

GIS based Analysis for Emergency Response A Case Study of Cuttack Town, Odisha

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Abstract

Emergency response plays an important role in all geographical areas prone to both natural and man-made disasters. Such a system in the urban areas would depend upon the physical condition of the terrain, road network (type / density / traffic flows), service area and closest facility, besides others. Poor mobility reduces emergency response in urban areas. Cuttack has a municipal area of 192 sq. km, carrying above 7 lakhs of population with a density of around 3,645 persons / per sq. km. The average elevation of the city is 30 m (100 ft.) above MSL and is geographically located in the alluvial plain of Mahanadi delta. It is frequently prone to cyclonic rainfall. The total road length is 783 km and has over 27,613 vehicles on road.

The spatial dataset selected for study has been taken from NUIS (2010) database and the non-spatial (attribute) data from NUDBI (2010), Tourist Maps (2008), CDP (2007) and Census (2001) data. The guidelines are referred from UDPFI Report (1996). The Network Analyst (vector based routing module) available in Arc GIS (Ver 9.3.1) was applied for analysing the datasets. The results suggest that the present road network in Cuttack is narrow with width less than 9 m (30 ft) and vehicle speeds at 30 km / hr. The impedances of weightage value of time delay of travel time of 20, 30 and 40 minutes suggest the average travel time of less than 30 minutes and average travel distance of less than 10 km.

Introduction

Disasters cause damage to property, loss of life and suffering depending upon its type, location and intensity. Occurrence of both natural and human induced disasters are showing increasing trend in the recent past. Disaster preparedness like early warning, risk assessment, response and recovery play an important role in the disaster management studies. Emergency response plays an equally an important role in all the geographical areas prone to natural and man-made disasters. Such a system in the urban areas can be assessed based on not only transportation mobility, but also on the physical condition of terrain, road network (type / density / connectivity / traffic flows)

service area and closest facility. Besides, details on length of road segments, node junctions, street attributes, landmarks are very important for emergency response operations in urban areas. Urban areas by virtue of concentration of large number of people in a relatively smaller areas, a good infrastructure facility in position would strengthen the disaster management and emergency response systems. Poor mobility reduces emergency response in urban areas. Therefore, a good understanding and analysis of urban mobility combined with road network would help to build safer cities. It is here, GIS based techniques enable to generate, integrate and analyse the databases useful for Disaster management

support and Emergency response systems in an urban area.

Study Area

Cuttack is the second biggest city in Odisha. It extends from 20° 30' N latitude to 85° 49' E longitude. It extends upto 4 km in North-South direction and 13 km in East-West direction. The municipal area of the city covers an area of 192 sq. km. It has a population of above 7 lakhs with a density of around 3,645 persons / sq. km. In the city centre the density is around 7,000 persons / per sq. km. as more than 40% of the population is residential (CDP 2007). It is located on the flat alluvial plains of Mahanadi Delta (between Mahanadi on North and Kathajori river in South) with an average elevation of about 30 m (100 ft) above MSL. It is in the cyclonic track of SW Monsoon and receives around 152 cms of rainfall between June and September months. The town is around 80 km inland from Bay of Bengal. (Fig. 1) (see page 51)

Review of Earlier Work

Remote sensing data helps to spatially map and assess the hazard prone areas due to cyclonic flooding, water logging in towns located in the coastal-deltaic regions. Disaster Management addresses four stages of preparedness, mitigation, response and recovery. Out of all the four, response system is very critical. Preparedness is measured in terms of ability to deploy emergency response systems in a timely and efficient manner. This warrants a good database on road network and its connectivity for understanding and planning, mobility in urban areas. Remote Sensing and Geographical Information

System provide timely and reliable database besides techniques for initiating such studies in towns / cities. Few studies using road network on shortest path / optimal route selection, connectivity analysis and trip circulation patterns in urban areas have been carried using GIS.

