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TRANSPORTATION NETWORK ANALYSIS BY USING REMOTE SENSING AND GIS A REVIEW

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ABSTRACT
With the advent technology of Remote Sensing (RS) and Geographic Information Systems (GIS), a network transportation (Road) analysis within this environment has now become a common practice in many application areas. But a main problem in the network transportation analysis is the less quality and insufficient maintenance policies. This is because of the lack of funds for infrastructure. This demand for information requires new approaches in which data related to transportation network can be identified, collected, stored, retrieved, managed, analyzed, communicated and presented, for the decision support system of the organization. The adoption of newly emerging technologies such as Geographic Information System (GIS) can help to improve the decision making process in this area for better use of the available limited funds. The paper reviews the applications of GIS technology for transportation network analysis.

Keywords - GIS, Network Analysis, Remote Sensing, Transportation

1. INTRODUCTION
Remote Sensing is a process of acquisition of data or information of object or targets, which is located on the earth's surface. For this, sensors are used which are placed on the satellite. Remote sensing is science of acquiring, processing, and interpreting images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation [1].

A Remote Sensing (RS) and Geographic Information Systems (GIS) technology is more useful in management functions and decision support systems which are more helpful in the planning process of urbanization. These RS and GIS application can support a variety range of planning, analysis and decision support system operations that can make extraordinary effect to the development and growth of urban areas. Instead of finding the optimal solutions for urban problems, bold approaches must be developed on the usage of heuristic problems, making it capable of supporting the dynamic requirements of the urbanization.

According to that when the spatial entity is associated with the non-spatial attributes; it can be useful to achieve the sustainable infrastructure planning or strategy. This is a key factor for applying GIS technology as a tool in supporting transportation network analysis or planning. In the GIS platform, the database of transportation network is normally extended by integrated with attribute and spatial data [2] [3].

As roads are the only means of transport available to the urban settlements, it plays an important role in the comprehensive development of a society. It acts as the lifeline of the urban economy and society. Urban transport network is very prominent sector for the growth of urbanization. The urban growth includes all aspects of development including settlements, education, industries, trade and other facilities and these all facilities depends on good transportation network [3].

In transportation planning by using GIS applications, mapping tools for a primary data can be Toposheets as well as the Satellite and airborne images. The various applications of GIS can be used for identification of road network area and change detection in road. It can also be used to detect the distance between the one place to another place. It not only detects the distance but also used to show the shortest path between two or more than places. These applications of GIS can be used in traffic control to generate the traffic control mechanism that provide fastest route.

The traditional planning is not sufficient in urban transport. The new approaches have to be used to present or identify serious issues on planning or analyzing urban transport network in a scientific way. The existing research work in the area of analysis and planning is limited. Now new methods and new approaches are required to incorporate the socio-economic parameters, local transport system and transportation cost aspects.

The ANDERSON classification of land uses and land cover also includes the transportation category. But this transportation category can be found within many other categories. But in which category it comes, is depends on at what scale is being mapped, so usually they are considered as part of the land use within which they occur. The transportation category comes in to the Level III [4].

In developed countries the use of Arial photographs and remote sensing images has become a common practice for urban planning. But in India, urban planning has been limited to aerial photography. Now it is being used for generating a thematic maps and base maps for urban planning, because it is very fast as considering time and requires a less cost. By using these images, one can do planning in the area of Land Use Land Cover, Change Detection, Transportation, Water Network management, Pollution Control and many more.

TABLE.1 Information of Remote Sensing Sensors images

Platform and Sensor System	Spatial Resolution (meter)	Year of operation	Mapping Scale	Extractable Information
Land sat (MSS) IRS-1A & 1B (LISS-I)	80 72	1972 1988 & 1991	1: 1,000,000 1: 250,000	Broad land-use/land-cover and urban sprawl
Land sat TM IRS-1A & 1B (LISS-II) IRS-1C & 1D (LISS-III) SPOT HRV-I (MLA) IRS-1D(LISS-IV)	30 36 23 20 5.8	1982 1988 & 1991 1995 & 1997 1998 2003	1: 50,0000 1: 5,000	Thematic data for broad structural plans and spatial strategies
SPOT HRV-II (MLA) IRS-1C &1-D (PAN)	10 5.8	1998 1995 & 1997	1:25,000 1:10,000	Data for land-use/ land cover for urban area
IKONOS Quickbird	1.0 0.61	1999 2001	1:4,000 1:2,000	Cadastral map, detailed information extraction for urban planning and infrastructure mapping
CARTOSAT-1 CARTOSAT-2	2.5 1.0	2005 2007	1:4,000 1:1,000 1:2,000	Large scale cartographic work and DEM generation cartographic applications at cadastral level, urban and rural infrastructure development and management
RESOURCESAT-I (LISS-IV)	5.8	2003	1:10,000 /1:4,000	Monitoring the urban growth, Inventory of land-use/ land-cover.

