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Remote Sensing and GIS for Urban Planning

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"The effective collection and use of remotely sensed geospatial data may provide significantly improved efficiencies in planning and assessing transportation infrastructure projects. To fully support these potential improvements, computational geolibraries are needed to efficiently manage, process, customize, and deliver geospatial and remote sensing data to planners, managers, analysts, engineers, and other stakeholders."

Land is the important property and economic resource where all the development activities are concentrated. Therefore, it is required to carry out long term and scientific land use planning and to carry out sustainable development on the basis of physical features, composition, quality and capability of the land. The land use planning process begins with an analysis of the existing land use characteristics, from which future land uses can be identified to compliment the present situation as well as to make improvements. Urban landuse planning is essential for effective growth and sustainability of a community. As population is increasing, land becomes an increasingly scarce resource, especially in urban areas, thus giving rise to planning. Urban areas promote economic growth and satisfy housing, industrial, and commercial needs of growing human populations. Planning can be at various levels: local, town, district, state, regional, national, and international. Effective urban planning often involves participation of local communities, scientific information on land resources, appropriate technologies, and integrated evaluation of resource use. The development of remote sensing as a technique for gathering land resource information has a history of more than 25 years in India. Remote sensing can range from black and white aerial photographs to colour infrared photographs, radar images and satellite images.

ROLE OF REMOTE SENSING TECHNOLGIES

Satellite Remote Sensing involves gathering information about the earth's surface using satellites orbiting around the earth (Figure 1). The direct benefits of space technology have been in the areas of communication, education, health, entertainment, meteorology, resource inventory monitoring and management. Remote sensing allows for the synoptic observation and analyses of urban growth. Satellite images with moderate resolution (10 to 30 meters) have for decades facilitated scientific research activities at landscape and regional scales. Satellite Remote Sensing is a relatively cheap and rapid method of acquiring up-to-date information over a large geographical area. It is the only practical way to obtain data from inaccessible regions and gives a cheap and rapid way of constructing base maps in the absence of detailed land surveys. The data thus obtained are easy to be manipulated with the computer, and combine with other geographic coverages using the Geographic Information System (GIS). Recent availability of satellite based imaging systems data *viz.* IKONOS, QUICKBIRD, RESOURCESAT and CARTOSAT that provide spatial resolutions of 1m or better, facilitates analyses that can be applied to urban growth and transportation development for site-specific investigations.

