) is a function of one or more input variables (A,B,C ...)

$$X = f(A,B,C...)$$

An example is a simple form of the Gaussian Plume Dispersion Equation for predicting air quality around a point source of emission:

$$C = \frac{Q}{U_h} \int_0^D f.dl$$

Where C = ground level concentration (g/m^3) at a distance of x meters in the wind direction
Q = rate of emission (g/m^3)
U = wind speed
H = height of emission (= stack height + plume rise) (m)

Lateral and vertical dispersion coefficients calculated for the required value of x (distance in meters) from standard empirical formulae appropriate to the emission height, the roughness of the surrounding surface and the atmospheric stability)

The exact shape of the relationship in a model is defined by establishing the model parameters which may vary according to the circumstances in which the model is applied; for example, the dispersion coefficients in the example above must be defined according to the conditions of atmospheric stability, the surface roughness of the surrounding area and the emission height. Various standard empirical formulae for these coefficients have been established by different workers for different types of emission, meteorological and topographical conditions.

By changing the value of input variables in the equation, the response of a system to new external influences can be tested.

Taking the previous example:

- The concentration of an air pollutant at different distances from the source can be calculated by changing **X**
- The concentration resulting from different chimney heights can be calculated by changing **h**
- And the concentration at different emission rates can be calculated by changing **Q**

The number of different variables in a model and the nature of the relationships between them are determined by the complexity of the system. The aim in mathematical modeling is to minimize the number of variables and keep the relationships as simple as possible, while retaining a sufficiently accurate and workable representation of the environmental system.

I. Types of Mathematical Models

Mathematical Models can be characterized according to various features:

i) Mathematical Models may be :

- **Empirical,** that is derived solely on the basis of statistical analysis of observations from the environment to find the "best fit" equation. Empirical models are sometimes called "black box models". The equations for calculating dispersion coefficients for the previously described Gaussian plume dispersion model are empirical;

  Or

- **Internally descriptive,** that is, where equations are based on an a priori understanding of the relationships between variables; the equations therefore represent some theory of assumption about how the environment works. The Gaussian plume dispersion model itself is internally descriptive.

In practice, most models are intermediate in .nature; they are proposed on the basis of some theory about the systems developed on the basis of observations, and checked and amended to match real data.

ii) Mathematical models may be :

- **Generalised,** that is developed for, and applicable to, a range of different environmental locations which meet certain specified characteristics

  Or

- **Site specific,** that is developed for and applicable to point sources in any area of relatively flat terrain

iii) Mathematical models may be :

- **Timein-varying(stationary),** that is models in whichthe conditions are fixed over the period of the prediction.

  Or

- **Time varying (dynamic),** that is models in which the predictions are made over a period of time in which conditions in the environment change.

The simple Gaussian plume dispersion model is derived for stationary predictions, i.e. for predictions where the emission rate, wind speed, wind direction and atmospheric stability stay constant over the period of the prediction. More complicated Gaussian plume formulations, which involve numerous repeated calculations usually carried out on a computer, can be used to predict changing concentration with time or to predict average concentration over longer periods when conditions cannot be expected to stay constant.

Mathematical models may be :

- **Homogeneous,** that is models which assume that conditions at the source prevail throughout the area over which predictions are made

Or

- **Non-homogeneous,** that is in which environmental conditions affecting the predicted outcome vary with distance from the source

Simple Gaussian plume models are generally used for homogeneous predictions. It is assumed that conditions (wind speed, wind direction, atmospheric stability, surface roughness) remain constant over the distance from the source to the location over the distance from the source to the location where air quality is predicted. Again, more complicated, long-distance formulations allow for meteorological and surface conditions to change as the plume moves away from the source.

iv) Mathematical models may be :

- **Deterministic,** in which the input variables andrelationships are fixed quantities and the predicted outcome from a given starting point is a single, unique value;

Or

- **Stochastic,** in which variables and parameters may be described probabilistically. Stochastic models allow the behavior of the environment to fluctuate in a random manner within certain defined probabilities, as it does in the real world. The models therefore reflect the natural variations which occur in the environment. The result is presented as a frequency distribution of probable outcomes rather than as a single value.

The single Gaussian plume model is usually used deterministically; fixed, single values for each variable and coefficient are defined and a single value for the resulting' concentration is calculated. In a stochastic formulation, probability distributions of values for each variable and coefficient could be defined and a probability distribution for the predicted concentration would then be calculated.