Shuvai and Cheng (1998) suggested the importance of GIS based network analysis for urban roads to earthquake response. Ian Heywood et al (2003) described three important types of networks namely, shortest path, route tracing and location allocating modeling. Rajamatha and Madhu Chandra (2007) highlighted the importance of efficient transportation system for spaces of mobility in Central Bangalore. Nijagunnappa and et. al. (2008) captured network for high resolution satellite data and carried optimum path analysis using impedances for Dehradun town. Network analysis functions were used to model real road segmentation for vehicular deployment by Zeng and Church, 2009. Vini Indriasari et al (2010) studied service area for optimal siting of emergency facilities like fire stations. Sriparna (2010) carried road network analysis of Bengaluru city using GIS module on network tracing, path analysis and closest facilities. Shubhasmita Sahani (2010) analysed high resolution satellite data and used Network Analyst Module and carried shortest path analysis, service area and closest facility in Cuttack town in Odisha.

Lack of database always hampers the planning process and decision making for disaster managers. GIS based studies in urban areas for emergency response could be varied, for example, developing scenarios of urban flooding, damages due to earthquakes and other hazards, locating

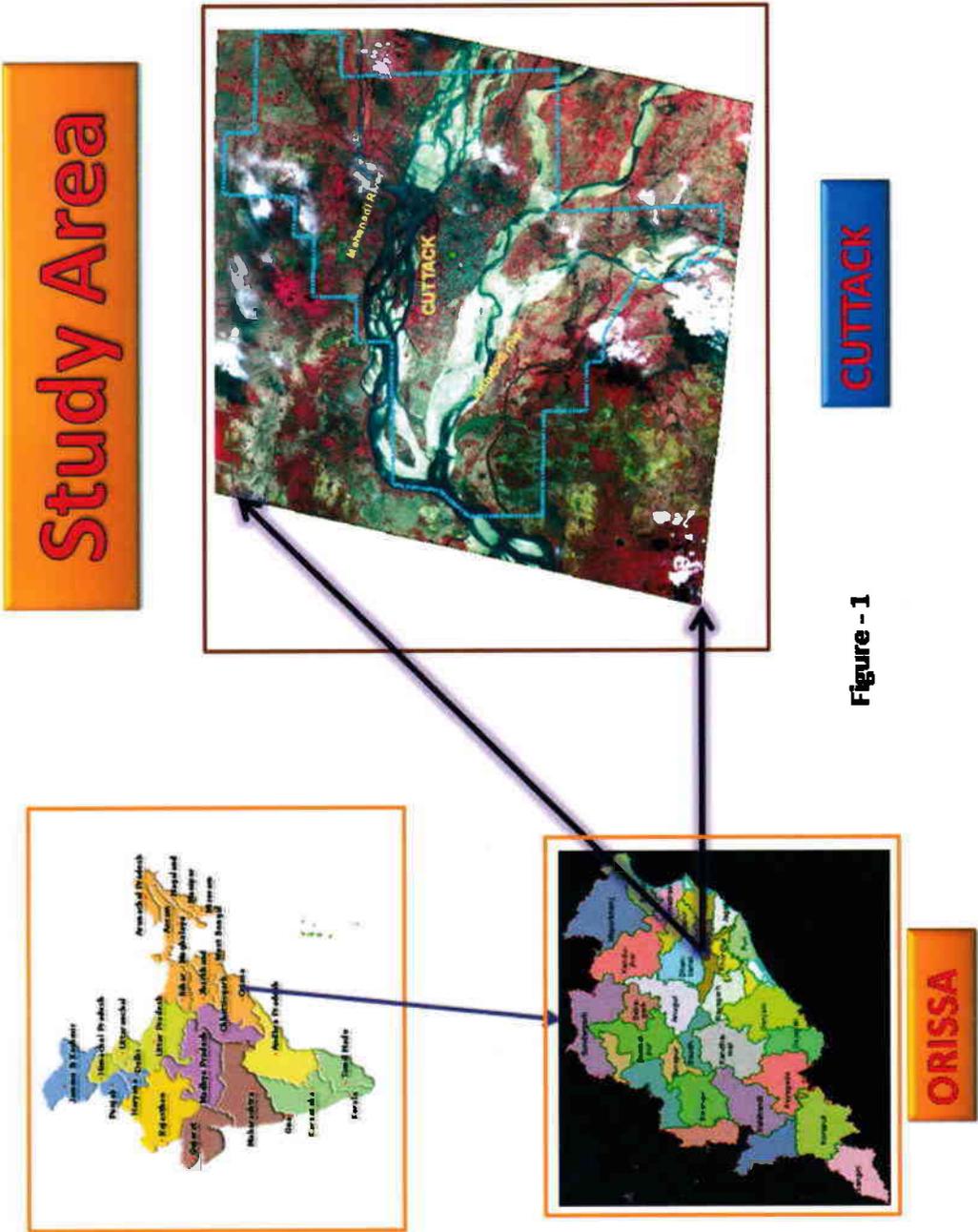
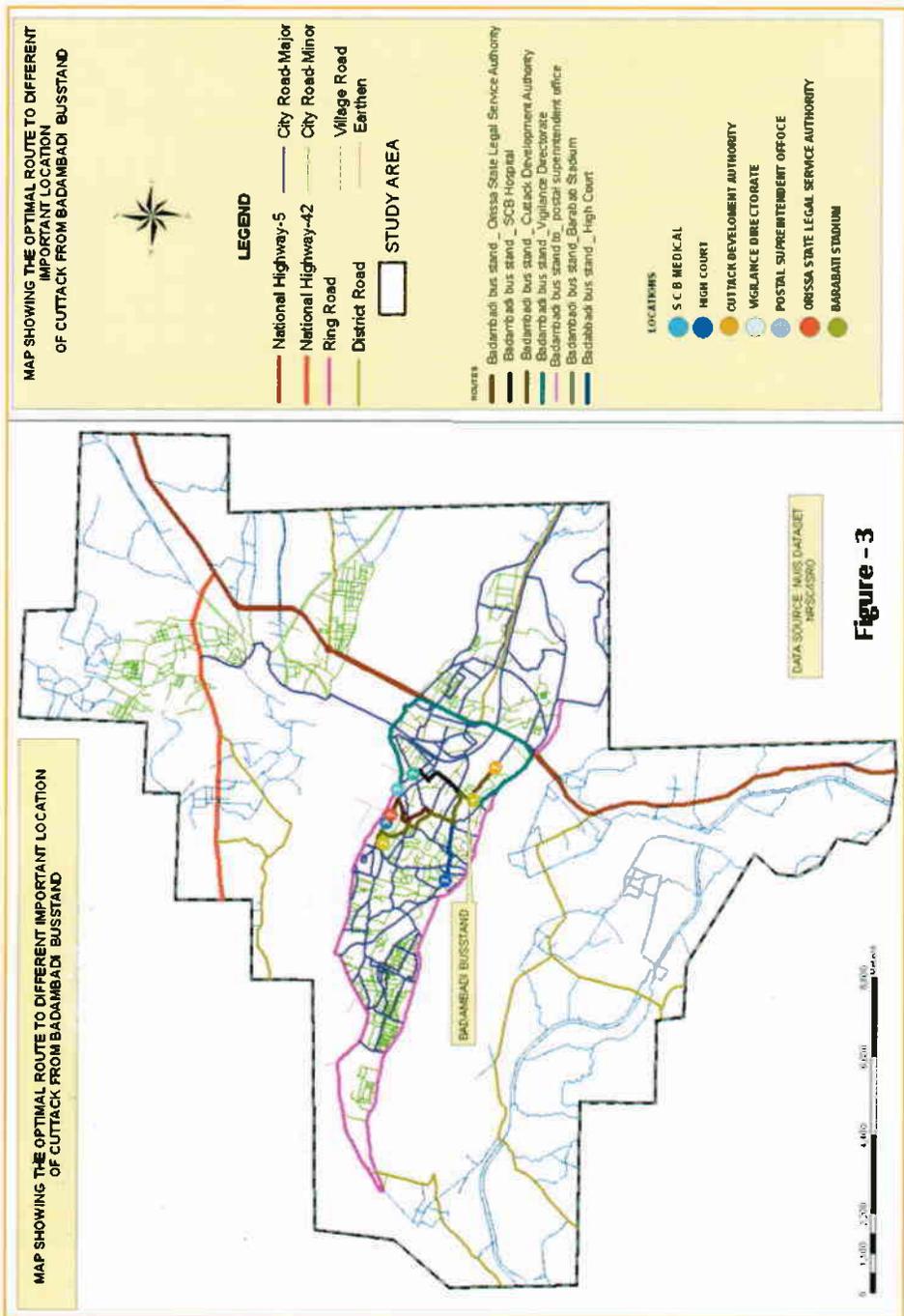
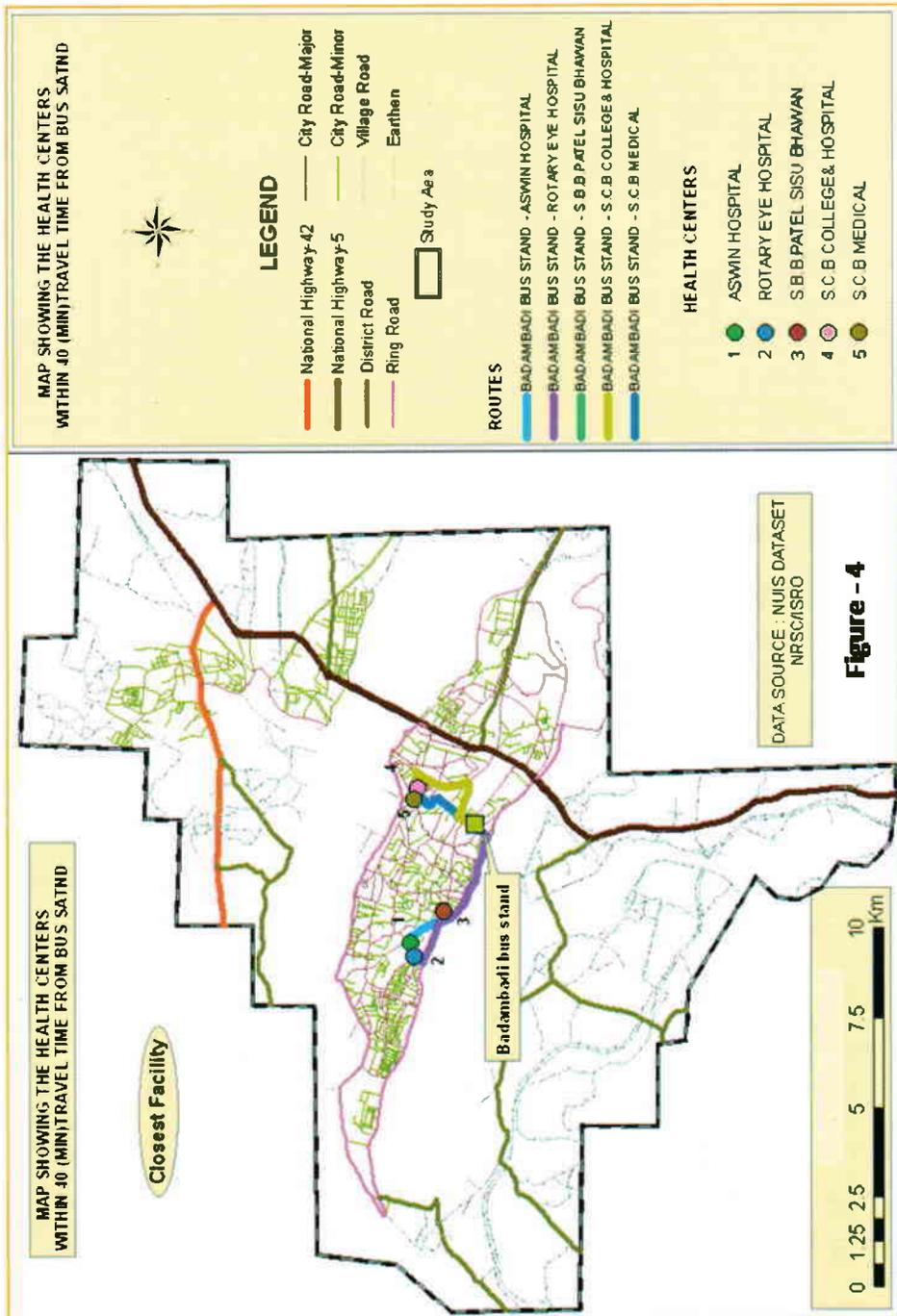