There are different types of Cameras and sensors that can produce a black and white, color or color infrared images. Resolution of images from 15 m to 80 m can be useful for application of broad land use and land cover of urban sprawl. For this purpose LISS-I sensor images were used and it had a resolution of 72m. The IRS-1C & 1D sensors can produce images with the spatial resolution of 5.8m, the sensors produces a Panchromatic images (black & white),and LISS-IV sensors produces the same resolution images with Infrared colors. Because of its resolution, it is more useful in the area of land use land cover of urban area and also for transportation network analysis. For transportation planning and analysis the images from LISS-IV, CARTOSAT-1 and CARTOSAT-2 are more useful than other as it produces images with the resolution of 5.8 m, 2.5 m and 1.0m respectively which is shown in the TABLE.1. The IKONOS and Quickbird sensors images are useful to produce Cadastral map and can give detailed information for urban planning [5].

2. LITERATURE REVIEW

The Line feature is more important in the maps, because it represents a major map feature. There are many GIS software that provides a Line Feature Generalization facility. The geometric operations are involved in this generalization like selection, merge, symbolization, elimination etc. But there is no proper definition for generalization. In ArcGIS 2005, a pointremove tool uses Douglas-Peucker (DP) algorithm. This algorithm was most popular algorithm, which was used in many applications like Road, river, coastal line generalization [6] [7].
The following operations are required to generalize a road network.

1. **Classification**: It identifies an object and makes groups according to properties. For easier selection and more accurate roads depends on the good classification. It minimizes the complexity. Ex. road width.
2. **Selection**: Select particular road class at the target scale.

3. **Elimination**: Eliminate shorter road of a certain length.
4. **Simplification**: selected roads can be simplified to reduce the details. Ex. Remove extraneous bends of roads.
5. **Typification**: This is manual editing approach. It reduces the Network density and simplifies the distribution and the pattern of the network. It reduces network congestivity.
6. **Symbolization**: To represent features on maps, graphic marks are used. Ex. Road Name, Road Number.

There are many applications like Google Earth, which can show the route between two selected places by using only major roads. Also these routes do not consider the obstacle like damage of road, accident, and flood. To overcome this problem, ArcGIS software can be used. The data collected from Google Earth and geo referenced in ERDAS and represented using the ArcGIS application. The application can show the shortest path between two points with all pros and cons of those roads. The Arc View was used to build the topology while performing the network analysis on a line theme. Before using the raster based images in GIS application it is required to be geo-referenced. But there can be multiple small images; they can be attached to form a single image so that it can be used for further analysis. In ArcGIS the geo-database has to be created, this database is further divided into datasets. The datasets are sub divided into the feature classes which consist of two classes a point and roads. Now the data and images are added into the Arc MAP to edit and draw the road network and to locate the points [8]. It is also possible to show the closest facility from any particular location. The closest facility means nearest hospital, hotel, bus stop etc. The application can be used to show the city bus routes [9].

In GIS by using Remote sensing high resolution IKONOS and collateral data for making the thematic maps were used in ArcGIS application. The Arc View was used to build the topology while performing the network analysis on a line theme. Like all GIS programs, Arc View attaches graphical features to a database that contain attribute information [10].

For the application of GIS in road network analysis takes the primary data from the survey of India (map of scale 1:2000). Further the map was scanned for digitization. For Geo referencing a Global positioning system (GPS) device was used to choose a number of control points and their co-ordinate were obtained. Attribute and labels were added while map digitized by using ArcGIS software. The bus routes were analyzed. After the digitization of primary data, a network analysis task was performed. This task was done by using ArcGIS software. It helps in the rout tracing and also in the creating the shortest path between two or more places. In each bus a GPS receiver and GSM modem with microcontroller interface was placed and this device was used to send the message to control station and modem or cell phone receives and gives the input to computer. The application was developed in Java to store and process data into a database. Then the co-ordinates from database were placed on map by using Visual Basic to show position of each bus on map [11].