II. THE STEPS IN MATHEMATICAL MODELING:

Mathematical Modeling	Example
Define the environmental system to be modeled and its salient features, and the effect requiring prediction	A prediction of the average annual and maximum concentration of a pollutant emitted from a single tall stack was required at the location of a planned housing estate. The surrounding area was open rural countryside.
Select an appropriate predefined model or prepare an adhoc model	A long-term plume model for predicting ground level local concentrations are estimated. A standard empirical sub-model was used to calculate plume rise.
Collect the necessary data from existing sources or by monitoring and	Data on wind speeds and directions and atmospheric stability during

surveys	average year were obtained from the meteorological Institute for the nearest measuring station, and analyzed to give frequency distribution of different sets of meteorological conditions. Input data on emission rate, stack height and emission characteristics (flux, temperature, etc.) were obtained from the proponent
If necessary, define appropriate model coefficients for the particular application, using either standard values or experimental data (calibration)	A set of atmospheric dispersion coefficients were defined for the different classes of meteorological conditions, using standard empirical formulae applicable to tall stacks in open rural countryside.
Test the validity of the model for the particular circumstances by comparing the behavior with observations in the field (validation)	As the model is well-tried and tested for this type of application, special validation was considered necessary
Apply the model to predict the future condition of the environment	A standard computer package was used to calculate the annual distribution of 24 hr concentrations and the annual average concentration at the proposed development location
Describe the model verbally for the non-specialist; identify all the relevant variables and relationships, identify the assumptions made and the factors omitted from the analysis and discuss their implications for the results (interpretation)	The model was described and the assumptions made and their implications for the results were discussed. The likely accuracy of the result was assessed on the basis of past experience with the model and with re9ard to other factors affecting dispersion which were not included in the model.

III. Resource Requirements

The resource requirements for mathematical modeling can cover a huge range. A simple model may require minimal input data and a simple manual calculation; for example, in a simple river dilution model:

$$C1 = \frac{Qo\ Co + QeCe}{Qo + Qe}$$

Where: C1 = downstream concentration
Co = upstream concentration
Ce = discharge concentration
Qo = upstream flow
Qe = discharge flow
C1 can be calculated simply without recourse to sophisticated techniques.

In contrast, a detailed lake eutrophication model might comprise, three sub-models involving, in total, 20 equations describing processes occurring within the lake, 38 parameters and 21 variables. The model uses a special simulation language, requires sophisticated computer techniques for its solution and demands considerable resources of input data, time and expertise.

3.1 Physical Models

In physical models, the environment is simulated at a reduced scale. Physical models can be either two or three dimensional.

I. Types of Physical Models

- **Illustrative models** simply present a visual image of the environment before and/or after implementation of the activity, by artists, sketches, photographs, cine-films or 3-d models. They can be used to illustrate the effect of activities on the visual environment.
- **Working physical models,** the processes which occur in the environment are simulated at a reduced scale. When the proposed activity is simulated in the model (e.g. the release of a substance or a change in morphology) the resulting changes can be observed and measured in the model.

Working physical models are used to predict air, water and noise effects, either by direct simulation or by analogue. Direct simulation modeling is carried out in wind tunnels, wave chambers and similar facilities. In analogue models, the environmental medium or the source is simulated using another medium (e.g. water to simulate the atmosphere or electrical currents to simulate water flows).

For a model to correctly represent all the phenomena and physical processes occurring in the environment, different conditions must be met with regard to scale. Usually, it is not possible to satisfy all these conditions all at the same time, so most models are a compromise in which faults arising from scaling are minimized. In some circumstances, it may be necessary to construct more than one model to overcome different scaling problems.

Most modeling exercises are carried out in ready built facilities (wind tunnels, wave chambers, etc.) which are adapted to suit the particular requirements of a prediction. Such facilities are available at both public and private research organizations. However, in some circumstances, special facilities must be constructed.

IV. Resource Requirements

The resource requirements for physical modeling will depend on the type of model. It is apparent from the examples that considerably more effort would usually be required for building and using working physical models, than for illustrative models. The former require very considerable technical expertise and understanding for design and testing and to interpret their results. Most illustrative models are relatively inexpensive although there are some sophisticated computerized visual simulation models available which are substantially more costly.

Working physical models are generally more expensive than alternative mathematical modeling approaches, although they can sometimes be used in circumstances where mathematical modeling is not suitable. Very considerable expertise and large quantities of data may be needed to build a physical model which adequately simulates the behavior of the real environment. The testing of these models may also be a lengthy operation and specialist knowledge is required for proper interpretation of the results.

V. Experimental Models

Experimental models form a particular group of physical models, in which experiments are carried out in the laboratory or in the field to determine the likely effects of an activity.

Experimental Modeling Approaches

A main distinction can be drawn between:

- Experiments in which the environment is modeled and tested in the laboratory. Examples include toxicological tests on living organisms using polluted air, water, food etc., micro-ecosystem experiments, and pilot scale plant tests.
- Experiments in which tests are carried out in the actual environment in which the activity will be implemented. Examples include in situ tracer experiments to monitor the movement of releases into the environment, controlled experiments in small parts of potentially affected ecosystems, noise tests to determine levels of disturbance, pumping tests on groundwater.

VI. Conclusion

In review of the literature on how the Predictive Techniques in Environmental Impact assessment contributes to sustainable development, including poverty alleviation, the main research finding have been extracted. Based on the findings, the possible role strategies in addressing the shortcomings as well as key issues for new research are recommended.

Aid strategies must respond to the main challenge, as identified in the literature review that left to the market forces does not significantly contribute to sustainable development in developing countries. An important implication is that Environmental Impact assessment projects with high development benefits are often the ones that find access to finance the most difficult. In India, this is still in primitive stage and lot of work is being done.

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