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GIS based modeling of socio-environmental impacts due to a highway development project- A case study

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Abstract
Infrastructure development is the basic need for economic development of a country. Highway is an important infrastructure for movement of goods and passenger traffic. In the recent years, the need for developing adequate road transportation infrastructure has been realized by Government of India and various state Governments. Major road development projects have been formulated at national level in India. Analysis of socio-environmental impact is an essential component of environmental impact assessment (EIA) that is required for the planning of all major road projects. Most of the socio-environmental attributes are spatial in nature and for a rational assessment of these impacts it is necessary to quantify the impacts considering their spatial variations.In this paper a methodology is demonstrated with reference to a case study of highway development project in India, for the quantification of impact on individual socio-environmental attributes based on the perception of public in the influence area of the project, and the spatial variation of impacts is modeled using Geographic Information System (GIS).

Keywords: Socio-environmental impacts, Highway development project, Public perception, and Geographic Information System (GIS).

INTRODUCTION

Infrastructure development is the basic need for economic development of a country. Highway is an important infrastructure for movement of goods and passenger traffic. In the recent years, the need for developing adequate road transportation infrastructure has been realized by Government of India and various state Governments. Major road development projects have been formulated at national level under National Highway Development Project (NHDP), which will strengthen and widen 14,000 kilometers of National Highways by 2007 (Maitra et al., 2002). Various State Governments have also started projects for upgrading some of the state highways. All these efforts are intended to provide improved road transportation facilities for passenger and goods traffic.

Highway development projects cause ecological destabilization and habitat disturbance of the surroundings. Ecological balance is of global prime concern for the environmental planners due to resulting consequences like global warming, acid rains and depletion of ozone layer (Canter, 1996; Rau and Wooten, 1980). The conservation of biological diversity (biodiversity) is an important global environmental concern (George, 1999; Diamantini and Zanon, 2000).Roads are long and linear structures and therefore, road development projects are more susceptible to ecology as compared to other types of development projects (Byron et al., 2000; Thompson et al., 1997). Development with environmental protection and sustainability are the main goal of the policies of Government of India. In India, Ministry of Environment and Forest (MoEF) has made it mandatory to conduct Environmental Impact Assessment (EIA) for major highway projects (MoEF, 1994). Assessment of impact on ecological attributes is one of the main components of EIA for highway project (IRC, 1989).

Highway development project may affect ecological components like plants, sensitive plants, amphibians, reptiles, mammals and sensitive fauna (Canter, 1996; Rau and Wooten, 1980; Agrawal and Dikshit, 2003). For predicting the impacts on ecological attributes the approaches available are qualitative approaches; habitat-based approach; physical-modeling approach and biodiversity based approach (Canter, 1996). All these generic approaches require an extensive database related to the ecological attributes of the project area as well as post-project impact data for the similar projects in the vicinity of the proposed project. In developing countries, normally such extensive database is not available due to the absence of post-project monitoring network. An alternative approach based on public perception for selecting more socially accepted management plan in order to protect or restore an ecosystem is presented by Pavlikakis and Tsihrintzis (2003). In the present paper a similar approach based on perception of the people in the surrounding of project area is adopted for assessing the impacts on ecological attributes due to a highway development project.

Most of the ecological attributes are spatially distributed in nature and the traditional methods of impact assessment do not consider the spatial variation of impacts. As a result, the assessment of impact on ecological attributes becomes incomplete and inaccurate. In order to utilize the spatial information of ecological

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attributes to the maximum possible extent, a suitable spatial database management tool is required. Geographic Information System (GIS) is an established tool for collecting, storing, retrieving, transforming and displaying spatial data (Burrough, 1986). In the present paper, ecological impacts due to highway development project are assessed by integrating public opinion in GIS framework.

Study area and selection of ecological attributes

A 56 km long stretch of National Highway (NH-60) from Jaleshwar to Kharagpur in India is selected for the present work. This stretch of National Highway is in the process of being upgraded from two lanes to four lanes. In order to assess the ecological impacts due to the development of study road stretch, approximately 15 km on either side of the road with existing physical boundaries, are considered.

