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Use of transportation network analysis for bus stop relocation, depiction of service area and bus route details

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Abstract: The growing population and urbanization are the major problems faced by the developing countries in the world today. Increase in traffic congestion is a critical issue. The main focus of this paper is on improving traffic situations and making travelling easy to a user by using network analysis modules of Arc GIS. The location allocation module of Arc GIS is used to shift the location of existing bus stops taking into consideration different factors such as traffic signals, traffic constraints, etc. Bengaluru's bus system is operated by Bangalore Metropolitan Transport Co-operation (BMTC) which has introduced different buses for different routes in the city. A network service area is a layer that shows all areas that are within the reach of a facility, e.g., the three kilometres service area for a point on a network will include all the streets that can be serviced by the identified facility within three kilometers. The service area helps to calculate the accessibility of a facility or to choose the nearest facility among facilities within the service area. As distance increases, accessibility to/from the facility decreases. The transport network analysis provides the information of bus routes with bus stops in between the starting point and the destination point to a person who wants to plan his travel from one place to other. This system is designed in such a way that a person can plan his travel based on the bus route details e.g. to use public/private mode of travel optimally and well in time.

Keywords: Geographic Information System, Arc Info, Network Analysis, Service Area, Location- Allocation

1. Introduction

India is the second largest populated country in the world. The growing population, environmental issues and urbanization are the major problems the country is facing today. In addition to the above, traffic problems are creating more havoc. Bengaluru is the third largest metropolitan city in India. Due to increase in IT companies, industries and other business sectors, a large number of people have migrated in the recent years from all over the world to the city. Due to this, vehicle population has increased drastically leading to the increase in traffic problems. In addition to all these factors, private cab companies such as Ola and Uber also started in recent years which are adding to the problem. Travel time has increased, comfort of passengers has reduced and travel costs have increased due to the same. If this problem is not controlled, travelling from one part of the city to other will become a difficult task. The main focus of this study is to use GIS to provide solutions to reduce traffic congestion in the city and facilitate better mobility for the public. Using Geographic Information System (GIS) in the field of transportation opens up a wide range of possible applications, as diverse as the field of transportation itself. The main objective of this project is to use GIS modules in modeling the transportation system for better mobility of traffic. Network Analysis is used for transport planning during the study. The traffic congestion at the signalized intersections is caused mainly due to piling up of vehicles at bus stops which are very near to the traffic signals. Hence, it is very important to monitor the location of an existing bus stop and shift it to a more accessible location.

Bengaluru's bus system is operated by Bangalore Metropolitan Transport Co-operation (BMTC) which has introduced different buses for different routes in the city. They have assigned different bus numbers for buses moving from/to different locations in which the bus numbers are specified in the format number-alphabet(s) or vice-versa. A person who wants to travel from one place to other, will need to know the starting point, end point and different stops in between the two points. This system is designed in such a way that a person can get all the above information after providing the given route number as an input information well in advance. The Network Analysis module is a function of Arc GIS which is basically developed for Urban and Transport planning. It helps transport planners to have a better understanding of the road network and its components. A transport planner can plan his objectives and execute them in this platform to achieve more efficient results.

2. Objectives

The following objectives were set up during the study:

- To find the accessibility of a service by a person from his current location in terms of time or distance.
- To relocate bus stops which are prone to choking of traffic near signals in certain stretches.
- To locate all the bus stops along a desired bus route and developing a decision support system to help a passenger to use public/private mode of transportation based on current location and the availability of time & resources.
- Providing access to similar service by government and private oriented transport services.

The following are the parameters that were required for carrying out the study:

- Time attribute: traversal time along elements of the

network
- Distance attributes: to determine the lengths along the elements of the network
- Capacity Count: they are required to describe the relevant limit of the vehicles
- U-Turn at Junctions
- Satellite data for validation of the dataset.

3. Study area

The area chosen for the study was Bengaluru which is popularly known as the IT capital of India displayed in figure 1. Currently, Bengaluru has a population of over ten million people and is the second fastest-growing metropolis of India. The longitude and latitude extent of the region is 77°25'00"E to 77°44'00"E and 12°49'00"N to 13°04'00"N respectively. In 1971, the city's population was around 16.64 lakh and vehicle population was approximately one lakh. With the growth of population, urbanization and increase in IT sectors, the vehicle population drastically boomed to 67.22 lakhs as recorded in Census 2011(http://www.censusindia.gov.in) leading to rise in traffic problems. As of today, the vehicle population is around 73 lakhs. Today, Bengaluru's major problem is traffic congestion. Researchers all over a city are searching for solutions to overcome the problem.