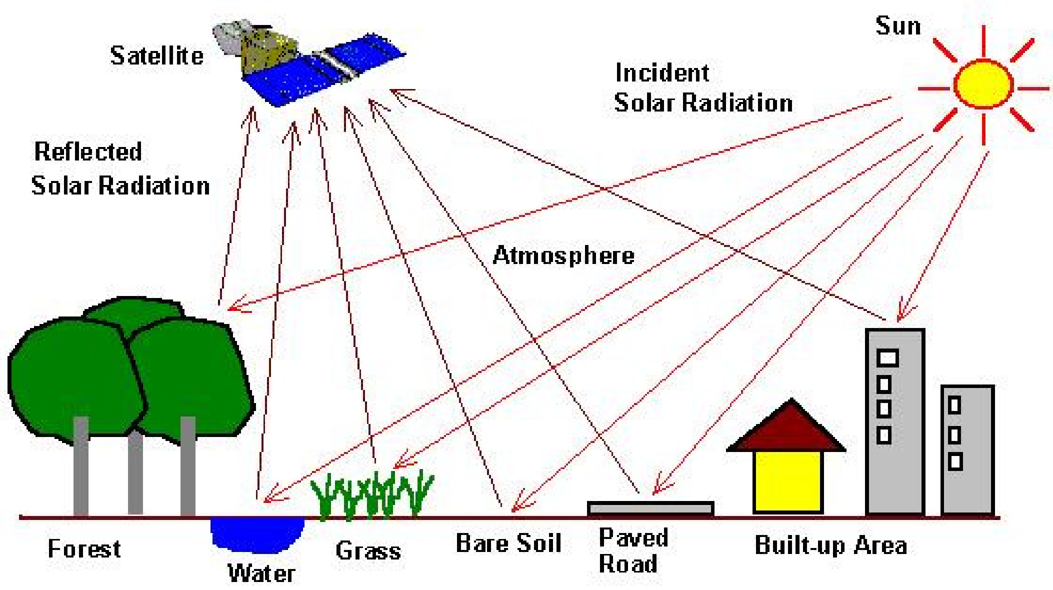

Fig. 1: Satellite Remote Sensing Process

Visual interpretation of multi-spectral satellite imagery such as IRS-P6 (Resourcesat) or merged (IRS-1C/1D LISS III + PAN) products, taking into consideration the image characteristics: viz. tone, texture, shape, size, pattern, location, drainage line network, vegetation and association, are carried out to generate thematic maps. Moreover, new hyperspectral sensors provide increased spectral resolution that can be used to further the analyses of environmental conditions. Remote sensing information is useful for land cover classification and change detection, wetlands mapping and assessment, watershed assessment and characterization, habitat assessment, cultural feature identification, environmental assessment and planning in transportation. Remote Sensing can supply some of the useful land information particularly natural resources that are needed for the planning of sustainable regional development.

Recently launched CARTOSAT-1 and 2 satellites carry state-of-the-art panchromatic (PAN) camera with spatial resolution of 2.5m and 80 cm respectively. The satellites can be steered up to 45 degrees along as well as across the track and have a revisit period of 4-5 days (Figure 2). The data from the satellites can be used for detailed 3-dimensional mapping and other cartographic applications at cadastral level, urban and rural infrastructure development and management, as well as applications in Land Information System (LIS) and Geographical Information System (GIS). The short revisit period helps in the monitoring of the same region durirng periods of disasters.

Fig.2: Hyderabad (Khairatabad and its environs), India as seen by CARTOSAT-2 *(Source: National Remote Sensing Centre, Hyderabad)*

Integrated regional land-use databases provide most geospatial data needed for an urban planning project. Aerial and satellite images give urban planners the ability to view geospatial information and identify features on the ground, and this helps them make logical decisions. 3D models are effective for showing details of major urban projects, and 3D GIS data can be generated with technologies such as LIDAR and CAD/GIS integration.

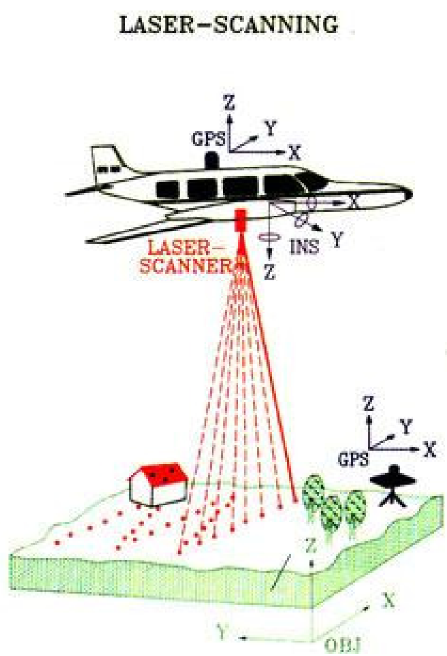

Fig.3: Airborne Laser Terrain mapping(LIDAR) Technology

LIDAR is the technology of using pulses of laser light striking the surfaces of the earth and measuring the time of pulse return (Figure 3). The LIDAR laser scanner is mounted photogrammetrically in the bottom of an airplane (similar to an aerial camera) along with an Inertial Measuring Unit and Airborne GPS. LIDAR technology offers the opportunity to collect terrain data of steep slopes and shadowed areas and inaccessible areas (such as, large mud flats and ocean jetties). These LIDAR applications are well suited for making digital elevation models (DEM), topographic mapping, and automatic feature extraction.

ROLE OF SPATIAL TECHNOLOGIES

Geographic Information System (GIS) is a computer-based system that enables users to collect, store, process, analyze and present spatial data (Figure 4). It provides an electronic representation of information, called spatial data, about the Earth's natural and man-made features. A GIS references these real-world spatial data elements to a coordinate system. These features can be separated into different layers. A GIS system stores each category of information in a separate "layer" for ease of maintenance, analysis, and visualization. GIS systems are dynamic and permit rapid updating, analysis, and display. They use data from many diverse sources such as satellite imagery, aerial photos, maps, ground surveys, and global positioning systems (GPS).

