Applications of Network Analysis Features in GIS

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ABSTRACT

More often than not, we may find offices, schools, shopping markets, and other general facilities are not nearby to our homestay for our convenience. So, there is a need for a system that could provide routing analysis to provide transportation convenience to the users to reach their destinations. The objective of this paper is to work upon Network Analysis Features of Geographic Information System (GIS) to explore its various applications such as to find the shortest routes between multiple facilities (considering time as the impedance such as nearest schools, hospitals or any other facilities from the homestay. It will also look into the best possible way to transport goods or people from one place to various other regions through multiple means. The work done was based on anonymous network data, and the discussion presents the significant applications of Network Analysis in the ArcGIS software and its usefulness to assist in the transportation issue.

Keywords: Network analysis, data description, GIS-base software, data application, Network Location Tool

INTRODUCTION

In a world of the contemporary 21st century which is moving with a speed of not less than that of a jet, the time is not far where people will be working like machines and will be no less than that of Robots. Time waits for none, and it will be the same in the coming years. Competition among humans will increase and wasting time will become a curse. In this situation, a system through which everyone can value the precious time is vital. Here transportation is taken into consideration. A system which can solve problems like the urgent need of hospitals and fire stations, nearest schools, the best way to go from home to workplace, airport, etc. is required. Therefore, the objective of this paper is to work upon Network Analysis Features of Geographic Information System (GIS) to explore its various applications such as to find the shortest routes between multiple facilities (considering time as the impedance such as nearest schools, hospitals or any other facilities from the homestay.

Geographic Information System (GIS) is one of the world's most pioneering topics which has a large number of applications. It is a digitized computer-based system which involves capturing, storing, manipulating, analyzing, managing, visualizing, and presenting all types of geographical data associated with geographic locations[1]. It stores and processes the data to make it easier to read and understand. Not only in the field of transportation, but it also has a lot of applications such as in engineering, management, telecommunication, and business.

The best route is the route which consumes the least impedance value while working on it[2]. Impedance can be any measured value, such as time, distance, money, etc. [3]. The example of finding the nearest service area includes finding the closest hospitals, schools, and homestays from a particular location or a point.

ArcGIS is a GIS-based software used for creating and

working on maps for various applications. One of its extensions is Network Analysis which works upon the road maps and network data and solves all of the above-stated problems, utilizing maps, lines, vertices, points and various other data formats.

MATERIALS AND METHODS

This section will elaborate on the data and method used in carrying out this study.

Data Description
The data on which the work has been done in the paper is a random network data consisting of road maps as shown in Figure 1. The basic idea is to show the ways through which the experiment is done so that it could be applied to any other data at any time and anywhere in the world. Certain point stations, which are produced through GPS technology, are also considered[4].

experimented, converted from one form to another and can be read through its various extensions such as ArcMap (Figure 2), ArcCatalog, ArcReader, ArcToolbox, ArcScene, ArcGlobe, etc. The experiments of this paper have been performed in the advanced version of ArcGIS 10.2.0.3348

Network Analysis
Network Analysis, one of the most useful extensions of ArcGIS software, is used in transportation planning and solving problems related to the road network[3]. It not only focuses on determining shortest paths, closest facilities, location-allocation, and route of vehicles but also helps the user to adjust the restrictions and the required network conditions. The latter includes adjusting of impedance, start time, speed limits, and directions and putting restrictions on U-turns, wrong ways and one-way paths to get the required result[2].

**Figure 1** Network Data

ArcGIS Software
ArcGIS is a geographic information system used for working on data, maps and geographic information. The software is one of the most famous and is highly used in the field of GIS. The data can be created,

Network analysis toolbox solves the above problems with the help of its well-functioning tools, as shown in Figure 3. Some of them are 1. Network Analysis Window tool - Opens the Network Analysis Window which further helps in managing the contents. 2. Create

a Network Location tool - Adds the network locations on the map. 3. Select/Move Network Locations tool - Selects or moves the added network locations. 4. Solve tool - Runs the analysis. 5. Network Identity tool - Identifies network elements. 6. Directions tool - Opens the dialogue box to determine the direction of the routes.

