Logistics Route Planning with Geographic Data Considering Multiple Factors

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ABSTRACT

In this paper, the author first discusses the main applications of GIS in logistics, based on the development trend and demand of modern information-based logistics, and then tries to explain, how GIS can provide services in logistics, especially in transportation process. The use of powerful spatial analysis function of GIS and detailed geographic data preparation can support the determination of the shortest path of vehicles, and assisting transport route planning and design. In addition, from comprehensive consideration of transit time, road conditions, transportation costs and other factors, the optimal transport path can be determined dynamically on the basis of the shortest path. Then the vehicle routing problem (VRP) can be solved partially.

1. INTRODUCTION

GIS (Geography Information System) is a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems. GIS is closely related to spatial location, so it has a wide range of applications, such as transportation, land planning, urban management, agriculture, forestry and other fields. Recent years, the application of GIS in the logistics field rises. Gradually, GIS plays a very important role in the field of logistics transportation and distribution. This paper will analyze the applications of GIS in site selection of logistics, transportation and distribution. Focused on the transportation route planning and related algorithms, a method taking into account multiple factors, changing weight dynamically in path selection is given.

2. GIS APPLICATION FIELD IN LOGISTICS

Most of the information in modern logistics relates to the spatial location, such as transportation, warehousing and distribution, which makes it necessary to integrate GIS and logistics. The application of GIS in logistics is mainly reflected in the following areas:

Logistics facilities positioning: Used to determine the location of the facilities, such as the best position of warehouses, stores, distribution centers. Through the performance of GIS electronic map, spatial location of the logistics elements can be marked. Via the function of GIS query between spatial data and attribute data, relations between logistics features attribute data and spatial location can be established. Using GIS buffering function, the surrounding circumstances around the point of logistics facilities can be identified as constraints by some factors. SUN Zhiyuan made some research in logistics site selection (Sun 2009).

Vehicle route planning: Vehicle route planning is used to solve the problem of the path for goods transportation, to determine the best distribution route from the start point to the end point, i.e. shortest distance, shortest time, least expensive, etc. (Tian, et al., 2008). For route planning, it requires a lot of detailed GIS spatial data and attributes data support. On this basis, using GIS-overlay function to analyze by overlaying multi-layer maps. We can overlay the road layer and traffic signal layer to provide more information. Using network analysis function, it is very convenient to analyze the complex road information and select the vehicle routing to meet the demand of users.

Spatial query and statistics: Including the query for the customer's geographic location, the surrounding circumstances around customer and attribute information associated. With GPS, you can also check the current location of vehicles, and query the planning route information, etc. (Qiu, et al. 2008). Simulation of the above query results can be displayed in different graphics or symbols. In addition, information statistics can be performed of different regions, different distances, and different users' types based on a certain statistical indicators.

All applications mentioned above should be based on adequate spatial data and attribute data, and the ability of graphic data processing, analysis, display of GIS. A typical application mode for the integration of GIS with logistics is: Overlaying the basic topographic data with logistics thematic data; using GIS tools to edit, query, statistics, and output etc. See figure 1.

