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Geographic Information Systems (GIS) in transportation

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ABSTRACT
GIS for transportation is an important planning and management tool for transportation professionals. Well built network data sets and decades of GIS modelling experience enables sophisticated analysis, such as optimal routing and allocation also on multimodal systems as combined street, railway. In addition, can play a significant role in decisions related to the new location of transport or logistical infrastructure

KEYWORDS: Geographic Information Systems (GIS)

1. Introduction

Transportation has great impact on our daily life and is growing immensely nowadays. The demand for transportation has increased dramatically over the past decades, helping the world to become more mobile and independent as international trade relationships have altered the dynamics of manufacturing and consumption [1].

The rapid development of communication and transportation network makes the management of the entire infrastructure more and more complex and demanding. The development of transport technology has contributed to an ever-increasing demand for advanced technologies supporting management, planning and designing of the road infrastructure.

Transport, public transport, domestic and international communication, management and maintenance of the communication network, forwarding, sea and air freight, airport and harbor management, fleet monitoring, logistics, route planning and optimization, itinerary planning and analysis – these are only some of the issues that come to our minds when we think "transport". Is here a place for GIS? Definitely yes. Geographic Information System has many faces – it is both a science and a tool for managing, analyzing and presenting geographical information using data, in order to understand and visualize spatial dependencies. In addition, GIS is a tool for smart decision-making through organization of data and its use in individual projects and tasks (fig.1).

By enabling visualization of all geo-referenced information GIS allows you for instance to examine the potential influence of transport investments on the environment, and present the results in the form of maps, graphs, reports, etc. It also facilitates the creation of databases containing detailed information about the transport infrastructure. With this technology you can inventory, process, analyze, present and archive the entire road network.

Through integration of descriptive, spatial and measurement data, GIS may also be applied in logistics, speeding up the planning, maximizing the efficiency of a car fleet, reducing delivery time and increasing productivity. In order to achieve full productivity by taking advantage of GIS technology, the first step is to create a network data set.

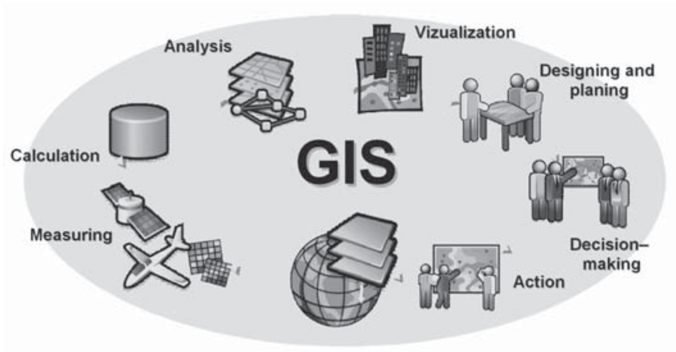

Fig.1.Enterprise GIS

2. Network Data Sets

Making a network data set is like making a topology. A set of participating feature classes is defined, properties are set and graph is made.

The properties of a network data set affect the way how network elements are discovered from feature coincidence, refine the connectivity model and optimize solver performance. The following are the steps necessary to create a network data set [4] (fig.2):

2.1. Setting sources

A network data set contains network elements built from features in network sources. These sources are either feature classes in feature data set, shapefiles, or feature classes Smart Data Compression (SDC) data sets. Network elements are made from features when a network data set is built. The network elements and their connectivity are discovered by finding geometric coincidences of points, polyline endpoints and polyline vertices [3]. The network elements and connectivity information are stored in a logical network, a set of element and index tables inside a network data set.

2.2. Setting connectivity groups and policies

Connectivity groups are used to distinguish different transportation networks, such as subways, streets, railway, etc. Building a network dataset begins by specifying which feature class will participate in the network. This is done by assigning the classes to connectivity groups. The number of distinct networks equals the number of connectivity groups. Each connectivity group must have at least one edge feature source. ESRI Network Analyst extension supports multimodal networks, where different modes of travel may be employed to define a path through the network.

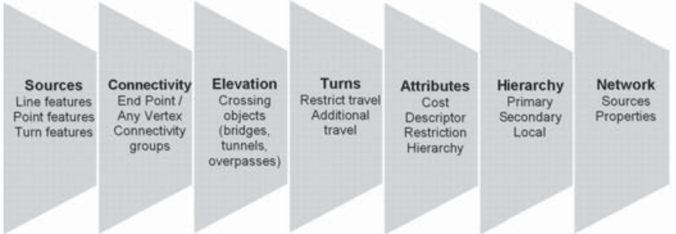

Fig.2.Network Data Set Workflow

2.3. Using elevation fields

Elevation fields are used to model crossing objects, such as bridges, tunnels and overpasses. It does not refer to an altitude but the logical levels of roadways, analogous to the stories in a building and are commonly provided on street networks from commercial data vendors [4].