Six ecological attributes are considered for assessing impacts due to highway development project in this study based on information available in the literature (Rau and Wooten, 1980; IRC, 1989; Canter, 1996; NHAI, 2000; Agrawal and Dikshit, 2003). The biological attributes used for the present work are as follows.

(a) Impact on Plants

(b) Impact on Sensitive Plants

(c) Impact on Amphibians

(d) Impact on Mammals

(e) Impact on Reptiles

(f) Impact on Sensitive Faunas

METHODOLOGY

For assessing impacts on ecological attributes due to the highway development project an approach for evaluation based on perception of people in the surrounding area of the project is used. A methodology is formulated for designing of questionnaire; collection of data; preparation of spatial database; and quantification of impacts. These major steps are described below.

- Designing questionnaire- A questionnaire was designed for this purpose. There were two major components of the questionnaire. The first part consisted of information regarding respondent's socioeconomic status like income, education, occupation, age, sex, etc. The next part of the questionnaire consisted of respondent's perception about the likely impacts on various ecological attributes due to the development of highway.
- Collection of data- For collecting data related with public perception about likely impacts on ecological attributes, the respondents were selected from different locations along the study road stretch and also at different distances from the centerline of the highway. The opinion was collected from respondents of various age groups, occupations, incomes etc. A detailed description of the ecological attributes was made available to respondents before they were asked to express opinions about perceived impacts on different attributes. For obtaining likely impact on each attribute, respondents were asked to select one of the five impact categories as Highly adverse/ Moderately adverse / No impact/ Moderately positive / Highly positive.
- Preparation of spatial database- For preparing spatial database, the responses obtained in the form of five impact categories were coded in GIS database using the discrete impact scores (Antunes et al., 2001) as given in Table 1. The impact scores at intermediate points were obtained by generating a surface of impact score in GIS environment. As the change of impact is continuous, the impact categories were redefined based on selected ranges of impact score rather than discrete values. The range of impact score used for redefining impact categories are given in Table 2.

Table 1.Impact scores associated with different categories of impact

Category of Impact	Discrete Impact Score
High adverse impact (HAI)	-10
Moderate adverse impact (MAI)	-5
No impact (NI)	0
Moderate positive impact (MPI)	+5
High positive impact (HPI)	+10

Table 2. Redefining impact categories based on range of impact score

Range of impact Score	Category of impact
-10 to –7	High negative impact
-7 to –2	Moderate negative impact
- 2 to + 2	No impact
+ 2 to + 7	Moderate positive impact
+7 to + 10	High positive impact

- Quantification of ecological impacts- For spatial quantification of impacts the area under each impact category was estimated for different ecological attributes. With the help of GIS database, the impact values for different ecological attributes were also estimated by multiplying the area impacted with the impact score. This impact value is a summary measure for the extent of impact on each attribute considering both the impact score and the area affected.

RESULTS AND DISCUSSION

Using the spatial analysis of the impact data obtained from respondents, separate contours were drawn based on categories of impact on each of the ecological attributes. Distribution of impacts on plants, sensitive plants, amphibians and mammals in the study area are presented in Figure 1. A similar map is presented in Figure 2, for impacts on reptiles and sensitive fauna. It is observed from Figure 1 and Figure 2 that all ecological attributes are found to have adverse impacts. For all attributes, areas adjacent to road are found to have high adverse impact. The width of area affected in case of each attribute is observed to be different and the spatial distribution of impacts along the length of the road is also found different. The adverse impact on the ecological attributes found to reduce with increase in radial distance from the road.

Using the spatial impact data, areas under different impact categories for each ecological attribute are estimated and presented in Table 3. It is observed from Table 3 that major portion of the study area is under No Impact (NI) category and Moderate Adverse Impact (MAI) category and a small portion of the area is found to be under High Adverse Impact (HAI) category for all the biological attributes.