In another system architecture was divided into two parts i.e. Spatial and Non-Spatial data. For spatial data analysis, the data was taken from the Maharashtra State Remote Sensing and Application Center (MRSAC Nagpur) and Survey of India (SOI) maps (1:50,000 scale) as base maps. After digitizing this row data, the updation was carried out on IRS satellites Panchromatic (PAN) and Linear Imaging self-scanned sensor (LISS). The PAN data were geo-referenced to survey of India maps. To validate the status of road the actual ground survey were performed. Non-Spatial data attributes are required to be attached to the spatial data layers. The application was designed and developed by using the Power Builder as front end tool and for data entry and storage of attributes a MS SQL were used as Back End tool. An ESRI's Arc View was used to customize the GIS interface [12].

The ArcGIS9.2 were used to geo-rectify the topographic maps and satellite imagery obtained from the Google Earth. For digitizing the boundary the polygon were used and for road the polyline were used in ArcGIS. The total length in kilometer and area in square kilometer was calculated in ArcGIS. The connectivity of the road was tested using Beta Index, developed by Kansky (1963) and adopted by Vinod et al. (2003). Here the nodes are the number of road junction and arcs are connections (straight lines) between nodes and straight lines. This Beta Index is used to decide the connectivity level of the roads [13].

There are few more algorithms for connectivity such as Alpha Index, Gamma Index and Beta Index. Alpha index is a ratio of actual number of circuits to the number of maximum circuits [14] [15].

Gamma Index is defined as the ratio of the actual number of edges to the maximum possible number of edges in the network [14] [15].

Shimbel index is a summation of all the shortest path distances among all points (vertex & node) in a defined zone or a circuit [15].

The Shortest Time Distance (STD) is a method of evaluating the road network accessibility. It refers to the total time from one node to other nodes within the road network by shortest time spending route. The lower STD value that a node has indicates that the node's accessibility is higher. The second method is Weighted Average Travel Time (WATT); it represents the importance of a node in the road network. The WATT value is related to the node's position in the road network. It can be also calculated by population density or economical indexes. Using ESRI Corporations ArcGIS and Microsoft .Net framework were used to build a weighted and normalized index to value the accessibility of road nodes [16].

The application to identify an optimal route from one destination to many destinations with the objective to minimize the travel distance and travel time is useful for state transportation department. The impedance values are required when network analysis is performed on each road in the network. For optimal route determination point of view an impedance value is very important because it gives a priority to roads. There are different types of impedances, but shortest time point of view speed impedance is more important. It means that there is a speed limit for different types of roads. And at the intersection of the roads, the turn impedance is useful, such as U turn, right turn, left turn is allowed or not [17]. In Arc GIS, Network analysis uses an impedance values to identify a road type like one way or two ways.

There is another technique to digitize the paper maps; these maps scanned using the video camera interface with a frame grabber card. Using Frame Grabber's software the map was captured and stored in jpeg format. The Autodesk product MAP for GIS was used for converting the raster into digital form, using this point, line and polygons can be digitized. The MAP utility has also an inbuilt database utility; also there is an option in it called as Link Path Name (LPN). This establishes the relation between the database and graphic file. But there is no option to find the minimum path between two points, but using Moore's algorithm one can write the program in C language or any other programming language [18].

3. TECHNIQUES FOR NETWORK ANALYSIS

Many Techniques have been done in the Transportation Network and for characterizing different ways are there [19]. Following are the Network Analysis Techniques.

- 3.1. Connectivity
- 3.2. Circuitry
- 3.3. Accessibility

3.1. Connectivity

In transportation analysis there are many research has been done, and most of the research focuses on the path analysis like finding shortest path, closest facility. Also some work has been done on the accessibility of the network also connectivity of the network. There are many different kinds of methods and every method has its own formula for different purposes, the selected methods are shown in TABLE.2 [13] [14] [15] [19] [20] [21] [22]. Which method has to be used for network analysis is depends on the objectivity of the research. These kinds of methods are used to compare two or more than two networks together. The comparison like which network has more accessibility and connectivity. To understand the urban structure, it not only requires understanding of a simple land use but also has to understand the network connectivity, accessibility, density and patterns.

In Transportation Network analysis the term connectivity referred as a connected quantity between nodes within a given network, so it extracts the structure of transportation network [20]. This extraction is much more useful information for assessment of transportation network. There are many categories in the area of network analysis, but among them Connectivity category is more useful and it has different types of Index, each index having its own special meaning.

