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GIS BASED DECISION SUPPORT SYSTEM FOR SEISMIC RISK REDUCTION IN URBAN PLANNING OF GUWAHATI CITY, INDIA

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SUMMARY

Urban planning in disaster prone areas especially in areas of high seismic activities is a difficult task. Presence of large amount of sediment and landfill may amplify the seismic waves and thereby causing greater damage during an earthquake. The city of Guwahati in India, which lies on a very high seismic zone (zone 5), is a typical case of haphazard and unplanned urbanization. In this study an integrated remote sensing and GIS based methodology is developed and successfully tested by generating an up to date digital database. Finally a Decision Support System (DSS) is designed for the city development authorities. The main objective of this study is to create a digital database containing urban sprawl information, available land for urban growth, the rate of land development and land use change, information regarding bedrock profile, liquefaction potential information etc. The entire database has been developed by using data from diverse sources. The pattern of urban sprawl is identified and modeled using remotely sensed data. The cadastral data comprises of the toposheets provided by the Survey of India. The remote sensing data was classified for land use, based on built up, transportation (road and rail network), water bodies, agriculture and barren. For the change detection, temporal data between 1972 and 2002 (SPOT-1, Landsat TM, IRS-LISS-III and PAN) were used. The geotechnical properties including the liquefaction potential are determined from borehole data and the soil reports available at the Guwahati Metropolitan Development Authority. The spatial and temporal analyses techniques such as Geographic Information Systems (GIS) and Remote Sensing are used to develop a Decision Support System (DSS) to provide facilities to the planning authorities to take strategic decisions and to set guidelines regarding the new constructions. Finally, the entire database has been transformed in to web supported format for immediate and easy access.

INTRODUCTION

Seismic hazards are defined as those earthquake-related geologic processes that have the potential to "produce adverse effects on human activities" (Earthquake Spectra, November 1984), whether the threat is to life, constructed works, or real estate. For urban planners it has been always a great challenge to go for

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proper planning of a city situated in a very high seismic zone. The cities are like trees; both of them grow under natural limits. These limits affect in the formulation of a city's master plan (*Mahrous, et al,* 2002). In India, rapid urbanization is resulted due to the unprecedented population growth coupled with unplanned developmental activities. This urbanization, which lacks in infrastructure facilities, has posed serious implications on the resource base of the region. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. The city of Guwahati in India which is placed at a very high seismic zone (Zone V) provides a typical case of haphazard and unplanned urbanization.

Keeping these perspectives in view, attempt has been made to provide opportunities to realize a strategic assessment to determine the current status of land use, land suitability information, identification of the patterns of change during the past years, assessment of the impact of infrastructure development in terms of zoning regulations, transportation facilities, public utilities, drainage system, population, industry, tourism etc to meet the challenges in Planning and Management of Guwahati City using integrated remote sensing and GIS technology.

The data elements (Landuse/landcover, infrastructure, drainage, geotechnical information etc.) which have both static and dynamic components pose a formidable challenge for proper maintenance and operations in different sectors concerns. Due to development of automation in technological processes applied to data gathering, integration and processing of topographic details and their customized presentation, analysis and interpretation the challenges can be met with the help Desktop GIS system. While **Geographical Information System (GIS)** involves in integration of spatially referenced data in a problem solving environment, **GIS-based Decision Support System (DSS)** is an interactive computer-based systems that help decision makers utilize data and models to solve unstructured problems. Properly implemented, a GIS can link geological and geotechnical data with information on urban development for studies of the impact of hypothetical earthquakes on human activities. The GIS facilitated the numerous repetitive calculations required to produce the individual seismic hazard maps that the overall relative hazard map is based on, as well as linking the seismic hazard data with information on buildings and infrastructure for the damage and loss assessment. Combining both the ideas, in the present times such powerful software technology has been developed that allows virtually unlimited amounts of information to be linked to a geographic location. Coupled with a digital map, GIS records, stores, and analyzes information about the features that make up the earth's surface, thus allowing a user to see regions, countries, neighborhoods, and the people who live in them with unprecedented clarity (Betty, et al.,1998).