Figure - 1

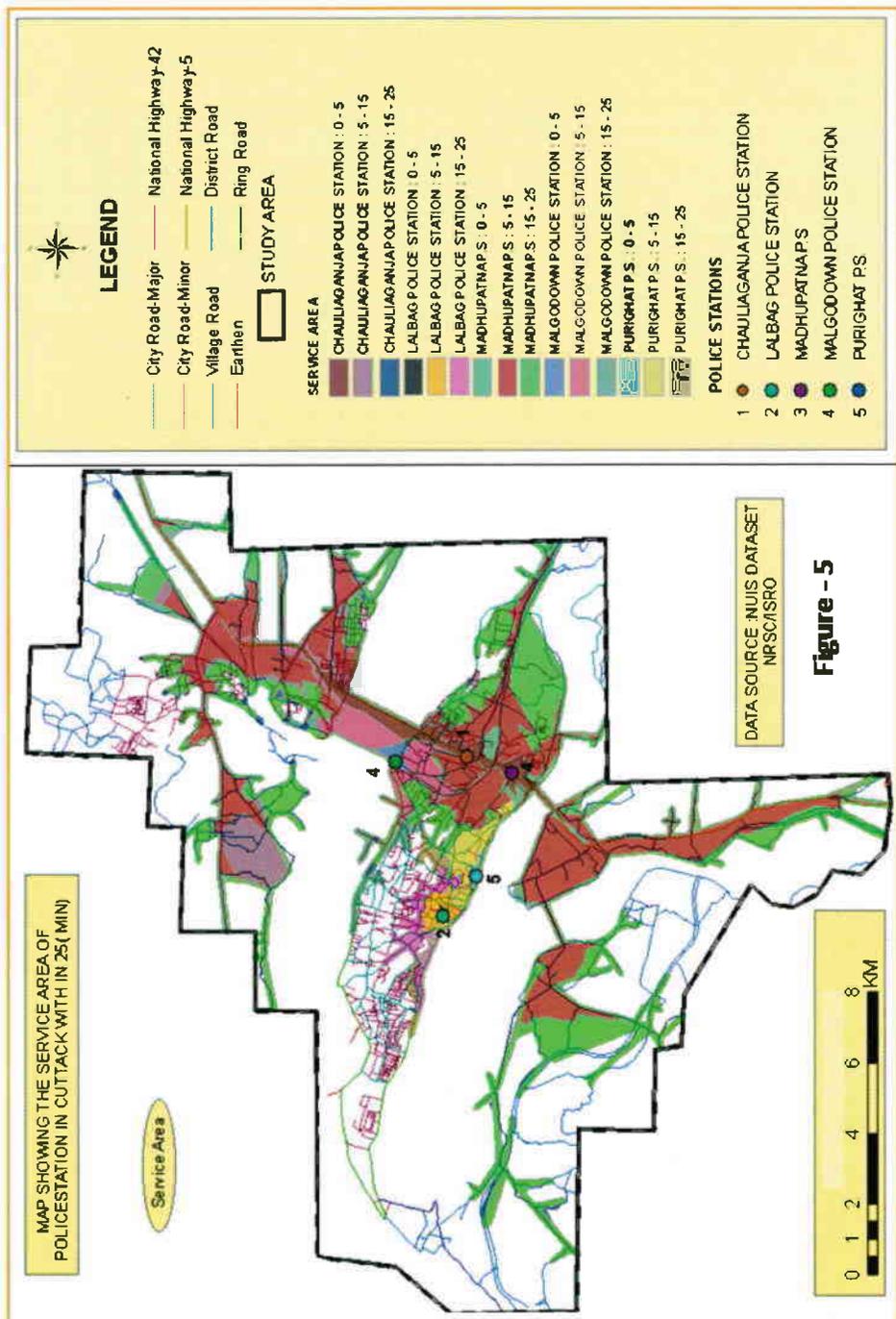
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emergency services like medical (hospitals, ambulance), tracing fire stations and traffic (vehicular) services, besides siting police stations and others.