Applications of Network Analysis
The flowchart in Figure 4 will provide processes used in this study.
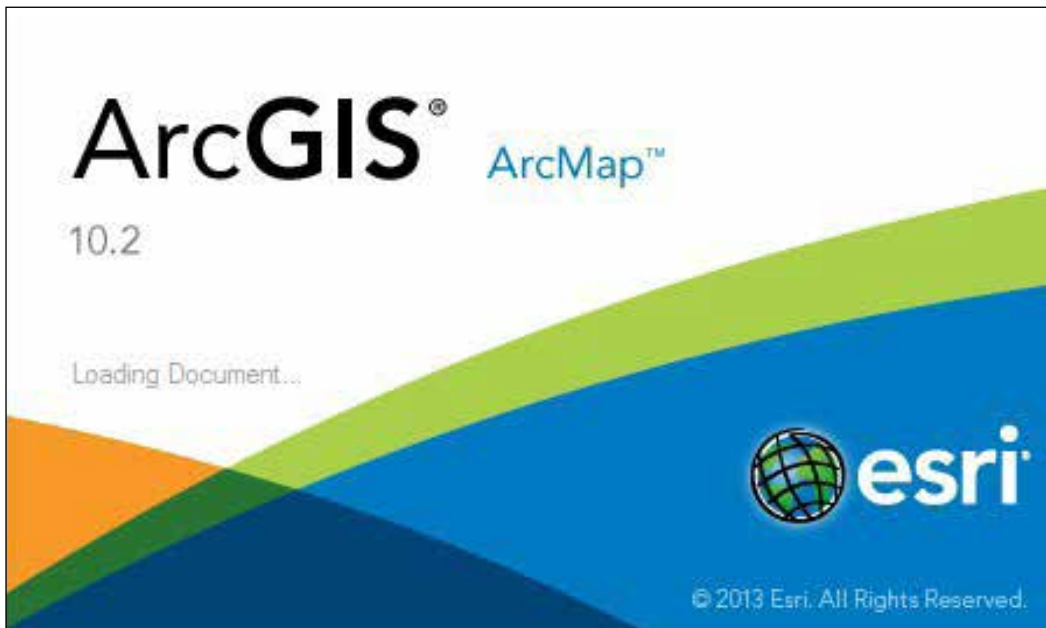
Figure 2 ArcGIS 10.2 Front User Interface
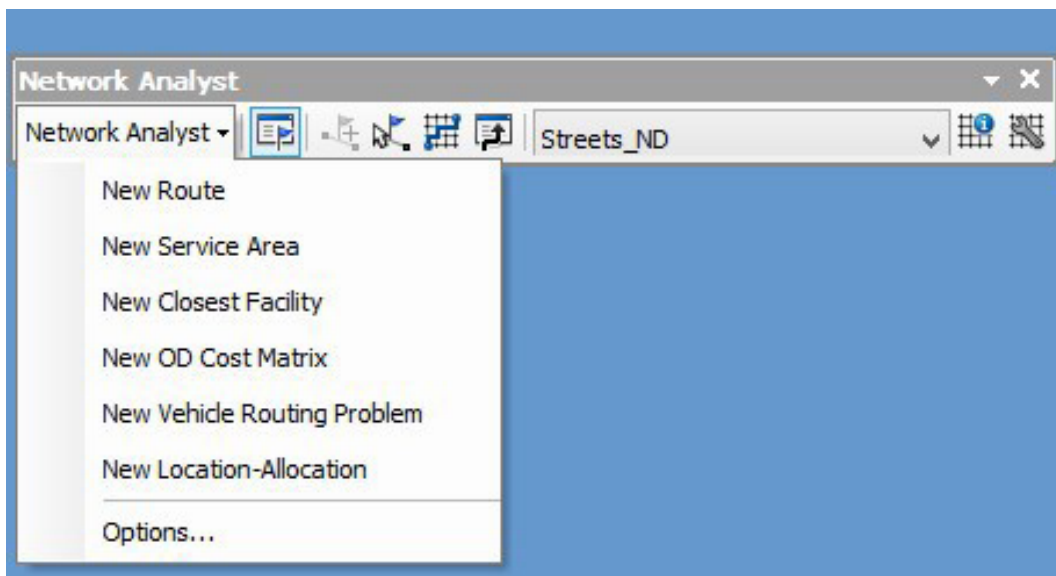
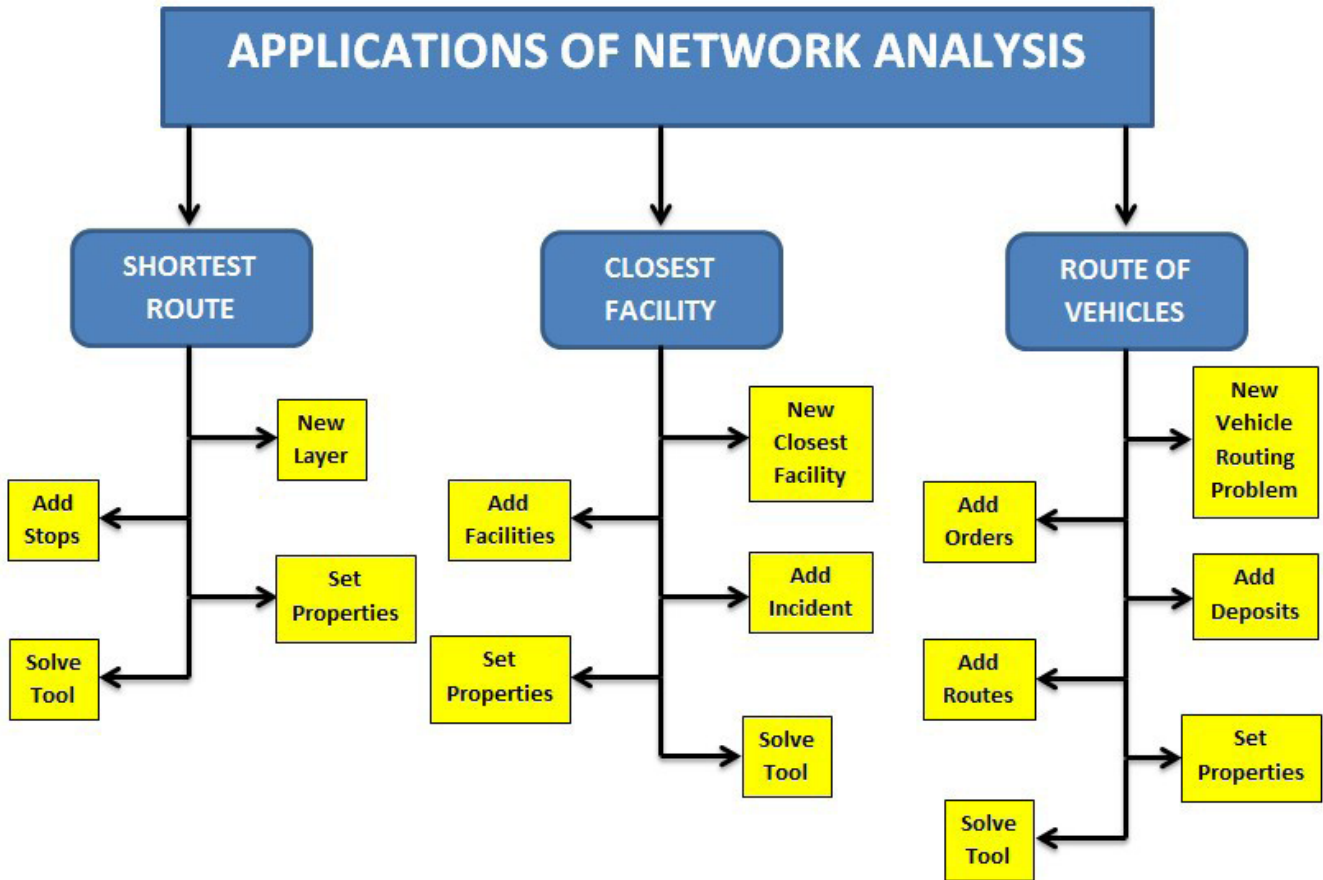**Figure 3** Network Analysis toolbar