The most fundamental properties of a Transportation network are measured by the Alpha Index, Beta Index and Gamma Index. For extraction of connectivity index it requires a road network (line), junctions (nodes). These indices can be useful for change detection system in network structure and also for traffic analysis [19] [20].

An Alpha Index for connectivity is a ratio of circuits to the number of maximum possible circuits in the network. It gives possible values from 0.0 to 1.0, higher the value of index, higher the degree of connectivity within the network. If the value from 0 percent - it indicates no circuits to 100 percent – a complete interconnected network [19] [21].

The Beta Index Measures the connectivity relating the no. of edges to the no. of nodes. It is more useful for simple network where no circuits are involved. If the value is 0.0 it means there are just nodes without any arc. Its value ranges from 0.0 to 1.0 and greater, where network are well connected [21].

The Gamma Index is a Ratio of actual no. of edges to the Maximum possible no. of edges in the network. Its values from 0.0 – indicates no connection between nodes, to 1.0 – maximum no. of connection with direct link to all nodes.

Network Density measures the Network Development. It is much more useful to compare 2 or multiple region or sub-regions. It can be also used in change detection system, so it can identify that any new developments were happened or not. The result of this is a kilometer per square kilometer.

Eta Index is used to Measures the average edge length in the network. And it is used as a measure of speed in traffic network. It requires a summation of all edges in the network and number of edges in the network. If a new link is added, so it will decrease in eta index, as average per link declines [22].

Pi Index is a relation between total length of graph and its diameter. It is more applicable for the urban transport network. It is labeled as Pi because of its similarity with the real PI (π = 3.14) value. If the value is high so it indicates that the network is developed network. It is a measure of distance per unit of diameter and indicator of the shape of a network [22].

Theta Index is used to measure the function of a vertex, which is the average amount of traffic per intersection. If the load on a network is high then the value of Theta index is also high.

TABLE.2 Connectivity Indices

Sr. No.	Index Name	Formula	Where	Purpose
1	Alpha Index	$\alpha = \frac{e-v+1}{2V-5}$	e = No. of edges (Line) v = No .of Vertex (Node)	It is a ratio of circuits to the number of maximum circuits in the network
2	Beta Index	$B=\frac{e}{v}$	e = No. of edges (Line) v = No .of Vertex (Node)	It Measures the connectivity relating the no. of edges to the no. of nodes.
3	Gamma Index	$\gamma = \frac{e}{3(v-2)}$	e = No. of edges (Line) v = No .of Vertex (Node)	It is a Ratio of actual no. of edges to the Maximum possible no. of edges in the network
4	Network Density	$ND = \frac{l}{A}$	L =Total length of Network A =Total Area Of Network	It measures the Network Development
5	Eta Index	$\eta=\frac{L(G)}{e}$	L(G) = Summations of all edges in the network e = No. of edges (Line)	It Measures the average edge length in the network
6	Pi Index	$\Pi = \frac{l}{D}$	l = Total Length of Graph D = Diameter	It is a Relation between total length of graph and its diameter
7	Theta Index	$\theta = \frac{Q(G)}{v}$	Q(G) = traffic v = No .of Vertex (Node)	measure the function of a vertex, which is the average amount of traffic

3.2. Circuitry

Circuitry is very important in transportation analysis because several systems use circuits to cover as much region as possible in one direction. Circuitry is the ratio of network to Euclidean distance. In transportation a distance can be measured using GIS in three forms: Network distance, Euclidean distance, and Manhattan distance. Manhattan distance is not commonly used in transportation research. Euclidean distance is the airline distance between sources to destination. Network distance is an actual representation of movements from source to destination; this distance is mostly measured using the shortest path.

3.2.1. Detour Index

It is defined as a ratio of the shortest path distance to the Euclidean (straight) distance between source to destination point [19] [22]. It Measures the efficiency of a connection in the network. If the value is 1 it means network is more spatially efficient, but the network having the Detour Index value 1 are very rare. By using Detour Index it is possible to assess whole city, but when it is applied on an individual rout then it is much more useful.

Formula: $DI = \frac{d}{L}$ (1)

Where d = Straight distance (km)

L = Network distance (km)

3.3. Accessibility

This Transportation analysis involves spatial and socioeconomic aspects with detail data, and involves a large amount of computation. Accessibility analysis is the collection, manipulation, and analysis of spatial and non-spatial data [23] [24].