Database

The spatial dataset selected for the study include the georeferenced Cartosat-I (PAN) with 2.5 m spatial resolution and LISS-IV (Multispectral) data with 5.8 m resolution for the period 2009-2010. The non-spatial (attribute) data referred and used are the tourist maps (2008), Comprehensive Development Plan (CDP) Report (2007) of State Urban Development Agency (SUDA), Urban Data Plan Formulation and Indicator (UDPI) Guidelines Report (1996) besides the data collected from limited ground truth. Further, the database of the National Urban Data Bank Indicators (NUDBI) and Census (2001) data were also referred and used.

Methodology

The flow chart (Fig. 2) describes the methodology adopted for the study. The road network geodatabase of Cuttack town created under the NUIS project using Arc GIS (Ver 9.3.1) was used for the study. Geodatabase schema is a data storage (spatial feature classes and attribute with annotation) framework to use geographic information (ESRI Manual 2010). The road network essentially was captured using Cartosat-1 (PAN) georeferenced imagery. It consisted of road central line joining with nodes and buffers drawn on either sides of the central line of road which are classified as minor and major roads respectively. The road bends and intersections have been labeled as nodes. The intra and intercity road

(classified from imagery) width have been assigned from UDFPI guidelines.

The non-spatial (attribute) details attached to road network have been taken from NUDBI and CDP reports, road atlas, town maps and from limited field work. The Cuttack landuse / cover information on public / semi-public, public utilities and transportation nodes have been taken from NUIS database and the point information attached to them from tourist maps and internet maps. Few, details have been added from personal knowledge about the city.

Impedance is defined as the amount of resistance required to traverse a line from its origin to destination node. The impedance values were used to show the routes with lowest impedences. The different impedences choosen include road width, condition of road, time delay due to traffic signals, vehicular congestion and speed limit besides, turning points and road distance.

Results and Discussions

The analysis has been confined between Cuttack railway station and Badambadi bus stand in the city. This is because most of the public to semi-public and public utilities like educational institutions and hospitals are located in the city centre. The network analysis (vector based routing module) available in Arc GIS (Ver 9.3.1) has been used for calculating the shortest path (routing), closest facility and service area analysis.

Routing analysis helps in minimizing the travel and transportation of goods and services from one location to another in shortest path or by undertaking more number of trips or a combination of both.