In this study an integrated remote sensing GIS based methodology is developed and successfully tested by generating an up to date database. Finally, a Decision Support System is designed for the city development authorities for proper planning with minimum seismic risk. This DSS sets a meaningful relationship which addresses zoning and its link to the existing urban density distribution, the demand of building permits, the rate of urban growth, and the index of saturation.

SEISMIC HAZARDS

Natural disasters are the outcome of many complex geophysical characteristics in addition to the related social circumstances that are subjected to a hazard. In order to grasp the impact of different disasters, it is necessary to understand the interactions and inter-relationships among these diverse and complex characteristics for any given magnitude of the hazardous event.As mentioned earlier seismic hazards are defined as those earthquake-related geologic processes that have the potential to "produce adverse effects on human activities" (Earthquake Spectra, November 1984), whether the threat is to life, constructed works, or real estate. Ground motion, the definitive characteristic of earthquakes, is a seismic hazard that causes damage to structures directly, by vibration, or indirectly, by inducing other seismic hazards such as liquefaction and landsliding.

The Amplification of Ground Motion

The intensity of seismic ground motion is a function of earthquake magnitude and distance from the seismic source, as well as local soil conditions, topography and geological conditions. Seismic zonation using probabilistic seismic hazard assessments (PSHA) are routinely used to estimate seismic intensity, characterized as peak ground acceleration (PGA), peak ground velocity (PGV) or spectral response ordinates for firm ground using the earthquake magnitude and the distance from source to site.Amplification of ground motions at soft sites above those predicted by PSHA for firm ground has long been recognized from damage patterns of historic earthquakes. The cost of damage from ground shaking alone in historic earthquakes has tended to be less than that from liquefaction and/or seismically-induced landsliding, though these phenomena are linked in that ground motion amplification can intensify the severity of liquefaction-related hazards. However, amplification of ground motion is at least partially accounted for in the seismic design of new structures through a foundation factor which increases for thick soft soils. Amplification of ground motion is therefore considered to be a somewhat lesser hazard than either liquefaction or landsliding.

Liquefaction

Liquefaction is considered one of the most important seismic hazards for integrated land use planning in for two reasons. First, liquefaction has caused severe damage to structures in historic, including buildings, dams, and lifelines such as transportation networks, water distribution systems, and wastewater collection and treatment facilities. Second, many communities are located near rivers and lakes where liquefaction-susceptible soils such as loose, saturated sands are commonly found. Liquefaction `potential' refers to the probability that soil will actually liquefy at a given site, and therefore depends not only on the soil's liquefaction susceptibility, but the level of seismic activity in the region (i.e., the liquefaction `opportunity'). For example, a very loose, clean sand may be highly susceptible to liquefaction, but if it exists in a region of negligible seismicity, then its liquefaction potential will be low. In contrast, a denser soil may have a lower susceptibility but a higher liquefaction potential because it is situated in an area of very strong seismic activity. Thus, liquefaction potential depends on soil properties and local seismic activity, whereas liquefaction susceptibility depends only on soil properties.

Landslides

Landslides are also considered an important seismic hazard for land use planning in because of the potential for causing severe damage to structures and the extreme risk to human life. In addition, the province's topographic relief results in a relatively high potential for landsliding. The high potential for loss of life and economic consequences of seismically-induced landslides are demonstrated by the impact of earthquakes in other areas, such as Japan, where studies have shown that landslides were responsible for more than half of the deaths attributed to large (M>6.0) events, and in Alaska, where almost 60% of the economic losses in the 1964 earthquake were due to landslides and liquefaction-related ground failure.

THE STUDY AREA AND IT'S PROBLEMS

The city of Guwahati, located at latitude 26^{o}10'45" N & longitude 91^{o} 45' 0" E in the district of Kamrup District, is considered as the gateway to the seven northeastern states known as Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Mizoram and Tripura of India. The city spreads about 10 km in north south direction and 27 km in east west direction. Naturally the city plays a vital role in the socio-economic development of the entire region. The first aspect of the city that strikes a visitor is the natural beauty of the place. It is ringed around on three sides by a chain of hills stretches to the horizon. The northern side is bounded by awesome Brahmaputra river.