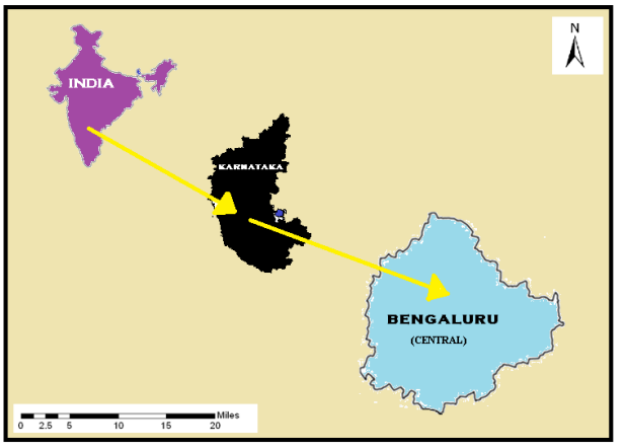

Figure 1: Study Area

4. Literature review

Kharel et al. (2018) in their paper discussed about using Network Analysis for solving problems related to best routes and closest facility which was petrol pumps in their case. They took the study area as CBD of Bengaluru City for their analysis. Their results showed that network analysis was very efficient in solving problems related to transportation. Yue et al. (2016) said that it was difficult to get the traffic values from video data and use it for traffic integration. Ranya et al. (2016) introduced a technique of establishing a spatial based location allocation computer program for emergency cases. Bigger cities have traffic problem often and finding the shortest path to reach a point is a big task. This was done by utilizing the different tools available in GIS. Ejiagha et al. (2012) in their paper described about an analysis on locating nearby health facilities such as hospitals, clinics, etc. and recommends that Healthcare facility should be provided to those deprived areas and GIS unit should be a basic component of all agencies responsible for administration of healthcare facility. Kumar et al. (2016) described the use of network analyst to find out service areas for different facilities required in day to day life in Chandigarh city. Ramos et al. (2012) showed in their paper a critical mission of an I.T.S. is to make efficient, safe and environment friendly transportation networks. Sidhtharthan and Durgadevagi (2016) reported that network analysis in GIS aims at finding solutions to routing problems related to traversibilty, rate of flow and network connectivity. Namoun et al. (2013) described an integrated approach for modeling transport infrastructure and optimizing traffic in urban areas. You and Kim (1998) gave a view about the integration of transportation modeling procedure beginning right from the data inventory to meeting the future demands of traffic. Arora and Pandey (2011) discussed about finding the solutions for routing problems related to traversing, flow and route connectivity. Visser and Wees (2000) discussed about a general simulation concept which was formulated to evaluate the performance of an intelligent transport system and introduce the virtual sensor concept as a concept for sensor system modeling. This idea was inspired from Electronic Fee Collection.

5. Data collection and organization

Open Street Map data which included the road and rail networks, bus stops, traffic signals, railways stations, traffic, etc. was used to prepare the spatial database for the study. Major routes such as ring roads were picked up for the study to ensure validity of data and ease of understanding. The main study area Majestic – Whitefield stretch has most congested traffic patterns. In addition to this, ancillary data like traffic volume counts, bus stops, traffic signals, etc. were collected from centers like BMTC, BBMP, Traffic Management Centre, Directorate of Urban Land Transport (DULT) and Bangalore Traffic Police. Information on latitudes and longitudes of the bus stops was obtained from Google. Different features of Network Analysis module were used to achieve the desired results during the course of the study. Figure 2 displays the overall methodology used during the study to achieve the desired results.