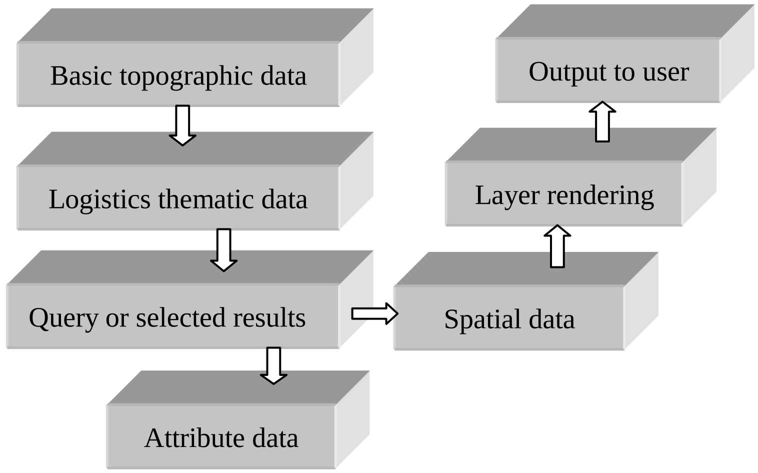

Figure 1. Typical application mode using GIS in logistics

3. ORDINARY SHORTEST PATH PROBLEM AND GIS INDICATION

For many years, the vehicles route plan has been one of the research hot spots in logistics, and shortest path issue is the core question (Ding et al., 2009). The shortest path not only points to the shortest distance, as is often said , but also expands to other measures, such as time, expense, line capacity etc. There are a lot of algorithms of shortest path calculation. In the static road network, Dijkstra algorithm and A* algorithm are the most common. These algorithms are also relatively mature, reliable, and applied in many path planning software (Wang 2009). But their drawback is evident, it is necessary to find a path to re-calculate in every change, so that, efficiency in the calculation is their common bottleneck.

In order to improve its search efficiency, the algorithm should be improved. CHEN Zhuo (Chen, et al., 2009) realized the improvement of Dijkstra algorithm with the straight-line optimization. LI Zhi-jian (Li, et al. 2009) improved the A* algorithm.

In recent years, a lot of new algorithms have emerged in shortest path calculation. Most of them are descriptive methods, such as genetic algorithm and artificial intelligence. Ant Colony Algorithms is a typical and popular method. ZHANG Wen-jie (Zhang, et al. 2009) has made some research about this algorithm.

With the integration of GIS technology and spatial data support, visualization of the algorithm can be realized. The results of shortest path are represented on digital map through display devices. Though this way better intuitive expression results can be obtained. At the same time different route path can be compared directly.

4. COMPREHENSIVE EVALUATION METHOD FOR VEHCHILE ROUTE BASED ON CONSIDERATING MULTIPLE FACTORS

For logistics companies and drivers, the shortest distance is necessary. Further, many other factors are as important as shortest distance, such as the quality of the road, smooth degree of road, and transit time etc. We need a combination of factors to make the final decision. Therefore, in the path choice, based on the shortest path, more considerations about the impact factor should be added as the weight, so as to obtain the most appropriate path.

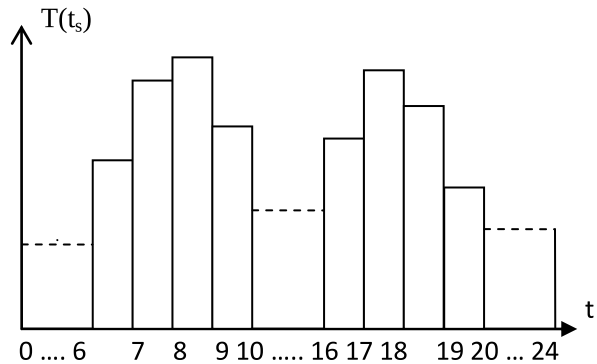

Figure 2. Road impedance changes in the different time

In this paper, the transport time T, the road grades R, the road smoothness degree F are comprehensively considered as factors that affect the transportation.

Transport time T. Vehicle traffic efficiency varies with time. In the rush hour, traffic jam is serious and need longer time, that is, large impedance. At noon or night, the road is smoother, shorter time that is smaller impedance, during other time it is in the medium. Set t_s for the moment at which the vehicle reaches node S, T_{SM} (t_s) for the required time vehicles moving with the traffic flow from S to M, called the impedance of road. From the statistics properties of traffic flow, the changing trend of a typical road's T_{SM} during a day is shown in Figure 2.

In practical dynamic traffic conditions, at different times, the impedance is different. Impedance of the road is not a fixed value, but rather a function of time. As the time interval reduces infinitely, a continuous distribution curve can be plotted. It might also be discretized approximately, divided by time, different impedance in different time, and roads of closet flow situation are considered to have the same impedance, such as from 2000 hrs to 0000 hrs.

Road grade R. With the main consideration of road design grade and the actual level of road quality, roads can be divided into highway, first class roads, second class roads, third class roads, fourth class roads, and substandard roads. According to the road grade, different weight is given, and it could be used to quantify the impact of passing time or distance, denoted by T(R).