Major problem with the study area can be identifies as are (i) Rapid Growth of Population within the three decades till date and (ii) Unplanned growth of the city both horizontally in all direction and vertically so also.

There is a rapid growth of population in the city from 292029 to 1067400 within a period of 30 years from 1971 to 2001 (Census of India, 2001). The rapid increase of population of the city coupled with its importance in terms of being the center of social, commercial, educational, political and industrial activities made the city to be the important center of the entire north eastern region of India. This has resulted in rapid expansion of constructed areas at a very fast pace almost beyond the control of the authorities entrusted with planning and development actions and regulation of the city works. Secondly, due to the unplanned growth of the city both in horizontal and vertical directions, there is a need for proper planning for the careful handling of this alarming situation.

OBJECTIVES OF THE STUDY

The main objectives of this study area with respect to its problems are:

- To identify the urban sprawl by using remote sensing data
- To identify the available land for urban growth or satellite township
- To monitor the rate of land development and land use change
- To highlight areas which are close to reach saturation and require immediate attention from the concerned authorities
- To know the growth pressure with land use and zoning regulations into perspective from available data
- To identify areas which exhibit high rate of development and are faced with the problem of over densification and suffering from stagnation due to lack of adequate infrastructure.
- To determnine the depth of bed rock profile from the borehole data with N vakues.
- To assist the decision makers in laying the foundation for the growth of the Guwahati Metropolitan area
- To develop a Web based interactive Decision Support System (DSS) for immediate and ready extraction of plotwise detailed information.

DATA USED

There are three different datasets are used in this study. They are (i) Satellite data in digital format, (ii) Analog data in the form of maps and (iii) field data collected from various sources. The data sets used in the present study with their specific purposes are listed in table 1.

To support image classification and thematic information collection, several field trips have been realized to the study area. Information on land cover and land use has been collected by using a video recorder and Konica LandMaster GPS camera. The GPS camera with a built-in GPS chip provides information such as date and time, geographical co-ordinates and bearing captured on the film media together with image. This information combination represents an excellent tool for accurate data registration and enhances the efficiency of the in-house work.

Table 1 : List of data used in the present study.

Name of Map	DATA BASE	Year	Scale
Proposed Land Use	DRG: TPO/GMP/83 – 84/ 01 dated 20/05/83	1983	1:30000
Master Plan for Guwahati	DRG/: GUO/TP/GMP/R/01 dated 10/05/79 Revised on07/05/79	1992	1:20000
Land Use	SPOT – 1 HRV 2PLA MLA PATH – D 238, ROW – 298; 78 N/12 NE, 78 N/16 SE 78 N/12 NW, 78 N/16 SW Acquisition date: 18/10/90; SOI 78 N/12, 78 N/16	1990	1:50000
Population	Ward map GMC, Census 1991 Survey of India, 78 N/12, 78 N/16	1991	1:50000
Drainage and Flood Prone	SPOT MLA P-238, P-298; Acquisition date:18/10/90 Landsat TM P-137, P-042 Acquisition date:10/06/88; Survey of India, 78 N/12, 78 N/16	1990	1:50000
Urban Sprawl	SPOT MLA P-238, P-298; Acquisition date:18/10/90 Landsat TM P-137, P-042 Acquisition date:10/06/88; Survey of India, 78 N/12, 78 N/16	1990	1:50000
Land Suitability	SPOT MLA P-238, P-298 Landsat TM P-137, P-042 Survey of India,78 N/12, 78 N/16	1991	1:50000

METHODOLOGY

The methodology adopted in the study can be described in the following steps.

(a) The map of Guwahati City and its surrounding areas is digitized. The Cadastral data comprises of the characteristics of the drainage network, road and railway network and infrastructure facilities in the city.

(b) The satellite data were processed and classified using supervised classification method to prepare the land use/land cover map. The spatial and temporal changes in growth pattern are recognized from the digital data.