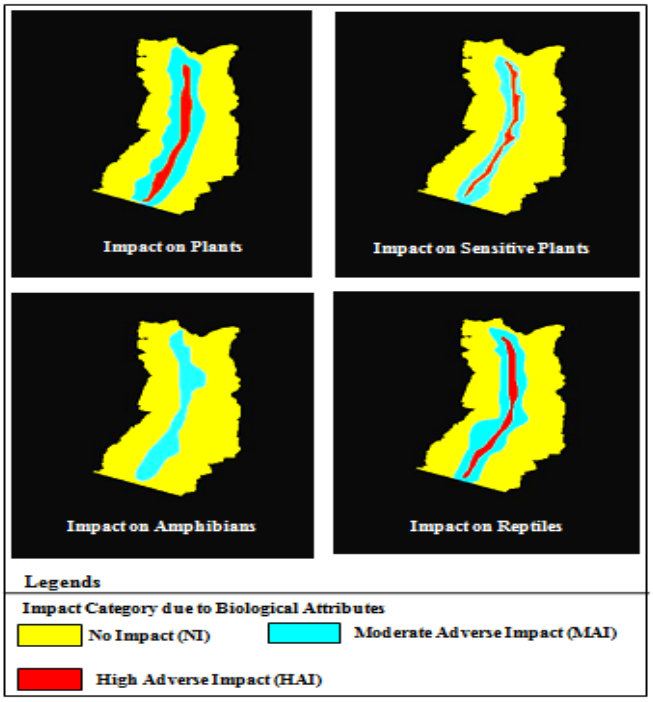

Fig 1. Impact map for Plants, Sensitive plants, Amphibians and Reptiles

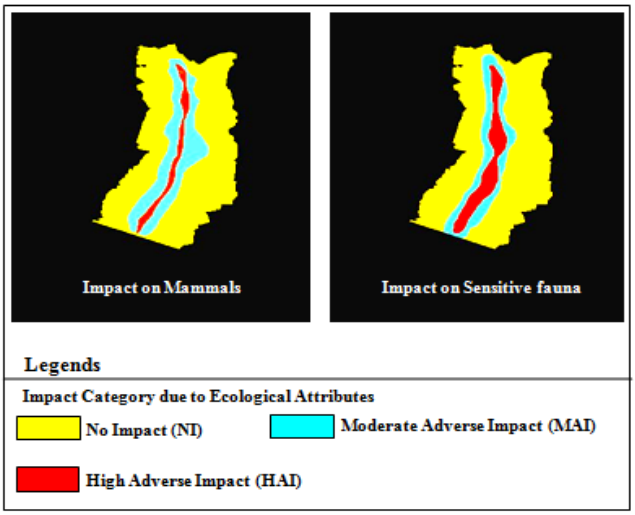

Fig 2. Impact map for Mammals and Sensitive fauna

Table 3. Area wise distribution of impacts

S. No.	Biological attribute	Area in km²		
		No Impact (NI)	Moderate Adverse Impact (MAI)	High Adverse Impact (HAI)
1.	Plants	1325.52	332.30	26.89
2.	Sensitive plants	1476.5	196.43	11.78
3.	Amphibians	1467.21	217.50	0
4.	Mammals	1368.78	298.57	17.36
5.	Reptiles	1388.48	276.56	19.67
6.	Sensitive fauna	1394.81	252.34	37.56

The impact values for different ecological attributes are presented in Table 4. The impact value for plants is found to be maximum. Impact values for sensitive fauna, mammals and reptiles are found to be moderate and for sensitive plants and amphibians it is marginal. These impact values are a measure of extent of impact on ecological attributes

Table 4. Impact value for each socioeconomic attribute

S.No.	Socio-economic attribute	Impact value= ΣPixel value*Area of pixel in km^2
1.	Plants	-1930
2.	Sensitive plants	-993
3.	Amphibians	-1087
4.	Mammals	-1566
5.	Reptiles	-1579
6.	Sensitive fauna	-1637

CONCLUSIONS

An approach for assessment of ecological impacts based on the perception of people in the surrounding area is demonstrated in the present paper with reference to a highway development project. The impacts on ecological attributes are spatial in nature. GIS is shown to be instrumental for incorporating the spatial nature of ecological impacts due to the development of a highway. The rationality for assessing socioeconomic impacts is therefore, improved with the integration of GIS. GIS based methodology presented in the paper is also found useful for identifying the areas under different categories of impact. An approach for quantifying the impacts on ecological attributes is successfully applied to the case study under consideration and is found to be effective in explaining the severity of overall impact on ecological attributes by considering the impacted area under each impact category and impact score for estimating the impact value. These impact values are the measure of extent of impact on ecological attributes.

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