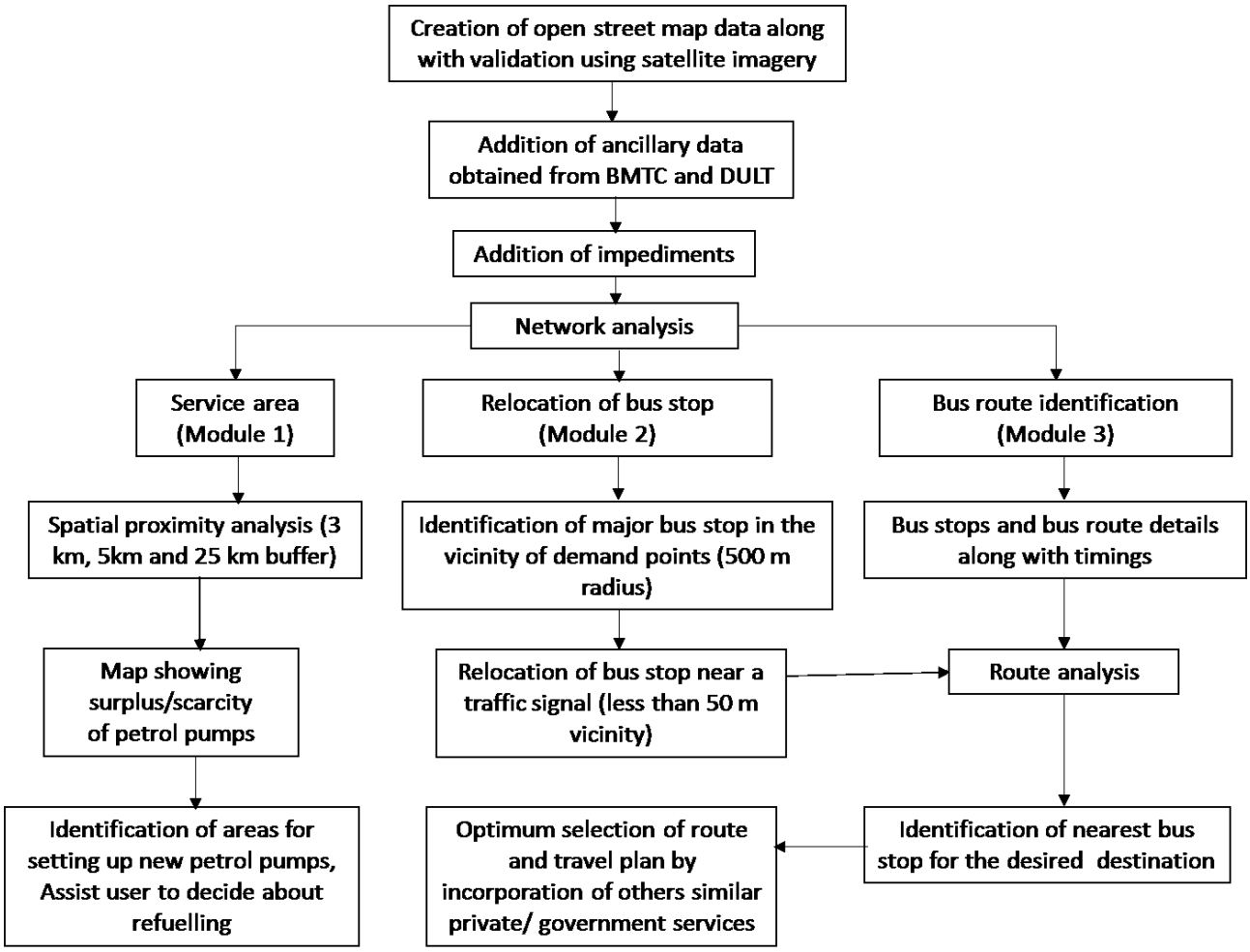

Figure 2: Methodology flowchart

6. Methodology

The methodology followed during the study is explained as listed below:

- The Network Analysis module of Arc GIS was used to carry out the study.
- The network dataset was created and the data to be used was validated using satellite imagery.
- Impediments/barriers were added to strengthen the above dataset (e.g. point, line and polygon barriers).
- Buffers were generated for creating service area polygons.
- The bus stops which had chances of increasing traffic congestion were relocated virtually taking into consideration various factors such as traffic, traffic signals, availability of facilities, etc. CCTV cameras mounted near signals will also facilitate in re-locating the bus stops. One of the bus stops was relocated based on CCTV footage available through downloading from Internet.
- All the bus stops along a bus route were located and a decision support system (DSS) was developed to help a passenger to use public/private mode of transportation based on current location & availability of time and resources.

6.1 Satellite images used during the study

The following satellite images were used during the study:

- Indian Remote Sensing Satellite, Cartosat-2 panchromatic images (2016-2017) of 1.0 m spatial resolution.
- Indian Remote Sensing Satellite, LISS 4 image (2017) of 5.8 m spatial resolution

The above two datasets were merged to obtain a hybrid merged image of 1.0 m resolution in colour.

6.2 Software packages and web mapping services used for the study

1) The software packages used during the study are listed below:
   a) ArcGIS software package – Used for digitization, topology and network analysis of the data that was collected from different sources.
   b) MS Excel 10 – Used for creating, adding, removing or manipulating the attribute tables of obtained data through web survey and data collection.
   c) MS word 10 – Used for the write up of the paper.