3.3.1 Shimbel index

It measures an accessibility which represents a summation of length of all the shortest path distances among all points (vertex & node) in a defined zone or a circuit [15] [19] [20] [22] [23].

Formula: $A_i = \sum_{j=1}^{n} dij$ (2)

Where A_i = degree of a node

dij = connectivity between node i and node j (either 1 or 0)

n = number of nodes.

4. Analysis of Transportation (Road) Network

In almost every field an output of remote sensing is an input a GIS. GIS not only take input from RS but also take input from scanned maps or toposheet. There are many application areas in RS and GIS but majorly these are categorized in Natural Resource Management, Urbanization, Agriculture and National Security. But in this paper the methodology is concerned with only urban transport analysis. The complete methodology process is drawn as a flow chart is shown in Fig.1 [10].

In first phase of methodology the acquisitions of preferred data should be done. The data such as topographic sheets like 1:50,000 or satellite images with good resolution or aerial photographs. If Toposheets are there then it should be scan with the defined resolution suggested. It should be Digitize with a defined zoom level, so all the features can be digitized in number of layers.

In next phase perform the GPS survey for maximum ground control points (GCP) of every Area of Interest (AOI) on the known roads / important places. If there is another registered image then image to image registration should be performed. And if the administrative boundary is there, then it should clip the selected area according to administrative boundary. Many times our selected region is not on a single toposheet / image then mosaics it. This leads to a resolution correction to a length of plus or minus 5 m.

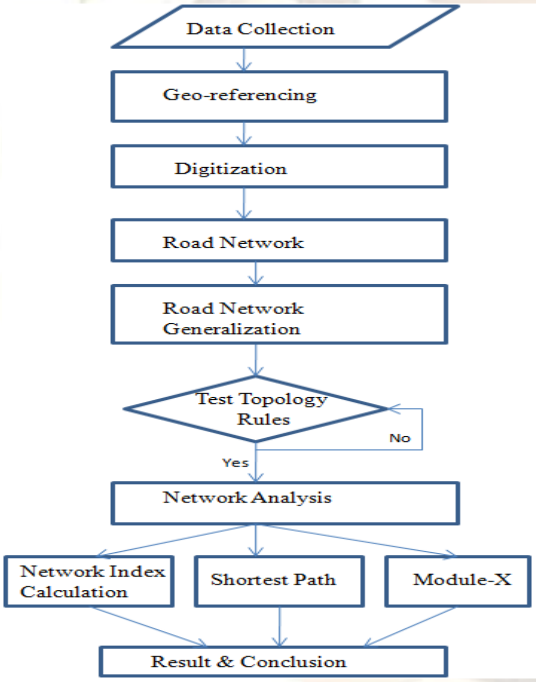

Fig.1 Methodology of Transportation Network Analysis

By using GIS software display all the spatial and attribute data about – the road, road type, bus stops support infrastructure and land use, administrative/ constitutional boundaries etc. It also performs the network analysis on that, by using topology rules of ArcGIS the errors can be removed, so the accuracy of the data will be good and it can be used for further processing. The network analysis is more important because after performing this, a data can be used in multiple application area like shortest path, tour analysis, index calculation etc. After detection of network (roads) with the help of GIS application, still this data is not perfect for the network analysis, for that purpose a road generalization process should be performed. After the Generalization process the topological rules have to be applied in the ArcGIS environment. After successful completion of topological rule all the error can be removed. Now this network is perfect for the analysis. By using this layer a network data set and junction should be created. This will provide a total number of edges and total number of vertex in the selected network. After wards it is possible to calculate the Network analysis index. There are many RS and GIS software's, but among them an ArcGIS is much more powerful than others. It also provides a network analysis tools to find the shortest path.

The output of this study can give answers with graphical accuracy to the most frequently asked questions. Also it can provide a result with spatial and non spatial information.

5. CONCLUSION

The larger cities have more connected road networks, so they are more accessible. Among many network analysis indices the Alpha Index, Gamma Index, Beta Index is more useful. The Beta Index gives the connectivity ratio, by calculating this index it is possible to identify in which area connectivity is less, so City planner can plan according to it. It is also possible to calculate the Zone (or ward) wise network density of any urban area. It is more useful to compare multiple Zones (ward) of city to identify the development of each zone.

In the context of city planning, the road networks with high value of gamma index are well arranged in terms of redundancy of choosing roads. The strength of connectivity within road network does not accurately indicated by the Alpha Index, but gamma index overcome with this disadvantage.

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