Geographic Information Systems for Campus/University Transportation Planning

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Abstract: - Geographic Information Systems (GIS) are having tremendous impacts on many scientific and engineering application domains. Interdisciplinary nature of GIS has also emerged in transportation analysis and planning. GIS based spatial and network analyses are witnessing a major enhancement of GIS in transportation sector. This paper explore the use of GIS in the development of transportation planning system using a close linkages between spatial and network analysis through a case study of road network of National Institute of Technology Hamirpur, India.

Key-Words: - GIS; networks; route planning; transportation

1 Introduction
The ability to solve for the optimal path connecting two points/locations in a space has been of great importance to various engineering applications, and recently to architectural and urban design communities [1]. Traditional methods of determining an optimal path that traverses from one point to another have been based on graph exploration techniques [2]. For decades, GIS based spatial analysis tackled fundamental problems associated with analyzing spatial data and modeling of spatial processes. GIS has spread in many scientific and engineering applications concerning with understanding of geographic phenomena. Substantial progress has been achieved despite the limited spatial information processing capabilities of traditional techniques. GIS provides new methods for capturing, storing, processing and communicating georeferenced information. Its use has spread to application domains concerned within the transportation sector.

GIS serves as a spatial and non-spatial database management system for managing georeferenced data and also a spatial decision support system for mapping and communicating geographic information to planners and decision makers in transportation sector. Spatial analysis is benefiting from new geo-computational tools that can handle more diverse data and can better exploit very large spatial datasets than traditional spatial analysis techniques. The computational tools and design principles of geo visualization can be combined with models of relative space in spatial analysis to develop powerful visualization techniques for transportation analysis [3].

2 Transportation Network
Network is a system of interconnected elements such as lines connecting points/locations. Highways connecting to various cities, interconnected streets at intersections, and sewer or water lines that connect to houses are the examples of networks. Connectivity among various elements of a network is essential order to travel or flow through a network. Network elements, lines and points, must be interconnected to allow travel or flow through a network. All network elements have properties which control navigation through a network [4]. GIS facilitates analysis of two types of networks: transportation and utility networks. Transportation networks are undirected networks, a road on a network may have a direction assigned to it, driver is free to decide any direction, speed and destination of traversal [4]. Driver can choose which street to turn into, when and where to stop, and which direction to drive. However, restrictions imposed on a network like: one-way streets, no left turn or no U-turn are guidelines for drivers which are in stark contrast to the utility networks [4]. The road network of National Institute of Technology Hamirpur, India, shown in Fig. 1 has been taken as a case study to demonstrate the capabilities of GIS in finding optimal route.
3 Network Dataset in ArcGIS

ArcGIS developed by Environmental Systems Research Institute (ESRI) run on standard desktop computer has been used in the present work. Optional extensions such as Spatial Analyst, 3D Analyst, ArcGIS Data Interoperability, Network Analyst, Survey Analyst, etc. allow performing additional tasks with ArcGIS. ArcGIS Network Analyst allows creating and managing sophisticated network datasets and generating routing solutions. Network Analyst is a powerful extension for routing and network-based spatial analysis (e.g., location analysis, drive-time analysis and spatial interaction modeling). The Network Analyst extension of ArcGIS allows building a network dataset and performing various types of analyses on it.

Networks for analysis in ArcGIS Network Analyst are stored as network datasets. Network dataset is created from a feature source that participates in a network, network dataset of National Institute of Technology Hamirpur in this case. It incorporates connectivity that represents complex scenarios. Network datasets also possess a rich attributes which help in modeling impedances, restrictions and hierarchy for a network. A network dataset is built from points, lines and turns. It can also be built from feature classes in a feature dataset of a geodatabase [6]. The shapefile network dataset is created from a polyline shapefile containing the network source and optionally a shapefile turn feature class. After creating or editing an existing network dataset it is built. Network dataset building is a process of creating network elements, establishing connectivity and assigning values to defined attributes [4]. The road network dataset of National Institute of Technology Hamirpur has been prepared from a shapefile containing road network has been shown in Fig. 2. When a network dataset is built, two new objects are added: the network dataset and point feature class containing all junctions/locations.