(c) Plot-wise urban land use map is prepared and attributes were assigned for every plot with full ownership and built-up information.

(d) A Decision Support System has been created to acquire information regarding every plot with its all attributes.

(e) The entire database is converted into a web supported format and is customized to provide query facilities for immediate and ready extraction of information through Web

The entire database has been developed by using data from diverse sources. The pattern of urban sprawl is identified and modeled using remotely sensed data. This helped in identifying the linear and radial pattern of growth and its rate. The analyses involved were land cover, land use, spatial and temporal changes and urbanization growth pattern recognition. The cadastral data comprises of the characteristics of land use / land cover, drainage network, roads and railway network and the administrative boundaries of 1991 from the toposheets provided by the Survey of India. The remote sensing data was classified for land use, based on themes - built up, transportation (road and rail network), water bodies (rivers, streams, etc.), agriculture and barren (uncultivable and waste land). For the change detection, temporal data between 1972 and 2002 (e.g. SPOT-1, Landsat TM, IRS-LISS-III and PAN) were used. This helped to identify the patterns of the change with respect to time.

RESULTS AND DISCUSSION

The entire database has been created using ArcView 3.2 GIS Software. The SPOT – I Satellite data and LANDSAT TM Digital Data are utilized for land use and land cover mapping. The different land use classes identified from these images are shown in table 2.

It is evident from the urban sprawl map that the city of Guwahati is rapidly increasing in the recent years and the growth is found mainly in south, south east direction of the original city (Figure 1). The infrastructure facilities are also growing in the city with its gradual expansion. Figure 2 shows the road network and the available infrastructure facilities found in the city. Figure 3 shows the land suitability map prepared using satellite data, which can provide a clear guidance to the city planners for proper planning of the city in terms proposed construction.

Table 2. Different landuse classes identified fro Guwahati city area from satellite data.

Level I	Level II	Level III	Code
Urban land Use	**RESIDENTIAL**	Medium	1
		Low	2
	Industrial	Heavy	3
		Medium	4
		Light	5
	Commercial	Commercial	6
	Transportation	Bus terminus	8
		Railway yards	9
		Air port	10
	Public & Semi-public	Educational institution	11
		Cantonment/army camp	12
		Other/ hospital	13
	Recreational	Stadium/ playground	14
		Parks/gardens	15
Mixed built up	Mixed built up	Mixed built up	16
Agriculture	Agriculture	Agriculture	17
Forest	Dense mixed forest	Dense mixed forest	18
	Open mixed forest	Open mixed forest	19
Wasteland	Water logged area	Water logged area	20
	Marshy/ swamps	Marshy / swamps	21
	Scrubland	Scrubland	22
	Grassland	Grassland	23
Water bodies	River /stream	River /stream	24
	Riverine sand	Riverine sand	25
	Tank /Lake	Tank /Lake	26
Others	Brick kiln	Brick kiln	27
	Excavation	Excavation	28