2) The online web mapping services used during the study are listed below:
   a) Open Street Maps – Used for downloading the basic data required for the analysis.
   b) Google Maps – For collecting the coordinates of

different points
c) Google Earth

7. Modules adopted

7.1 Service area

It is very important for a driver to keep note of the fuel and number of nearby petrol pumps. This module helps a user to identify the number of petrol pump in the vicinity of his location and decide whether he needs to refuel immediately. Hence, proximity analysis was carried using major road networks and existing petrol pumps in the city. It is briefly described below:

- Study area is initially crowded spatially with existing Indian oil petrol pump locations of the city.
- Proximity analysis in between existing petrol pumps are carried out using a special proximity analysis tool specially designed for proximity of objects in a transportation network.
- Multiple buffers of 3 km, 15 km and 25 km were taken into consideration as the distribution of facilities within an area depends upon the buffer value.
- GPS locations were used to identify the current location of a user on the map.
- This informs a user about his current location and the options available for him to refuel. Depending upon this, the user will be facilitated to know his nearby petrol pumps and his needs to refuel.

7.2 Relocation of bus stops

Bus stops and demand points (areas where a bus stop is essentially required such as railway stations, temples, schools, etc.) are needed to be in synchronicity with each other but in most cases this synchronicity is altered by the presence of impediments. In Bengaluru city, it was observed that most of the major bus stops are near to existing junctions / traffic signals (in a radius of less than 50 meters) making them one of the major causes of traffic congestion in the city as most signals in the city are fixed time signals and the presence of nearby bus stops creates unusual traffic queues which ultimately result in the traffic accumulation at the signalized junctions. In order to give a potential solution to this problem, Network Analysis was used during the study in which major bus stops were located using location allocation module of Arc GIS.

The procedure followed is briefly described below:

- An initial buffer of 500m radius was generated around each bus stop in order to locate all facilities within the vicinity of 500m from the existing bus stops which helped the location allocator to come up with important bus stops (depending upon the number of facilities in and around the bus stops and the distance between the facilities and the bus stops).
- These facilities were taken as demand points using which location allocator optimized the most important bus stops.
- Later a buffer of 50 m was generated around all existing traffic signals (as the nearness of the bus stops to the traffic signals was the major cause of traffic congestion as identified in the city).
- All bus stops that were within the buffer generated around the signals were manually shifted outside the buffer also taking into consideration the distance between two bus stops does not get drastically reduced since there will be a possibility of evolving traffic jams in between the two bus stops.

7.3 Decision Support System (DSS) for boarding a bus from any desired location

Bengaluru's bus system is operated by Bangalore Metropolitan Transport Co-operation (BMTC) which has introduced different buses for different routes in the city. They have assigned different bus numbers for buses moving from/to different locations in which the bus numbers are specified in the format number-alphabet(s) or vice-versa. For a person who wants to travel from one place to other he will need to know the starting point, end point and different stops in between the two points. This system is designed in such a way that a person can get all the above information after providing the given route number as an input information.

- Bus 335-E (Whitefield-Majestic) and 500-D (Hebbal to Silk Board) picking up passengers in the most congested routes as specified above were chosen for developing this methodology.
- Buses, bus stops and their respective bus numbers passing through each bus stop consisting of XY co-ordinates and bus numbers for all the buses passing through the routes were extracted using Google coordinates and ancillary data provided by BMTC.
- From a list of more than 500 bus stops, specific bus stops through which 335-E and 500-D buses along with their regular time of pass were loaded as a new shape file.
- Route analysis was integrated with bus stops information to direct a passenger towards the bus stop for catching the next bus well in advance.
- It was then left to the user to choose whichever mode of transportation he may desire for depending upon the availability of time and resources.

8. Results and discussion

The analysis was done for generating service area layers, bus stop location allocation and tracing buses by sorting their route numbers. The service area module was used to find the area served by existing petrol pumps. The area serviced by each petrol pump was displayed. The distribution of petrol pumps in the city is shown in figure 3. The blue color depicts petrol pumps in the center of the city and ad too many petrol pumps are nearby the distance between two nearby bus stops generated is less than 3 km. The pink color depicts that the distance between two nearby petrol pumps is less than 15kms and the third color code indicated there is no petrol pump in the area.

