Significance of Spatial Data and GIS for Environmental Impact Assessment of Highway Projects

M.L. Agrawal and **A.K. Dikshit**
Department of Civil Engineering,
Indian Institute of Technology Kharagpur (W.B.) 721302, India
Telephone: (03222)-83422, Fax: (03222)-755303
Email : mohanlalagrawal@yahoo.com

Keywords: environmental impact assessment, GIS

Abstract

Environmental Impact Assessment (EIA) consists of a systematic investigation of both positive and negative impacts on the physical, biological socioeconomic environment, which would be caused or induced due to a proposed developmental project. Its primary objective is to encourage the inclusion of environmental considerations in planning and decision making and to ultimately arrive at actions that are more environmentally compatible. Most of the environmental attributes are spatial in nature and to understand and manipulate these attributes, suitable spatial database management system is required. Geographical Information System (GIS), which is a tool for collecting, storing, retrieving at will, transforming and displaying spatial data for a particular set of purposes, can provide all desirable requirements. In present paper, the methodology to prepare EIA, different information and data requirements for EIA of a highway project, importance of cartographic input for spatial data, and potential of application of GIS in EIA have been discussed. Finally a brief case study has been included to demonstrate the successful role of GIS in undertaking EIA.

Overview

1. Introduction

The Environmental Impact Assessment (EIA) is a systematic, well documented and multidisciplinary procedure, where we identify, describe and assess the direct and indirect effects of a project or an activity on different environmental factors such as soil, water, air, climate, landscape, cultural heritage, flora, fauna, human beings; and also interactions among the factors. EIA helps to develop environmental friendly projects and seeks to reduce environmental degradation caused by developmental activities. EIA is a pre decision tool with many different purposes useful for different actors - planners, designers, project proponents, public and decision makers. It also provides a plan to reduce the negative environmental effects of development project through alternative approaches, design modifications and remedial measures. In preparing EIA, main two tasks are involved - one is to manage huge and diverse nature of database (spatial, non-spatial, discrete, continuous and temporal); and other is to make final interpretation based on these data, which by most of the conventional methods is very subjective. Due to the involvement of huge environmental data of spatial nature in every stage of EIA procedure *viz.* project definition; screening; scoping; baseline information; impact identification; impact prediction and evaluation; and mitigation measures, Geographical Information System (GIS) can be of a potential utility in all EIA stages. GIS acts as an integrating framework for generation, storage and display of the thematic information relative to the sensitivity of the affected resources.

Highway construction or expansion projects are major activities of economic development especially in developing countries. Road development is major source of damage to the environment, including ecological destabilization, habitat disturbance and damage to flora and fauna. Significant benefits gained from the use of GIS for EIA of highway projects are: GIS offers a virtual environment within which decision makers and scientists

can explore theory and evaluate competing management strategies; GIS are unique in its ability to capture, store and manage spatially referenced data; GIS supplies a framework in which spatially resident engineering phenomenon can be modelled; spatial operations of GIS supplements the traditional map-based modelling and it derives model-dependent parameters (area computation, length measurement, nearest distance determination etc. (Miles & Ho.,1999); most obvious and appealing feature of GIS is the ability to present analysis result in map form.

Production of cartographic quality maps is very much effective in pursuing the effect of different changes taking place due to the activities of the proposed project. It also facilitates the good presentation and better understanding of the resultant impacts particularly to the non-technical decision makers, who really dominate the decision making process.

2. Environmental Impact Assessment Process

It is imperative to understand the inter linkage and dynamics between various activities, direct, indirect and cumulative impacts on physical and social environments to evaluate the impacts and to provide mitigation measures. Following are the steps involved in a systematic EIA of a highway project:

2.1 Project definition: The importance and need of the project is defined here and its relation with regional and national developmental activity is mentioned in this section.

2.2 Screening: Screening is done as per the statutory notification. Screening criteria are based upon:

- Scales of investment;
- Type of development; and
- Location of development.