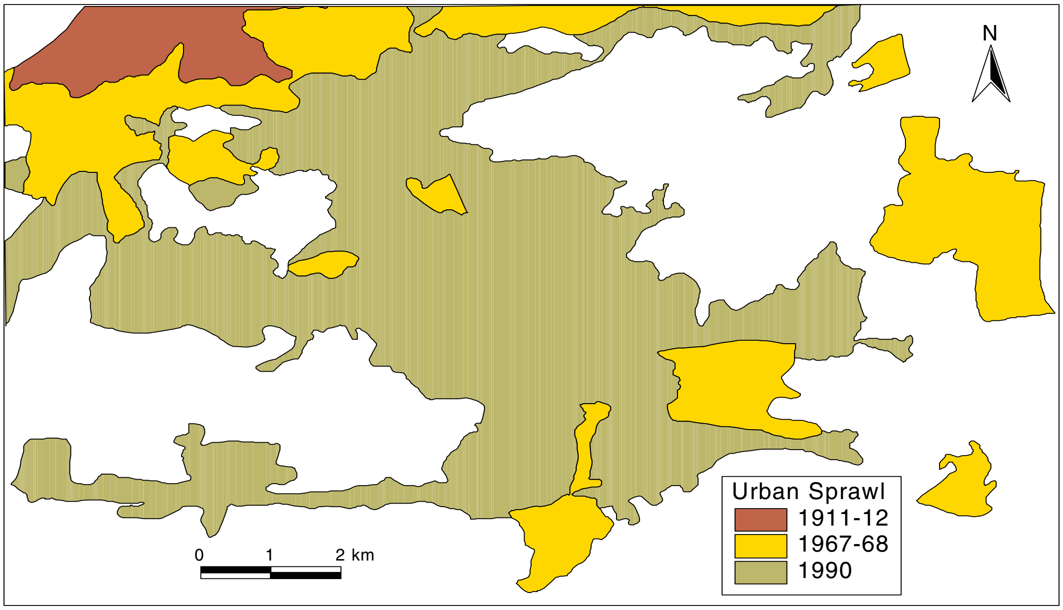

Figure 1: Urban Sprwal map of Guwahati City.

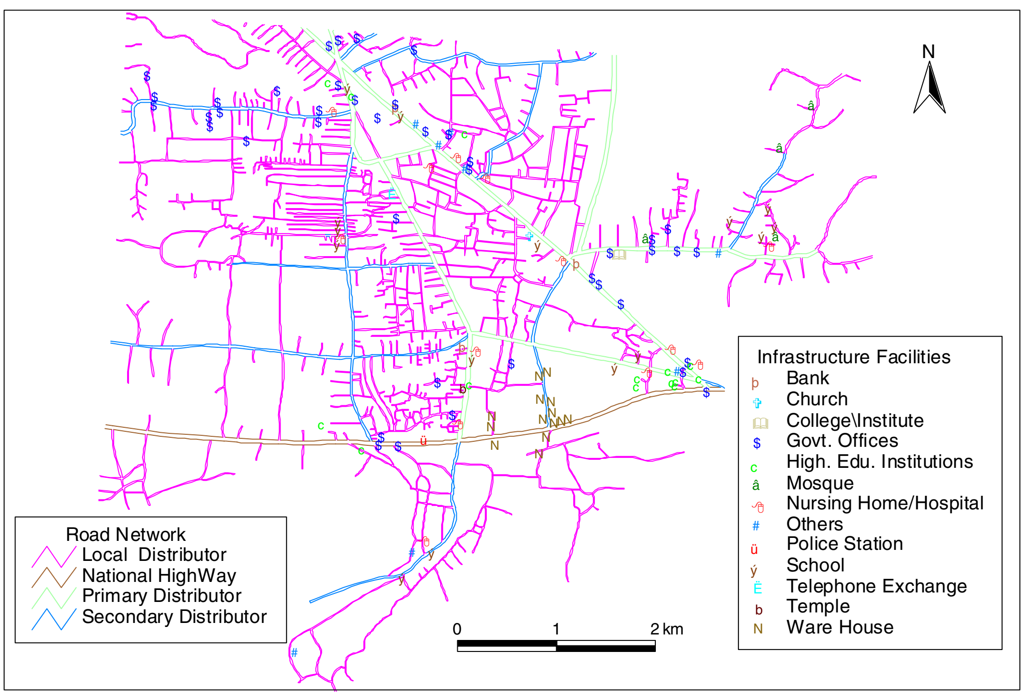

Figure 2: Road network and infrastructure facility map of Guwahati City.