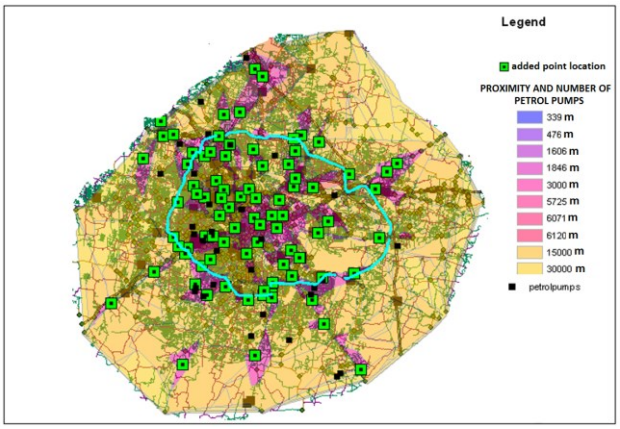

Figure 3: Area served by Indian Oil petrol pumps

This helps us identify a potential location for constructing a new petrol bunk in the city and facilitating the user to know his nearby petrol pumps and his needs to refuel.

Location allocation module helped in understanding the requirement of bus stops in the vicinity of different demand points and buffers around traffic signals helped in relocation problematic bus stops from their original position to a nearby position to help reduce traffic congestion as displayed in figure 4.

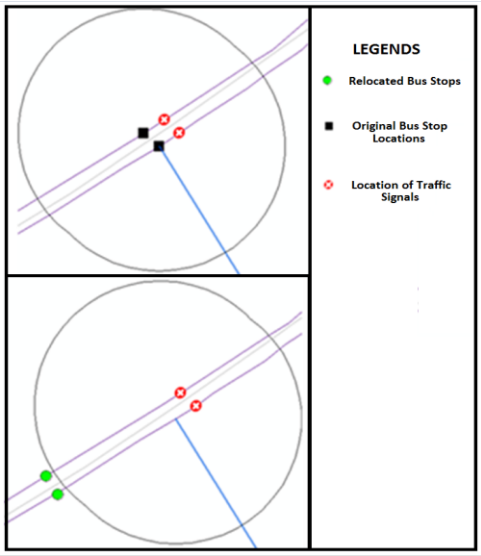

Figure 4: Example displaying relocation of bus stops

Bus numbers 335-E / 500-D were loaded from the attribute table and all bus stops through which the buses passed were traced. Integration of route analysis layer with bus routes and number helped to direct a passenger towards the bus stop for catching the next bus. It was then left to the user to choose whichever vehicle mode he wants to reach his destination depending upon his convenience and availability of resources.

Figure 5 displays an example of the decision support system showing the information about the origin, destination, nearest bus stop and the route the user needs to follow to reach his desired direction well in advance. After the analysis of the data, service area for facilities were found out, bus stop position was shifted and bus routes were traced out using bus numbers. The efficiency of GIS is clearly demonstrated by the above analysis. The network analysis tool is very efficient in solving different problems such as identifying routes, finding the closest facility, finding a service area, location-allocation, route tracing, vehicle routing problem, origin-destination matrix generation, and much more.

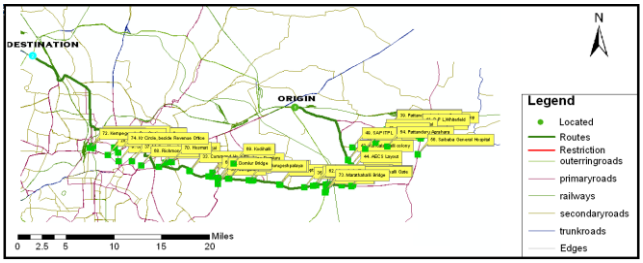

Figure 5: An example of route selection using Decision Support System

9. Future scope of study

Transport Network Optimization has a great scope of future study especially in developing countries. The collection of data for Origin-Destination Matrix creation is one of the most challenging tasks for a traffic planner. The study was only done for signalized intersections but planning needs to be done for un- signalized intersections too. These are some of the major tasks that could be taken up for future study. The study has been done for only one route of the city. Further research can be taken up on relocating bus stops on different routes of the city. Relocation of bus stops with respect to the metro stations and sub-urban railway stations is still a major task to be completed. In future, GIS can be used for transport planning and infrastructure development if more data is available for study. Integration can be done with respect to all modes of transport for better understanding of the traffic situations, provided more data is available. Web GIS applications can be developed to solve traffic related issues which will be very useful for public in upcoming years.

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