Figure 4 Flowchart of Network Analysis

Finding the best route between two stations
It depends upon person to person that what kind of path they want to follow to reach their destination. Some of them look for paths which take the least time while others look for the minimum distance routes. The best path is the path which requires the least impedance to travel from one station to another. It can be travel time, distance, etc. [5]. Here, Travel time is taken as the impedance factor to solve the problem. At first, New Route is selected from the Network Analysis bar in the Network Analysis toolbox. After choosing the Points on the Network Analyst box, stations are marked on the Network data by using the Create Network Location tool. Multiple points can also be drawn which gets automatically numbered to determine the direction of the path according to the preference. Preference can be changed in the

Network Analyst box by clicking and dragging the names of the stops[2]. Move Network Location Tool can also adjust points on the map. Once the stations are marked, settings such as impedance, U-turns, hierarchy, and one-ways are adjusted in the Layer Properties dialogue box. The final step is performed by selecting Routes on Network Analyst and then clicking on the Solve tool to determine the result. The best path appears on the screen as shown on Figure 5 whose directions can be further read by the Directions tool.

Determining the closest facilities from a station
Closest facilities are nearby stations to a particular incident station which can be approached during the time of emergency. Situations such as accidents and crimes can be tackled by approaching the closest

hospitals and police stations with the help of this application[6]. It reduces the workload, saves lives and money and handles the situation in a better way.