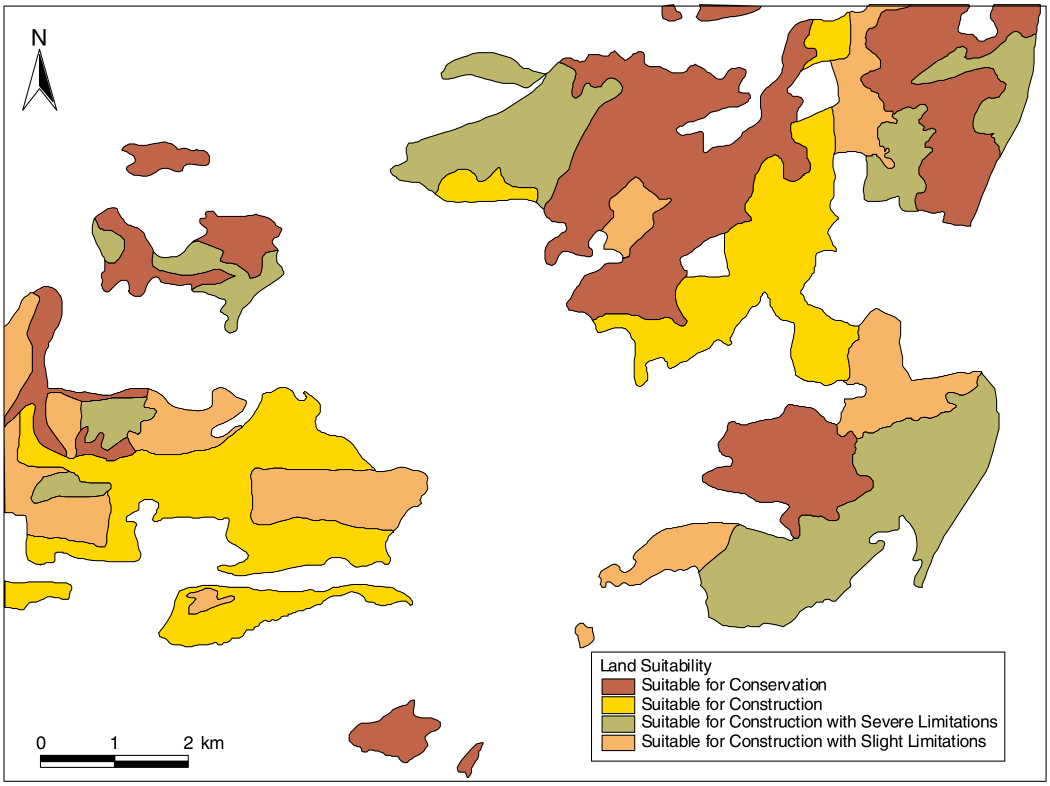

Figure 3: Land suitability map of Guwahati City.

Figure 4: Plotwise land information map of Guwahati City.

IRS-1D-LISS-III data merged with IRS-1D-PAN data are used to generate plot wise urban landuse map (Figure 4) of the Guwahati city and attributes regarding ownership as well as built up information were provided. This is very helpful for the controlling authorities to extract all the relevant information immediately. The Decision Support System thus produced helps the development authorities to set up the required guidelines for further development of the city.

Borehole data have been used to determine the depth of bedrock profile and geotechnical properties including the N value for different layers. These datasets have been incorporated in the final database which provides the facility of immediate extraction upon query. This also facilitates the calculation of liquefaction potential at different sites.

The entire database has been converted to a web-supported format, which makes it more accessible, and faster information system for a large number of users. Moreover it is customized to offer multiple query facilities which enables any individual to extract any information regarding any area, plot or individual plot owner (Figure 5).