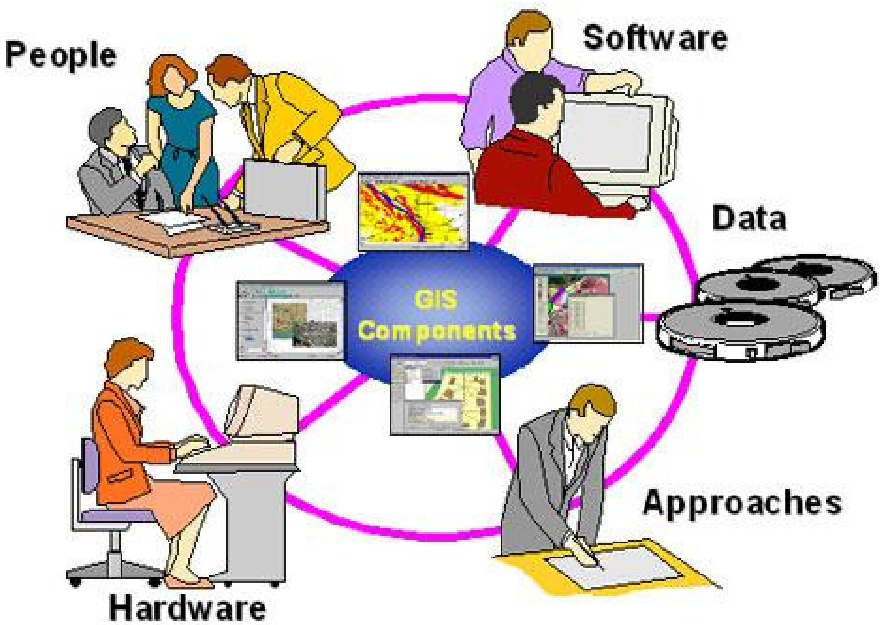

Fig. 4: Components of Geographical Information System

Maps are generated using satellite data interpretation and GIS software to assess the present natural resources available (land utilisation, land system, geology, water resources, climate and topography), land capability (soil, topography, climate, infrastructure and technology), vegetation (land utilization) and other environmental situations like cultural and natural heritages and impacts of natural and man made calamities.

Virtual Reality GIS has been developed to allow the creation, manipulation and exploration of geo-referenced virtual environments, e.g., using VRML modelling (Virtual Reality Modelling Language). Virtual Reality GIS can be also Web-based. Applications include 3D simulation for planning (to experiment with different scenarios). The increased availability of high-resolution satellite images and aerial photography in support of detailed terrain surface elevation models assists urban planners and municipal managers to create a model and visualize the urban space in three dimensions (Figure 5). Accurate cartographic feature extraction, map updating, digital city models and 3D city models in urban areas are essential for many applications, such as military operations, disaster management, mapping of buildings and their heights, simulation of new buildings, updation of cadastral databases, change detection and virtual reality.

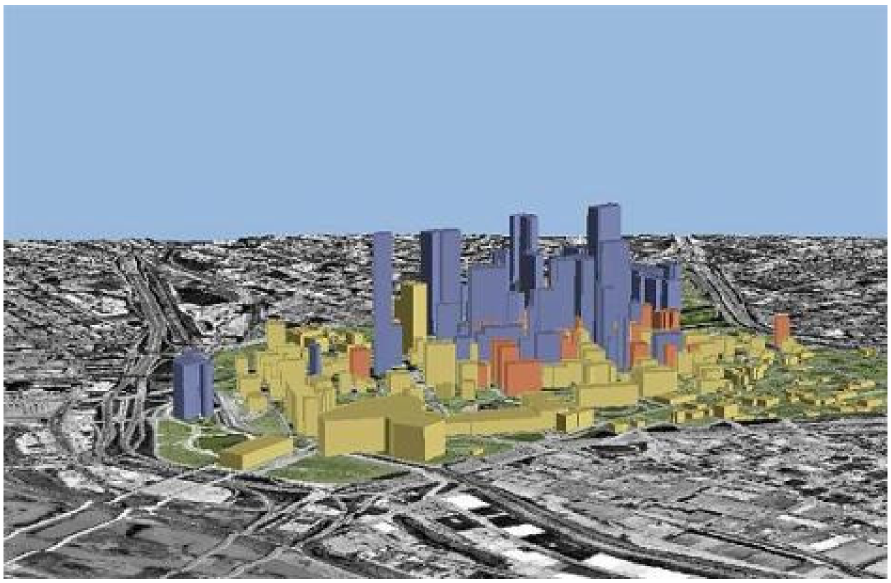

Fig.5: 3D visualization of an urban environment
(Image Credits: University of Texas at Dallas)