2.3 Scoping: Scoping is a process of detailing the terms of reference of EIA. It is done by the consultant in consultation with the project proponent and guidance, if needed, from Impact Assessment Agency. Quantifiable impacts will be assessed based on magnitude, prevalence, frequency and duration and non-quantifiable impacts (such as aesthetic or recreational value). Significance is commonly determined through the socio-economic criteria. After that the areas, where the project could have significant impact are identified and the baseline status of these will be monitored and then the likely changes in these on account of the construction and operation of the proposed project will be predicted.

2.4 Baseline information: Baseline data describes the existing environmental status of the identified study area. The site-specific primary data is monitored for the identified parameters and supplemented by secondary data if available.

2.5 Impact prediction: Impact prediction is a way of mapping the environmental consequences of the significant aspects of the project and its alternative. Environmental impact can never be predicted with absolute certainty and this is all the more reason to consider all possible factors and take all possible precautions for reducing the degree of uncertainty.

2.6 Evaluation of impacts and alternative criteria: For the project possible alternatives are identified and environmental attributes are compared. These alternatives cover both project location and process technologies. Alternatives consider 'no project' also. Alternatives are then ranked for selection of the best environmental option for optimum economic benefits to the community at large.

2.7 Management plan: This section of the EIA will describe about the mitigation measures to reduce the harmful effects of the proposed project. Particularly, it will also contain the provision for rehabilitation of the people affected and displaced by the project.

2.8 Public participation: Law requires that the public must be informed and consulted on a proposed development after the completion of EIA report. Public participation can be assured by:

- Consulting the public directly affected by the proposed project and the voluntary groups like NGOs or pressure groups having a concern with a specific aspect of the environment.
- Conducting direct interviews with the sample from public or by sending questionnaire to the people from public.
- Publishing the summary of EIA report for objections and suggestions from people.

2.9 Decision making: Decision making process involves the consultation between the project proponent (assisted by a consultant) and the assessment authority (assisted by an expert group if necessary). The final decision on acceptance, rejection or clearance is arrived at through a number of steps including evaluation of EIA and environmental management plan.

2.10 Monitoring Plan: Monitoring should be done both during construction and operation phases of a project. Monitoring will enable the regulatory agency to review the validity of predictions and the conditions of implementation of the Environmental Management Plan.

3. EIA-Methodologies

There are many methodologies available for evaluation and assessment of environmental impacts. Most of the methods suffer from excessive dependence on subjective-judgment and are weak in predicting and quantifying the impacts of the project on the environment, but the development of computer-based modeling techniques using GIS promises the bridging of the existing gap (Sinha, 1998). Some of the main methods adopted individually or in combination are mentioned below (Rau & Wooten, 1980; Canter, 1996; Li et al., 1999)-

3.1 Ad hoc approach: This method provides minimal guidance for total impact assessment while suggesting

the broad areas of possible impacts. This gives the qualitative assessment, based on subjective or intuitive assessment. It does not address secondary impacts.

3.2 Checklist method: It is a method of combining a list of potential impact areas that need to be considered in the environmental impact assessment process with an assessment of the individual impacts. This type of method does not provide for the establishment of direct cause-effect links to the various activities and generally does not include an overall interpretation of collective environmental impacts.

3.3 Matrix method: It incorporates a list of project activities or actions with a checklist of environmental conditions or characteristics that might be affected. Combining these lists as horizontal and vertical axes of a matrix allows the identification of cause-effect relationships between specific activities and impacts. The entries in the cell of the matrix can be either qualitative estimates or quantitative estimates of these cause-effect relationships. The latter are in many cases combined into a weighting scheme leading to a total "Impact Score" (Sinha, 1998).

3.4 Overlay method: In this method a set of maps of a project area's environmental characteristics are overlaid to produce a composite characteristics of the area's environment. Impacts are then identified by noting the impacted environmental characteristics within the project area boundaries. This provides a graphical display of the types of impacts, the impacted area, and their relative geographical location.