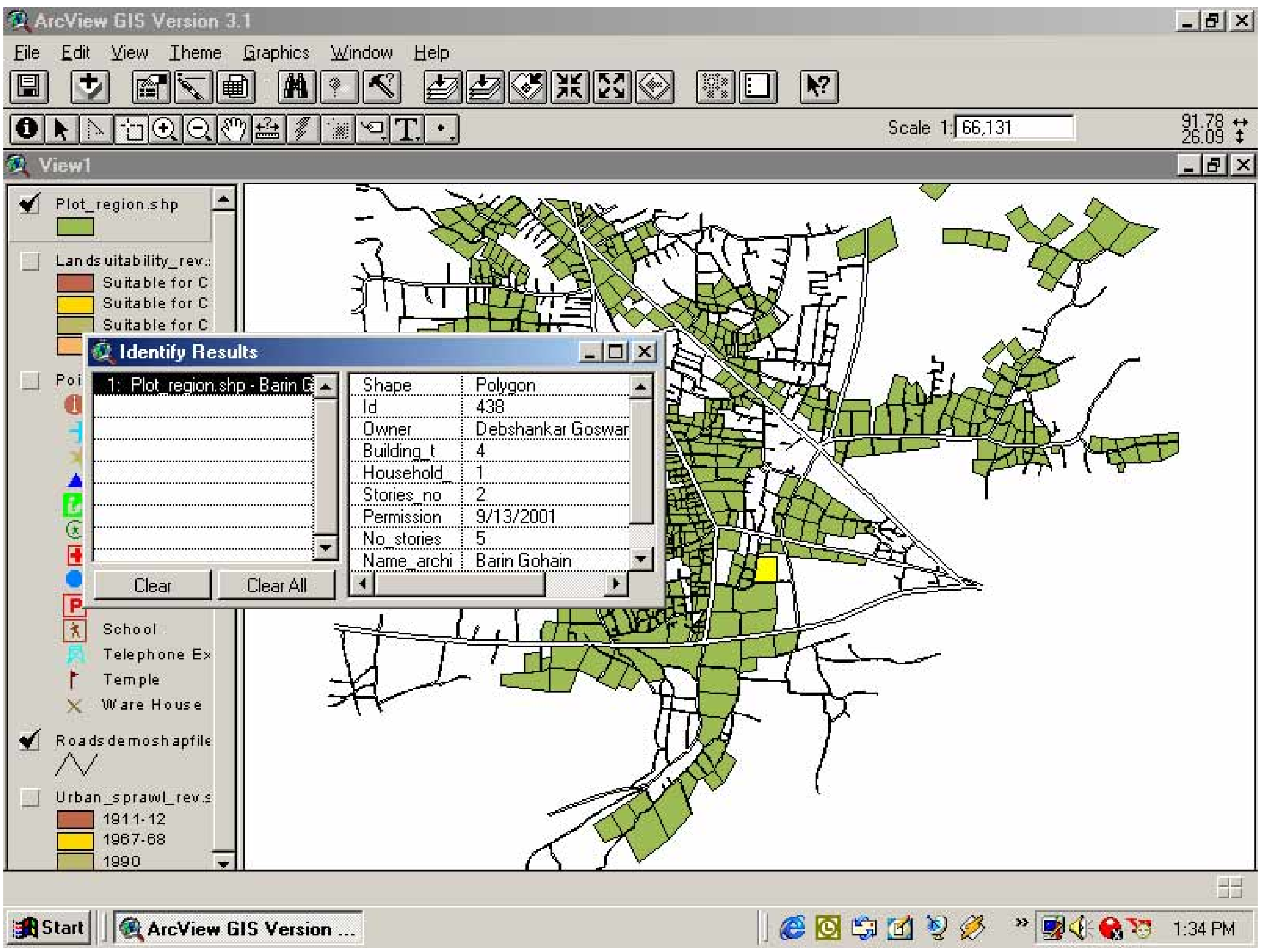

Figure 5: GIS based plotwise Decision Support System (DSS) for Guwahati City.

CONCLUSIONS

The following conclusions can be made from the above study:

1) The Integrated remote sensing and GIS methodology is found to be very useful in monitoring the urban growth of a thickly populated and rapidly increasing city like Guwahati in India.
2) The GIS based Decision Support System provides important tools for the developers and planners to extract information of the infrastructure facilities.
3) The geotechnical properties have been determined from the bore hole data with N values.
4) The liquefaction potential at any site can be easily determined from the geotechnical properties.
5) The web based plot wise information system provides the facility for ready and immediate extraction of information regarding land ownership, built up history and geotechnical characteristics.
6) The multi query facility provided in the Web based Decision Support System allows any individual to gather information regarding land holding.
7) This DSS sets a meaningful relationship which addresses zoning and its link to the existing urban density distribution, the demand of building permits, the rate of urban growth, and the index of saturation.
8) This Decision Support System can be utilized in much larger cities anywhere in the world with the addition of more information and desired modifications.

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