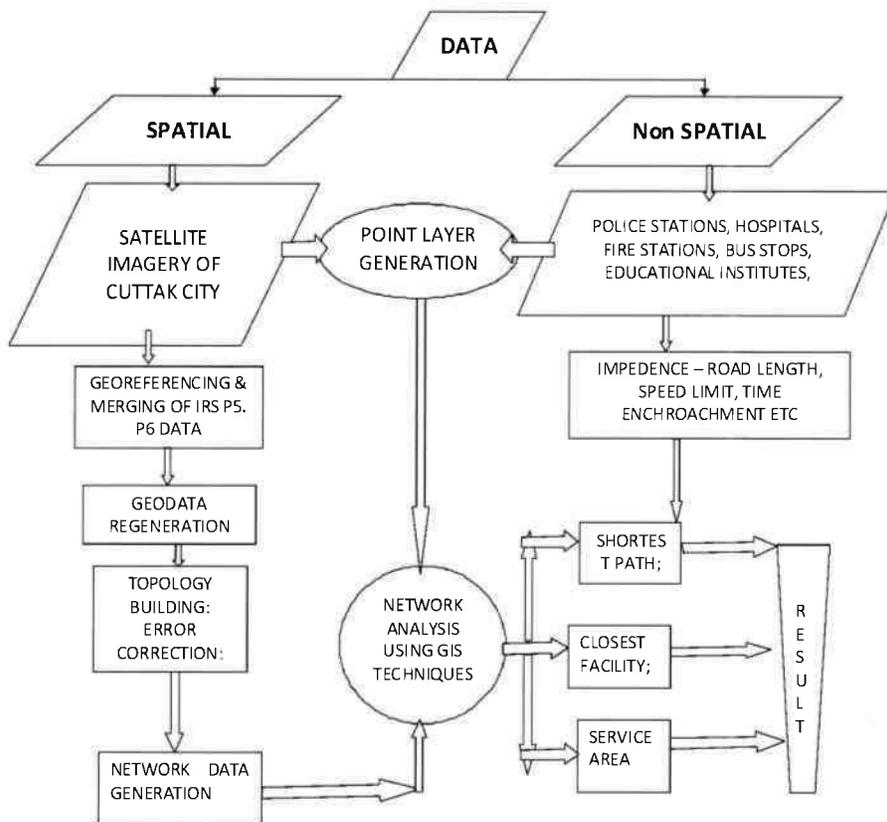


FIG 2

Selection of shortest route based on travel time / cost and trip circulation pattern is also equally important.

The total road length in Cuttack municipality is around (783 km). Out of which the major (metalled or pucca) roads cover 77% of road length of 603 km and minor (unmetalled or kucha) roads cover 23% of road length of 180 km. The total number of vehicles on road are over 27,613 (CDP, 2007). The number of vehicles have increased from 17,555 (2001) to over 27,613 (2007).

In the study, to know the shortest path between two destinations, the travel cost is determined based on the distance

of travel and speed and time of travel. Routes of different travel time of 20, 30 and 40 minutes against distances of 3 km, 5 km and 9 km., have been analysed using Path Analysis Module. Considering the impedences of weightage value, suggest the average travel time of 30 minutes for an average travel distance of less than / upto 10 km. is optimum for Cuttack. ArcGIS helps to attach not only the graphical features to the database containing the attribute information but also provides the ability to solve multiple queries (ESRI, 2010). This is because the present road network in Cuttack is narrow with width less than 9 m (30 ft.) and the vehicle speeds

at 30 km / hr. Optimal path is the path with lowest impedances and it may not be the shortest path (ESRI-2010). Operating public transport in Cuttack is difficult as the overall speed of the vehicles has decreased due to heavy traffic congestion. During 2001-02 and 2006-07, the percentage of vehicles increased by 63% out of which 90% are two wheelers (CDP 2007). Only 5% of city area is covered by transportation as against 12 to 14% suggested by UDFPI norms. GIS helps to integrate, multiple datasets, analysis, query and develop visualization scenarios.

The type of roads and the speed limits adopted from the UDFPI guidelines is shown in Table 1

The impedances are ranked and the weightages are assigned in terms of time delay in seconds. It has been seen that as the Cuttack city-center roads basically being narrow (9 m or 30 ft width) they have been given the higher weightage due to maximum number of impedances. Fig.3 (see page 52) the example of shortest path to important locations from Badambada bus stand in Cuttack city.