GIS can use and combine all layers that are available for an area, in order to produce an overlay that can be analyzed by using the same GIS (Figure 6). Such overlays and their analysis radically change decision-making process that includes, among others:

- Site selection
- Simulation of environmental effects ('what-if' scenarios)
- Emergency response planning (to foresee the impacts of a potential earthquake or floods)

At its simplest level, GIS can produce maps that are an integral part of the master planning process. GIS can also be used for land and capacity analysis, build-out analysis, neighborhood planning and viewshed and watershed modeling.

Extensions to standard GIS software have greatly improved the value of GIS, including:

- Visualization in three dimensions, through the addition of height to buildings and other database features, often through integration of GIS with the computer-assisted design (CAD) packages;
- Animation, through the computation of dynamic fly-bys that simulate the view from an aircraft flying over the area;

- Rendering of the future appearance of the landscape, or artists' impressions of the consequences of alternative decisions, using technology to simulate trees, buildings, and other land covers.

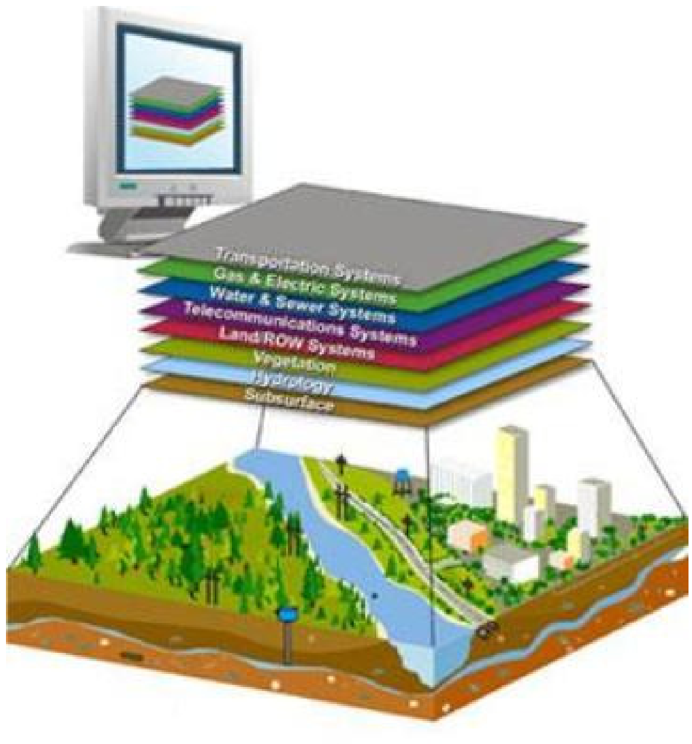

Fig.6: Different layers overlayed in Geographic Information System

A wide range of computer-based numerical models are now available for the simulation of such natural phenomena as forest succession, tectonic uplift, groundwater flow, and slope erosion. More recently progress has been made in simulating processes of urban growth, and other primarily social phenomena, and in the coupling of models of different but interacting processes.

GIS helps to communicate planning decisions to the public. Providing accurate information and opening up a two-way line of communication between planners and citizens can result in greater levels of involvement and interaction. The integration of GIS and the Web has greatly changed how the public becomes involved with the design and planning process. Information can be shared easily, and many websites are set up so that people can add information and provide input on any project or policy decision. These sites also function as interactive forums.

CASE STUDIES

Infrastructure development along the transport corridor:

Infrastructure development along the transport corridor – a study using Remote Sensing and GIS by Ramesh (2006) carried out at the Institute of Remote Sensing, Anna University, analyzed the development that had occurred along the transport corridor by means of comparing landuse maps belonging to different periods and studied the impacts of human settlement. The corridor is a part of inner ring road located in the southern part of Chennai, TamilNadu, India. A buffer of 1 km was generated on either side of the road between Taramani and Gurunanak College of Chennai using ArcGIS software and was taken as the study region.