2.4. Adding turns

Turns are added to restrict certain movements through a junction beyond merely prohibiting wrong–way movements on a one–way street. It is also necessary to properly describe any multi-angle turns, which involve multiple maneuvers through a complex intersection to compete a turn from an approach edge to a departure edge.

2.5. Defining network attributes

Network elements have network attributes that are assigned, calculated, or derived from source feature attributes. Attribute model has five basic properties: name, type of usage, units of measure, data type, and default value. The usage type specifies what kind of input the attribute serves (a cost, descriptor, restriction, or hierarchy). Any element can have multiple cost attributes. It can be a true distance, bus ride time, walk time or drive time. Before conducting an analysis it is necessary to set the cost. Descriptor attribute is a description that is true for the entire length of a network element and is used for detailed driving directions or to help derive other attributes. This can be used for speed limits or describing a road as dirt or paved. Descriptor can determine other information, such as dividing street length by speed limit to get drive time. Restrictions are used to model streets that are not allowed access or turns. To create hierarchy an integer rank needs to be assigned to certain road classifications [3].

2.6. Optimizing with hierarchy

A network data set can use a feature classification to make a N-level hierarchy, such as highways, major roads, minor roads or local roads. The logical network uses hierarchy to optimize route solving on large transportation networks.

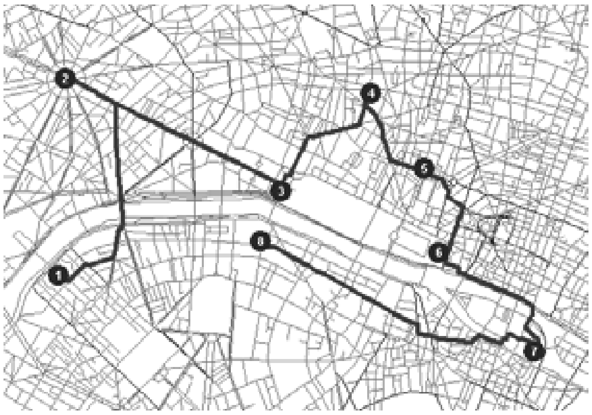

Fig.3.Route solver

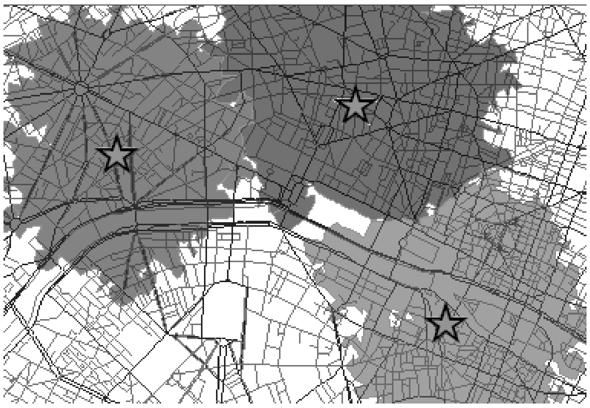

Fig.4.Service area solver

2.7. Building the network data set

Network data set can be built when the network data set sources and properties are set. This will create network elements in the logical network. The simplest way to build a network dataset is to use a feature class as the source and generate the junctions at each endpoint and midpoint intersection [3]. When a network source is edited, the network must be rebuilt.

The point of modeling with network data sets is to enable network analysis. Having network data set built, network objects, such as stops, facilities and barriers can be dynamically placed or loaded. There are five network solvers that perform the desired analysis on the network data set and network objects:

- Finding the best route
- Finding service areas
- Finding the closest facility
- Origin - Destination cost matrix
- Vehicle Routing Problem (VRP)

3. Network Analysis

3.1. Finding the best route

The Network Analyst route solver helps to find the best way to get from one location to another or visit several locations. The locations can be specified by placing points on the screen, entering an address or loading points from an existing dataset. The best route can also be determined taking into account specific options such as order of locations as specified by user or, the best sequence of stops for end user. Properties of stops are shown in a Time Window with time ranges in which the route should visit those stops. It is also possible to create multiple routes or specify time a route must begin and generate directions for the route after it has been solved.

3.2. Finding service area

Service area solver is used to find areas which can be reached from one or more locations meeting given criteria. A network service area is a region that encompasses accessible streets within specified boundaries, such as a five–minute travel time or three-kilometer distance limit. You can set parameters, such as impedance, U–turn policy and restrictions or polygon break to limit the service area. This analysis may also be an important factor in assisting the decision–making process for establishing the best location of a new distribution center, and therefore predicting the positive and negative effects of such location.

3.3. Finding the closest facility

Closest facility solver helps to find the best route to the closest facility or set of facilities from an incident or set of incidents. It contains options such as: impedance, cutoff value, number of facilities to find and direction of travel. You can narrow down the number of facilities to find, for example by searching for every gas station within 15 minutes from current location. When you apply the closest facility solver to an input set of facilities, incidents and barriers, you specify additional parameters, such as a cutoff value to restrict the maximum number of facilities to find.