Closest Facility

A closest (proximity) facility allows to find out places that are within certain travel time or cost distance as specified. Closest facility include educational centers, public / semi-public places, railway stations, bus stands and so on.

A closest (proximity) facility is a type of road network analysis that allows to find out different facilities like hospitals, fire stations, railway stations, bus stands to any location in the network within certain travel time or specified (cost) distance (eg: all streets within 5 minute response time from fire station). The city has only two fire stations (CDP-2007). A closest facility algorithm first computes the shortest path from the selected location to all the candidate facilities and then chooses the closest facility among the candidates. The screenshot of the closest facility of Health Center generated using Arc GIS Network Analysis module is given in Fig. 4. (see page 53) The network analysis uses the process of assigning the links in the network to the closest centers. Allocation requires the continuous evaluation of impedance along the entire path from a specific location by specifying the travel time or distance to be covered to a particular closest facility.

Table 1

Sl. No.	Classification (Type of Roads)	Vehicle Speed (km/hr)	Speed (meter/sec)	Impedance Time delay (in seconds)
1.	National Highway	80	22	0
2.	District Road	60	17	10
3.	Ring Road	40	11	70
4.	Major Road	30	8	125
5.	Minor Road	30	8	175
6.	Village/Earthen Road	20	5	95

Source: Road Classification (NUIS, 2008) Speed Limit, UDFPI Guidelines

Note: Formula for conversion adopted: speed in meters per second equals to speed km / hr * 5/18 (RC Aggarwal)

Service Area

It is an area served by a particular service facility on the basis of distance and time. Service area considers time factor to reach emergency service centers like hospitals, ambulance stations, police stations, fire stations and so on which are essential for public safety. Minimising distance and travel time and the availability of service centers in the nearest neighbourhood of closest facilities is important for planning for emergency services. Roads with connectivity to closest facility and service area complement each other and they are very important for developing a sound emergency system. It is possible to know the service area (for any given facility) using GIS. The quality of emergency services like ambulance or hospital would depend upon the response time or distance travelled. Faster response indicates good services and longer response convey poorer services. GIS allows the service area to be calculated by taking into account the accessibility / connectivity and impedance attributes of the road. Service area tool in network analysis allows the analyst to create services of polygons (service area) representing the distance that can be reached from a facility within a specific amount of time. In the study, the service area polygon is delineated for facilities like hospitals, police stations and educational centres by assigning the break points (drive time) of 5, 15 and 25 minutes. The screenshot of the service area generated using Arc GIS Ver 9.3.1 for Cuttack town is shown in Fig. 5. (see page 54) The service area of police stations vary from 5 to 25 minutes of time and from 1 sq km to 40 sq km areas, whereas the service area of health centers vary from 5 to 25 minutes of time and from 1 sq km to 46 sq km of area.

Conclusion

Road network and urban landuse database are of primary information for any network analysis study. The generation of road network and urban landuse has been made possible from the NUIS databases of Cuttack town using PAN sharpened Cartosat-1 imagery at 2.5 meter spatial resolution. This was equally supported from non-spatial database from NUDBI, CDP, UDPFI Guidelines, Census (2001) and from limited field work.

The network analysis Arc GIS (Ver 9.3.1) was used to understand shortest path, closest facility and service area. From the study, it is very much evident that GIS is useful for transportation and emergency response studies.

The results suggest that only 5% of the city landuse is covered by transportation as against 12 to 15% requirements based on UDPFI norms. The present road network in Cuttack town is narrow with width less than 9 m (30 ft). With increasing number of vehicles, road congestion, increasing population densities, vehicular traffic, longer time to cover shorter distances the vehicle speeds have reduced to 30 km / hr. The impedances of weightage value of the time delay of travel time of 20, 30 and 40 minutes suggest the average travel time of less than 30 minutes and arrange travel distance of less than 10 km.

Acknowledgements

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