3.5 Network method: It starts with a list of project activities and then generates cause-condition-effect networks. This method provides a chain type of approach to identification of second and third order effects.

4. Use of GIS in EIA

4.1 In Project definition: During project identification and definition, the project proponent conducts feasibility studies and defines the usefulness of the study. GIS can be very well used for defining the project by showing the location of the project and its need can be established with respect to other geographical identities like source of raw material, market for selling, source of labourer, climatic conditions favorable for the project etc.

4.2 In evaluating environmental and visual impacts: Using GIS various types of visual impacts can be evaluated like, how a road will look like? How much portion of the road will be visible from a particular point? By using DEM we can calculate and visualize the impact on ground levels either in filling or cutting and area of quarries etc (Oterholm, 1999).

4.3 In scoping system: GIS can serve as a basis for scoping of environmental effects. Once the basic databases are available, a GIS based system may provide better-targeted guidelines for EIS. A centralized institutional scoping structure, where by EIS guidelines are issued by a single entity, is found to be important for the operation of such a system as it can enjoy the economees of scale and scope involved in setting up and operating a GIS system for scoping purpose (Haklay et al., 1998).

4.4 In impact significance determination: A spatial impact assessment methodology based on the assumption that the importance of environmental impact is dependent, among other things, on the spatial distribution of the effects and of the affected environment. For each environmental component like- air, water, biological resources etc., impact indices are calculated based on the spatial distribution of impacts (Antunes et al., 2001).

The fact that GIS is not used in practice to the extent that it could be used in principle may also be the due to a number of **limitations** of GIS like:

- Availability of digital data
- Cost of start up
- System maintenance
- Database construction
- Availability of hardware and software

5. Case Study

The case study discussed here has been adopted from Zura et al., 1995). It is a GIS based application for assessment of road and traffic impacts on the environment and helped in the selection of optimal road layout. Environmental perception were estimated based on information about different environmental parameters like- soil, water, air, climate, landscape, natural and cultural environment by assigning weightages to the importance of different layers.

5.1 Methodology

- Different experts prepared the database on different elements of environment. The estimation of area vulnerability was made while entering data, taking in consideration available information on the particular phenomena of the area. The vulnerability of individual environmental factor, which was prepared on its own layer, was shown in different colour shades.
- Four grades were used to assign different stages of impacts, 1 – no impact; 2 – small impact; 3 – large impact; 4 – unacceptable impact.
- Assigning weightages to the importance of different layers and then all these layers were joined together which was later used in the analysis.
- Total vulnerability of each polygon was calculated as a sum of grade multiplied by layer weight. The optimal workflow would be first to determine the best corridor and after then to develop some