3.4. Origin – Destination cost matrix (OD)

Origin–destination cost matrix solver (OD solver) generates a table of the cost to travel from each origin in a set of origins to each destination in a set of destinations. If you are modeling distribution of goods, such as the flow of manufactured goods from a warehouse to store locations, you can generate an origin–destination cost matrix used for logistics planning. You input a set of origin points (such a warehouse) and another set of destination points (such as stores) on a network data set. A cost such as travel

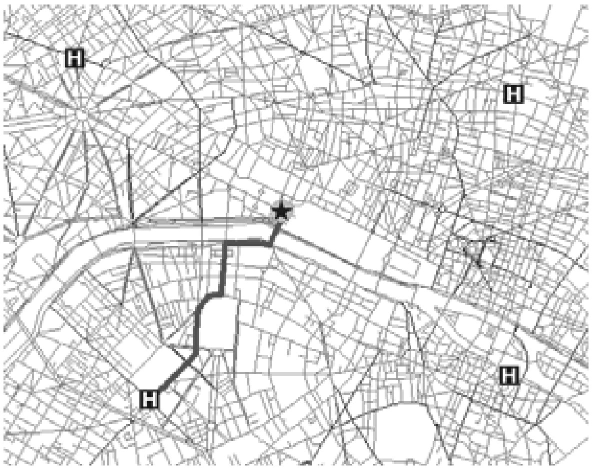

Fig.5.Closest facility solver

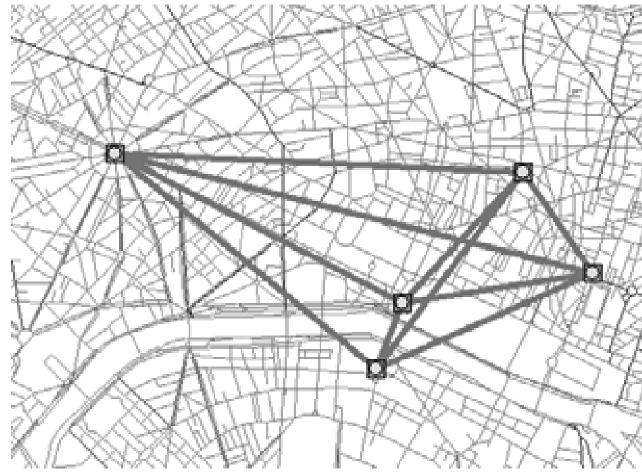

Fig.6.Origin–destination cost matrix solver

time, can be calculated for the best routes between all possible origin–destination combinations.

3.5. Vehicle Routing Problem (VRP)

The Vehicle Routing Problem (VRP) solver helps to determine how best to assign a group of customers to a fleet of vehicles and to sequence and schedule the visits. VRP contains such options as: multiple vehicle capacities, order sizes, time window, driver specialties, route duration constraints, defining route zones, route seed points and driver breaks. Along with the driver specialties it is possible to set vehicle characteristics such as cost per mile, cost per hour or cost per day. To ensure that a vehicle doesn't travel for more than 8 hours or over 250 km per day, such constraints can be defined with route duration constraints. Furthermore routes can be limited by route zones or seed points to keep drivers within areas they are familiar with or near specific group of customers. VRP is the most advanced analysis in a logistic system and helps to reduce operation costs, reduce gas consumption and optimize fleet.

4. Conclusions

GIS for transportation is emerging as an important planning and management tool for transportation professionals. Transportation network modeling has many requirements and functions, including the ability to support:

- multiple travel modes, such as walking, public transit systems, and driving in automobiles, for any journey,
- the options and costs of transferring between modes of travel,
- travel costs and routes that vary by time of day or the changing conditions of the network,
- the ability to represent complex turn restrictions and costs between any elements in a transportation network,
- modeling a hierarchy of transportation systems (e.g., primary use of freeways between destinations combined with travel along city streets and sidewalks near each destination),
- handling very large network data sets (with millions of features) and continuous updates and edits coming simultaneously from many users [2];

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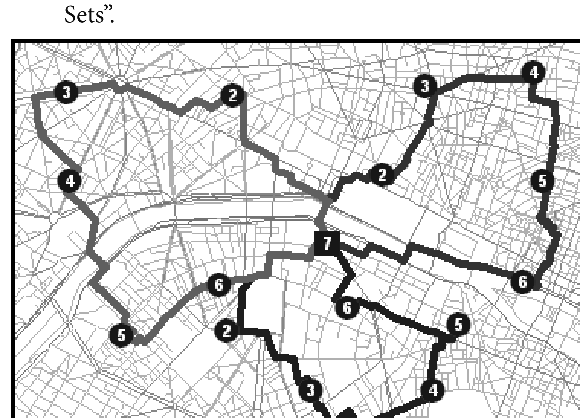

Fig.7.Vehicle Routing Problem (VRP) solver