The Landuse maps were derived for the years 1989 and 2002 using aerial photographs of 1:6000 scale and PAN imagery of IKONOS satellite. The changes in the landuse such as built-up area, agricultural land and water bodies were detected by overlaying the two layers in GIS environment (Figure 7). It was found that the built-up area had considerably increased to 60 % in 2002 as compared to 22.43 % of 1989. A growth pole theory was applied to study the growth occurring as discontinuous spurts leading to the formation of several growth points spread throughout the area. The various growth poles identified in the study region were Private industries, BPOs, Software consultancy services and other small companies.

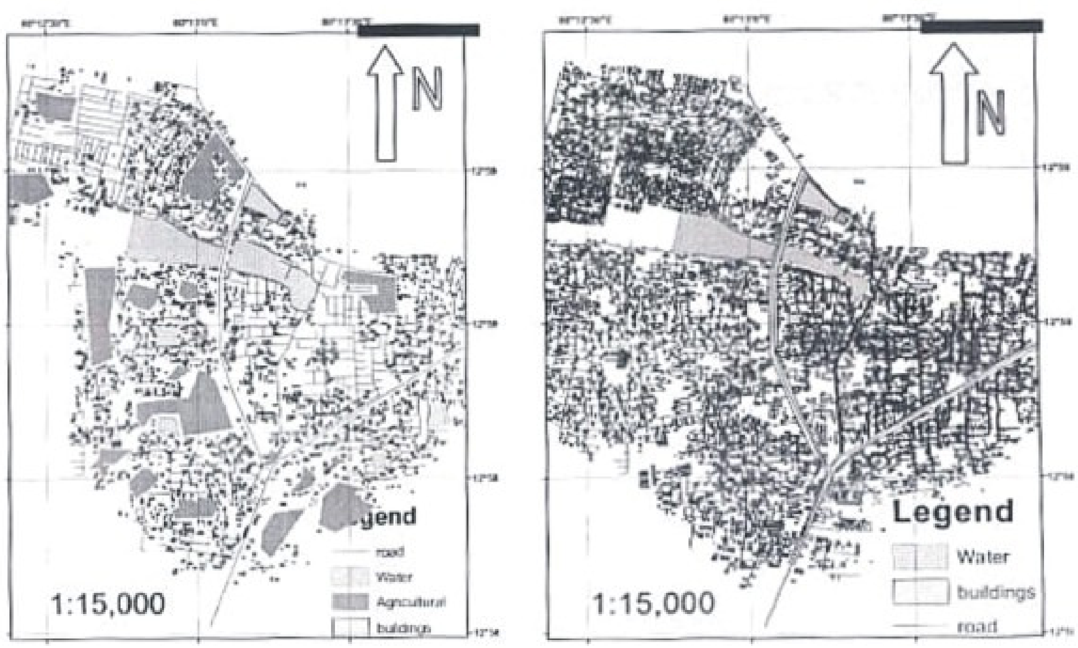

Fig.7: Landuse for 1989 and 2002 derived from Aerial Photos and IKONOS imagery
(Source: Ramesh 2006)

The road layer was digitized from 2002 IKONOS imagery using GIS software. The sources of damage to environment including ecological destabilization and habitat disturbances were identified from the landuse change map. The increase in population along the road resulted in an increased traffic along the corridor. The current traffic situation with major accident zones along the route and their causes were identified using data collected from the Joint Commissioner of Police, Chennai. Based on these, three zones were created identifying the major hotspots for accidents in the study region. All the above layers were input into GIS and analyzed to derive the impact of infrastructure development and the following inferences were arrived at: Land values had dramatically increased, floods had started occurring due to encroachments, region had become highly accident prone and the spread of agricultural land and water bodies had reduced.

Route Planning For Underground Cable Transmission Line:

A project for route planning for underground cable transmission line using GIS was undertaken by Viswarani (2007) at the Institute of Remote Sensing, Anna University. Generally, transmission and distribution of power are done through overhead transmission conductors. But in cities like Chennai, there are several disturbances on implementing the overhead lines. Therefore underground cables are preferred providing increased safety, reliability, trouble free service under lightning and storm conditions. Hence, the project has focused on underground transmission system with focus on route planning for cabling of such a system.