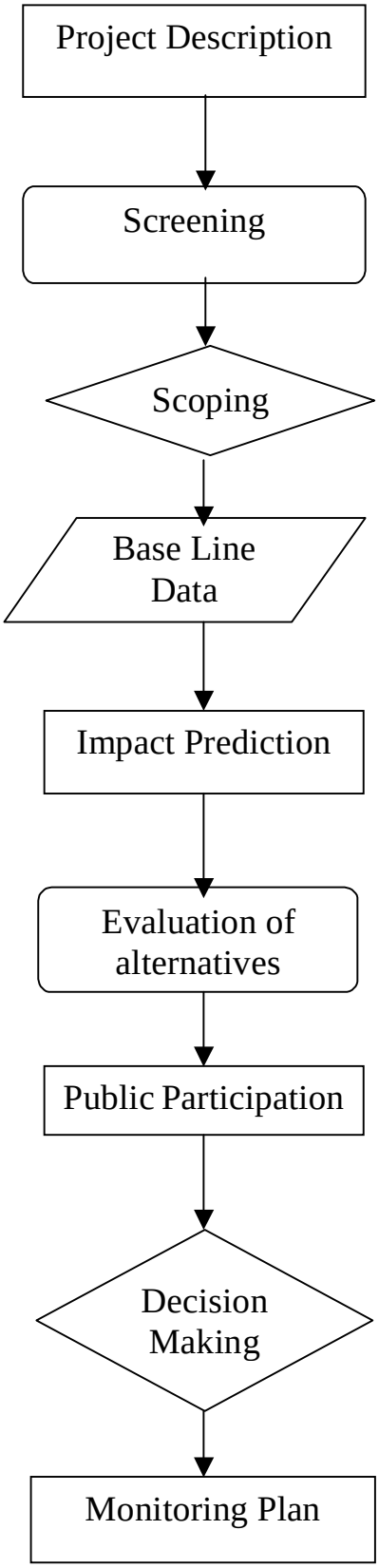

Figure-1: EIA Procedure

possible layouts through corridor. This corridor was plotted and used as a base map and all the layouts should go through this corridor.

- Specialized roadway design package was used for alignment development. When the different road alternatives were set for the estimation by overlaying the layers of area vulnerability and the road centerlines. This vulnerability was multiplied by the length of the arc and the cumulative value for each alternative was calculated.

5.2 Output: The best alternative was one, which had the minimum cumulative value calculated above.

6. Conclusions

- The GIS is very efficient and convenient to collect, manage and analyze the data and visualize the result of assessment.
- The GIS reduces the subjectivity in the process of preparing EIA of a highway and provides transparency to decide over the possible alternatives.
- The GIS based EIA is having the final output in pictorial form, which is very helpful and easy to understand by non technical decision makers.
- Since GIS based database can be easily integrated with remote sensing data, which are dynamic and temporal in nature, it will help in a great way to prepare environmental audit of the same project at a later stage.

7. References

[1] Antunes, P., Santos, R. and Jardao, L. (2001). "The Application of Geographical Information System to determine environmental Impact Significance", *Environmental Impact Assessment Review,* Vol. 21, pp 511-535.

[2] Burrough, P.A. (1986). *Principles of Geographical Information System for Land Resources Assessment*. Clarendon Press, Oxford.

[3] Canter, L.W. (1996). *Environmental Impact Assessment,* Second Ed. McGraw-Hill, New York.

[4] Haklay, M., Feitelson, E. and Doytsher, Y. (1998). "The Potential of a GIS-Based Scoping System: An Israeli Proposal and Case Study", *Environmental Impact Assessment Review,* Vol. 18, pp 439-459.

[5] Li, X., Wang, W., Li, F. and Deng, X. (1999). "GIS Based Map Overlay Method for Comprehensive Assessment of Road Environmental Impact", *Transportation Research Part D 4* , pp 147-158.

[6] Miles, S.B. and Ho, C.L. (1999). "Applications and Issues of GIS as Tool for Civil Engineering Modeling", *Journal of Computing in Civil Engineering,*

ASCE, Vol. 13(3), pp 144-152.

[7] Moragues, A. *and* Alcaide, T. (1996). "The Use of a Geographical Information System to assess the Effects of *Traffic* Pollution", *The Science of the Total Environment,* 189/190, pp 267-273.

[8] Oterholm, A. I. (1999). "Using GIS to Evaluate Environmental *and* Visual Impacts", *EPPL7/EPIC GIS Conference, Oct. 26-27, St. Paul, Minnasota.*

[9] Rau, J. and D.G. Wooten, D.G. (1980). *Environmental Impact Analysis Handbook*. McGraw Hill, New York.

[10] Sinha, S. (1998). "Environmental Impact *Assessment*: An Effective Management Tool", *TERI Information Monitor on Environmental Science,* 3(1), pp 1-7.

[11] Zura, M. and Lipar, P. (1995). "The Road and Traffic Environmental Impact Assessment and Optimal Room Layout Selection", *ESRI user conference 1995 proceedings,* http://www.esri.com/library/userconf/proc95to200 /p157.html.