After opening the network data on ArcMap, New Closest Facility is chosen from the Network Analysis toolbar. In the Network Analyst box, various functions get loaded. Next step is to load the locations (facilities to find) which is done by right-clicking on Facilities icon, then on Load Locations followed by uploading the data on the map. The incident point near which the facilities need to be found is marked by using the Create Network Location Tool. Multiple points can also be marked if required[2].

Network Analysis provides a lot of specifications which is adjusted in the Layer Properties dialogue box. Impedance is selected as TravelTime, no of facilities to find and default cut off values are marked, and restriction on one way and U-turns are removed due to emergencies and then executed by clicking on Apply option. Default cut off value indicates the no of facilities that need to be found in case of rush and lack of equipment in the nearest stations. The final step is performed by using the Solve tool after selecting the Routes option in the Network Analyst. Road Maps showing tracks to closest facilities will be displayed on the map as shown in Figure 6[3, 4].

Solving the vehicle routing problem
The need of the world is increasing as the growth in population. Factories, wholesale shops schools, and offices will see extensions in the number of employees and students over the years. In this case, multiple transportation systems are required to transport goods and humans from one place to various destinations. It will save human resources, fuel, and money which in turn will help in making the operation of the abovementioned items manageable.

In ArcMap, once the map gets loaded, New Vehicle Routing Problem option is selected to start the process. Orders and Deposits are added by right-clicking on them, Load Locations in the sub-level followed by uploading the facilities data. As the aim is to cover multiple areas, multiple busses (assume 3 here) are added by right-clicking on Routes in Network Analyst box. The most crucial step is to insert the correct properties of the three routes. Some of them are- StartTime, EndTime, Max time and distance, Capacities, Cost, etc. In the end, attributes are marked in Layer Properties box followed by clicking on Solve option to find the result. Three paths get displayed on the map. Directions can be studied individually by selecting the specific route and then the Directions tool. All can also be read at once by clearing the selections.

RESULTS

This section will explain the result from the analysis of finding the shortest path, closest facilities and multiple route choices for multiple deliveries.

Shortest Path
Figure 4 shows the five stations on the map and the red line depicts the best path covering all of the stations. The five points depict the initial, mid and final locations. The movement starts from Point 1, takes the shortest route, with time being the impedance, and goes to Point 2. The process repeats and the movement occurs in increasing order numerically. Here, Point 5 is the destination.

Closest Facilities
The blue box is the emergency point, and H depicts the hospitals in Figure 6. During the time of the experiment at the blue box, i.e. the emergency point, a range of 2 km with 4 hospitals (more than 1 in order to check availability of services) has been set. 4 red lines get displayed as a result, determining the pathways to reach the nearest hospitals within the shortest interval of time. The same results can be found out for other emergencies too and thus can help in increasing the safety of people.

Figure 5 Best routes to selected facilities

Figure 6 Closest facilities

Routes of vehicles

Transfer of goods from a factory to multiple shops is done by using three trucks. Each of the figures (Figure 7, Figure 8, and Figure 9) below represent different paths to supply the goods. In Figure 7, the highlighted root represents the path of Truck1 and the same as in the rest two. During the time of the experiment,

3 trucks have been taken into service. StartTime, EndTime, per hour cost, extra charges and all other properties are set before getting the result. The process helps in making the system a well-managed one with proper involvement of adequate amount of human resources and energy.

Figure 7 Highlighted Root of Truck1

Figure 8 Highlighted Root of Truck2

Figure 9 Highlighted Root of Truck3

DISCUSSIONS AND CONCLUSION

In this paper, work has been done on one of the most powerful extensions of the Geographic Information System by using the network data of a random area on ArcGIS software. It focused on finding the best path between two stations, closest facilities near an incident point and routes of multiple vehicles. With this application, the optimal route in terms of the distance of travel, time of travel, one-way roads, the hierarchy of roads, U-turns and delay due to traffic at different slots of the day, are identified. Problems like emergencies and unmanaged travel systems can be tackled by using the above processes on any network data of any region. Taking inputs from the methods of this paper one can learn the software and apply it anywhere to assist in managing transportation and routing issues.

In conclusion, this work has shown the significant feature of route planning for good and service delivery can be done using network analysis features from - the-self GIS software. However, to add commercial value to this work, further works in the form of apps development should be encouraged from this kind of work so that the usage of such work and benefit could be more accessible. It may also complement the existing routing-providing apps (such as Waze, Google Map) since this work also provides impedances to find the optimum routes such as cost and time.

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