The substation considered for the study was the Anna University 33 KV substation. To meet the increasing demand of power supply in the University campus, it had been decided to design the route plan for getting power supply from R.A.Puram 110/33/11 KV substation located farther. Since, the cables are laid usually on any one side of the road, the road layer was digitized using GIS, with the following attributes, namely, road ID, road name, road width, road length, weight given to each road and end nodes of the road, from IKONOS satellite imagery (1m resolution). The landuse map comprising different classes like built-up area, water bodies etc was prepared from IKONOS imagery, based on which the roads were given weightage for cable laying. (Figure 8).

Fig.8: Landuse and road feature classes overlayed on IKONOS image
(Source: Viswarani 2007)

After preparation of the thematic layers, Route Network Analysis was performed on the road feature class and the output served as input for the Simple Ant Colony Optimization Method which was coded in the inbuilt Visual Basic editor of ArcMap and Route Solver of Network Analyst of ArcGIS software. These methods were applied to find the shortest path between origin and destination nodes by considering both length and weightage of the route sections. The output generated was a Route Network Map between the origin and destination nodes (Figure 9).

The ArcGIS Network Analyst is an extension used for routing and network-based spatial analysis and allows users to model realistic network conditions and scenarios. To work out the right solution out of numerous possible solutions, technical issues and development scenario should be considered.

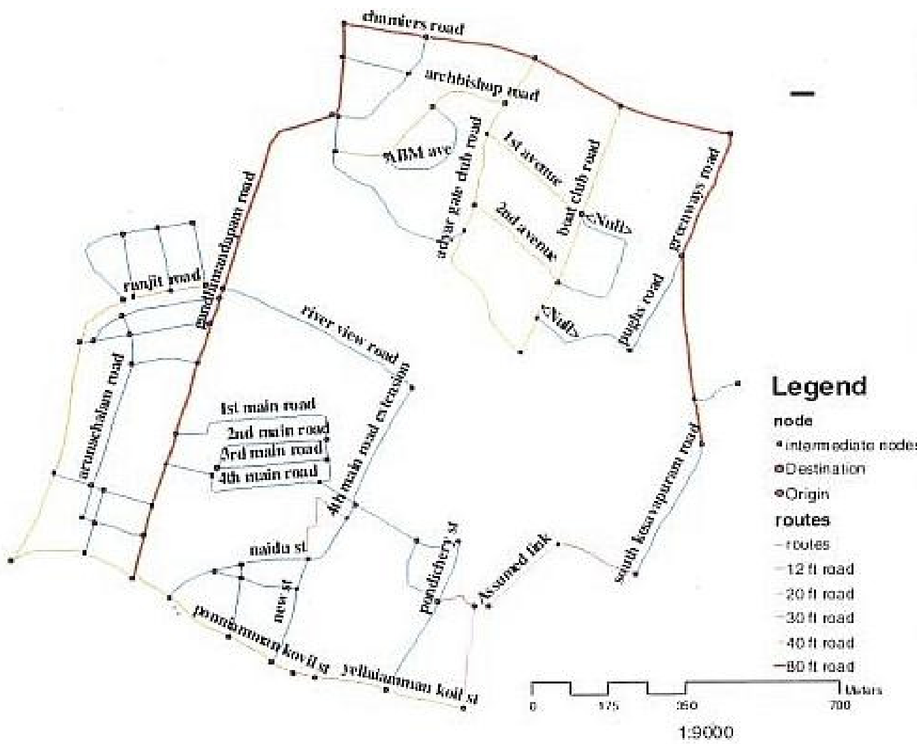

Fig. 9: Route Network Map *(Source: Viswarani 2007)*

FUTURE TRENDS

As urban problems increase in complexity, the need to access spatial data will continue to increase and stakeholders take a more active role in how their community is designed and built. Programs like Google Earth and Virtual Earth are helping democratize geospatial data by allowing individuals to input information about their particular homes and businesses.

Urban growth simulations and predictive modeling can be used to help get a better understanding of how a community may grow over time, and GIS tools can help identify preferred alternative scenarios. New ways of effective land-use planning include information management through GIS (geographic information systems), computer simulation, and spatial-temporal data modeling on present land use, alternative scenarios, and assessment of consequences. While zoning and regulation are the primary methods adopted by land-use planners, public education often is a neglected area that is increasingly being recognized.

SUGGESTED READINGS

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