Road smooth degrees F: From the empirical data based on the original road traffic situation, road smoothness degree is assessed, and the effect on the transport time denoted as $T(f_1)$. In addition the number of traffic lights is also an important indicator of evaluation of road smoothness degree. Generally, city road design speed is 60km/h, and every 1 minute lights means 1km distance, with start-up and deceleration time the impact will be even greater. In many cities, the lights are very intensive, and in some roads there is a few hundred meters interval. Therefore, the number of signal light affects the traffic efficiency directly. Suppose in a S km road, there are k signal lights in each kilometer, each time to wait for signal is t_k, then the full impact to pass $T(f_2) = t_k * S / k$. Therefore, the combined effects of the road smoothness degree may be denoted as $T(F) = T(f_1) + T(f_2)$.

Comprehensive consideration of the above three factors, taking into account previously calculated static shortest path D, the time effect of the path from the starting point S to the final target Z is as follows:

$$T(S\text{-}Z)= D/V_{AVG}+ T(t_s)+ T(R_i)+ T(F) \qquad (1)$$

Road route planning based on overall weight. For different users and different transport focus, varying weights could be given according to the above four factors, denoted Pi respectively. Then, the overall weight is as follows:

$$P = p_1 \cdot D/V+ p_2 \cdot T(t_s)+ p_3 \cdot T(R_i)+ p_4 \cdot T(F) \qquad (2)$$

This equation could be more comprehensive in adjusting the weight of various factors in the final route planning.GIS data source required for the method. If you want to take these multiple factors into account in GIS for supporting route planning, detailed spatial data and attributes data are required, as shown in Table1.

Table 1. GIS data source required in vehicle route planning

No	Data type	Data description	Shape
01	Urban infrastructure road	main road, sub-trunk roads, branch, etc	Line
02	Highway	Trans-regional, closed management, fees	Line
03	Railway	Common rail, high-speed railway	Line
04	Waterway	Ports, piers and water	Polygon
05	Air route	Airports and air routes	Line
06	Traffic lights	Record the location and waiting time	Point
07	Toll station	road, bridge, tunnel toll station locations	Point
08	Topography	Main buildings and structures	Polygon

Each of the above data contains different attributes and spatial items, to ensure the different needs of different data items. For example, road data for the urban infrastructure is required to convey its accurate location relationship with the surrounding features, and detailed records of the related information, such as road grade, road quality, the number of lanes, etc. as shown in Table 2. Route planning can be carried out to retrieve the corresponding attribute information, and is used to determine the corresponding weights, by this way, the optimal route is obtained.

Table 2. Data tables' structure of urban roads

No	**Type**	**Name**	**Grade**	**Limiting-velocity Km/h**	**Number of two-way lane**	**Length km**
0011	01	RaoCheng	1	100	6	20
0012	01	XuanWu	2	80	10	7.12
0013	01	Longpan	3	60	8	5.3
0014	01	HuaYuan	4	40	4	3.61

To sum up, during route planning, according to the following several steps: Firstly, calculate the shortest path between the start point to the target point by the improved algorithm; the second step, determine the road impedance $T(t_s)$ according to the transit time; the third step, searches for the above shortest path from the map layers using GIS tools, get road grades and the highest speed, so as to calculate the ideal transit time, or according to different road grades give different weights. The fourth step, search the signal lights included in the shortest path, calculate the average impact to the transit time, coupled with empirical data determined by the degree of the road, and determine the overall impact on the shortest path. Comprehensively considering the above factors, according to formula(1), the actual transit time could be calculated, or calculate the weight according to formula(2), a more comprehensive evaluation will be calculated.

5. CONCLUSION

After the analysis of the applications in logistics using GIS, a common GIS application mode in the logistics filed is given. Emphasis is on the vehicle route planning, especially the shortest path or optimal path. The paper demonstrates that transport time, road grade, road smoothness degree are significant factors affecting the efficiency of vehicle traffic which should be comprehensive consideration in vehicle route planning. In road smoothness degree, it specifically introduced the impact of traffic lights on travel time. Through the traffic lights GIS layers, specific queries can be made and the impact to the transit time is calculated. Considering the above factors, the selected vehicle route will be more suitable for the actual road conditions and driver's actual driving experience. With the GIS functions, users can look, query and contrast the results more vivid, intuitive and precise.

Although several factors have been discussed here, and some quantitative indicators have been given, there are still many needs for improvement, such as on various factors, a more accurate value of the quantitative indicators and experience need to be determined by long-term practice. In addition, the other factors affecting the vehicle route planning and its effects are topics for further discussion and study.

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