4 Road Network Elements

Network datasets are made up of network elements which are generated from the sources used to create a network dataset, that is, feature dataset of a geodatabase or shapefile [6]. There are three kinds of network elements: edges, junctions and turns. Edges are the elements that connect to other junctions. Edges are the links over which vehicles flow. Junctions/locations connect edges to facilitate navigation from one edge to another. Turn elements record information about movement between two or more edges. In addition, network elements have attributes which control vehicle movement over a network. Edges and junctions form the basic structure of any network. Turns are optional elements to store information about a particular turning movement like: a right turn is restricted from one particular edge to another.

5 Network Attributes

Network attributes are the properties of network elements which control movement over a network. Attributes include: time to travel a given length of road which streets are restricted for which vehicle classes, speed limit along various roads, and streets which are one-way/two-way. In ArcGIS network attributes have five basic properties: name, usage type, units, data type and use by default [4]. The usage type specifies how attribute will be used during analysis, which is identified as either a cost, descriptor, restriction or hierarchy.

To create network attributes, name of attribute, its usage, units, data type and use by default need to be defined. The evaluators for each source is assigned that provide the values for the network attribute when the network dataset is built. Network attributes may
also have parameters that can be used by its evaluators. Parameters allow for dynamic analysis with network attributes by modeling such descriptor attributes as truck height or weight, weather factors or current speeds [4].

5.1 Cost
Certain attributes are used to measure and model the impedances such as travel time. Travel time and distance are cost attributes of a network dataset. Such attributes are dividable along an edge/length, that is, they are divided proportionately along the length of an edge. If travel time is modeled as a cost attribute then travelling half an edge will take half the time as travelling the whole edge. Network analysis often involves minimization of a cost, also known as impedance, during the calculation of a path, also known as finding the best route. Analysis in this study includes finding the fastest route by minimizing travel time or the shortest route by minimizing distance.

5.2 Descriptors
Descriptors are attributes to describe characteristics of a network or its elements. Unlike costs, descriptors are not dividable. Descriptors value does not depend upon length of edge element, for example, speed limit of streets, number of lanes are the examples of descriptors. It is not a cost attribute and cannot be used as impedance. It can be used in conjunction with distance to create a cost attribute [4].

5.3 Restrictions
Restrictions can be identified for particular elements, such that during an analysis, restricted elements cannot be traversed. For example, one-way streets can be modeled with a restriction attribute, so they can only be traversed from one end to another and not in the reverse direction. Certain sources where vehicles are not allowed could be restricted using restriction attribute [4-5]. Restriction can be used as a parameter during best route analysis to ensure the vehicles do not use streets that are restricted.

6 Directions Chart for Driver
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Fig. 2: Road network dataset has been prepared from a shapefile containing road network.

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and at least one text field on edge source [4]. The directions generated when a route is computed are customizable at the network dataset level. The street names are used for reporting directions, length units are used to report length. Length attribute is used to calculate the length of each segment of the route for which the directions are reported. Any cost attribute can be selected as a length attribute. Time Attribute is used to calculate the time taken to traverse each segment during the reporting of directions [4].

7 Finding Best Route
GIS has been used to find the best route to get from one location to another or the best route to visit several locations simultaneously in the institute campus. Locations may be specified interactively by the user by placing points on a computer screen, by entering an address if data is geo-coded [5], or by using points in an existing feature class or feature layer. The best route is determined for the order of locations as specified by a user. It determines the best sequence to visit the specified locations. But best route may mean different things in different situations. The best route may be quickest, shortest, or most scenic route, depending on the impedance chosen [4]. If impedance is time, then best route is the quickest route. Hence, the best route may be defined as a route that has lowest impedance, where the impedance is chosen by the user. Any valid network cost attribute can be used as the impedance when determining best route. Accumulated attributes play no role when computing the solution.

4 Conclusion
There are several fundamental network and spatial analysis issues in transportation sector [7]. Ever changing nature of transportation problems is offering new and unique challenges to the spatial analyst and transportation researchers. Road congestion will also continue to increase; attempts to build our way out of this congestion will not work. GIS provides network and spatial analysis tools to transportation researchers and practitioners in such situations. It not only provides new ways of analyzing transportation systems but even new ways of thinking about these problems. GIS provides a graphical solution that is easily understood, users can convey highly technical information to the non-practitioner/technical personal in a very straightforward and understandable manner.

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References: