A GIS Based Route Determination in Linear Engineering Structures Information Management (LESIM)

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SUMMARY

Linear Engineering Structures (LES) such as roads, natural gas-oil pipelines, irrigation-drying channels, power lines and railways cover larger areas than other technical infrastructure facilities. Because of the need of route selection, linear engineering structures require strategic planning, evaluation and management. The operations to choose optimum route depends on the effective collection, processing, storing and analysis of spatial data such as topography, vegetation, geology, soil type, land use, and landslide areas about land. This situation requires to use of Geographical Information Systems (GIS) by providing effective data management. In LES information management, spatial data belonging large study area are especially collected via Remote Sensing (RS) easily. In this context, using raster network analysis has some advantages for route selection operation with the assistance of these data. In literature, it is seen that, route selection operations of LES are determined optimally with the minimum cost. But, in some developing countries, route selections of linear engineering structures are determined via classical method on medium scale topographic maps and only slope data is taken into consideration. In this route selection operation, because of spatial data belonging land use is not used in many points route is changed and this causes an increase in the cost. Consequently, in these situations it is necessary that GIS based dynamic models have to be designed for LES information management. In this study, types of issues faced are determined for LES in route selection in developing countries and the needs of raster network analysis to solve these issues are investigated. In this respect, a model with pilot application is formed for natural gas pipeline route selection operations in a selected area in Turkey.

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1. INTRODUCTION

GIS based route determination processes using raster or vector data models are named as network analysis. Traditionally, network analysis, path finding and route planning have been densely used in graph theory and vector GIS, in which there are most algorithms in this application. However, it is not difficult to adapt these algorithms to a raster environment, as it will be highlighted in this article. Raster applications are more likely to be based on movement across a surface than movement along a network, since the general idea of finding the least cost path is linked to movement from cell to cell, and not along a finite line. Many researches have already sought to improve the shortcomings of the raster approach and have developed various solutions and proposals.

The conventional route planning has solely been based on topographical considerations-gradient and curvature in developing countries. Usual practice involves manually marking segments of permissible gradients for route alignment on large-scale topographical maps. Such an approach is cumbersome and tedious, and it may not be feasible when variety of factors such as landslides, geology, soil type, vegetation, landuse, and landcover are considered (Saha et al. 2005).

The present study was initiated to demonstrate the use of various data from different sources, GIS analysis and raster network analysis techniques for developing a least cost pathway for linear engineering structures. The study area is selected in Trabzon which is situated in the Black Sea Region of Turkey.

2. ROUTE PLANNING AND GIS

Determining the best route through an area is one of the oldest spatial problems. This problem has recently been solved effectively using GIS and Remote Sensing technologies. During the last decade, a few attempts have been made to automate the route-planning process using GIS technology. A review of a number of papers suggests that the methodology is still at an exploratory stage (Saha et al., 2005)

A number of research have already been performed in pipeline route design using GIS which include optimal routing for pipeline selection of best route for expansion pipeline and gas/petrol pipeline route selection using high resolution remote sensing image. In this context, physical, environmental, political, social, economical and legal processes was considered and implemented for pipeline routing determination (Rylsky 2004, Saha vd 2005,

Delevar and Naghibi 2003, Yusof and Baban 2004, Glasgow vd. 2004, Berry 2000, Çevik and Topal 2003, Luettingear ve Clark 2005). Multiple factors were considered using GIS techniques for road, highway, forest roads and bike roads routing determination (Mackenzie and Walker 2004, Malpica ve Pedraza 2001). In literature, GIS based route determination for railway (Ashish and Dhingra 2005, Kov vd. 2005, Gipps vd. 2001), irrigation/drying channels (Yusof and Baban 2000, Smith 2006), power line (Cheng and Chang 2001) have already been implemented.

3. STUDY AREA

The study area is selected in Trabzon which is situated in the Black Sea Region of Turkey In this area, existing pipeline route is optimized. Source point is Macka County, Cayirlar Village (in the southern part) and target point is Bulak Village (in the northern part). Route length is approximately 38 km. and corridor area is approximately 43 km^2 (Figure 1).

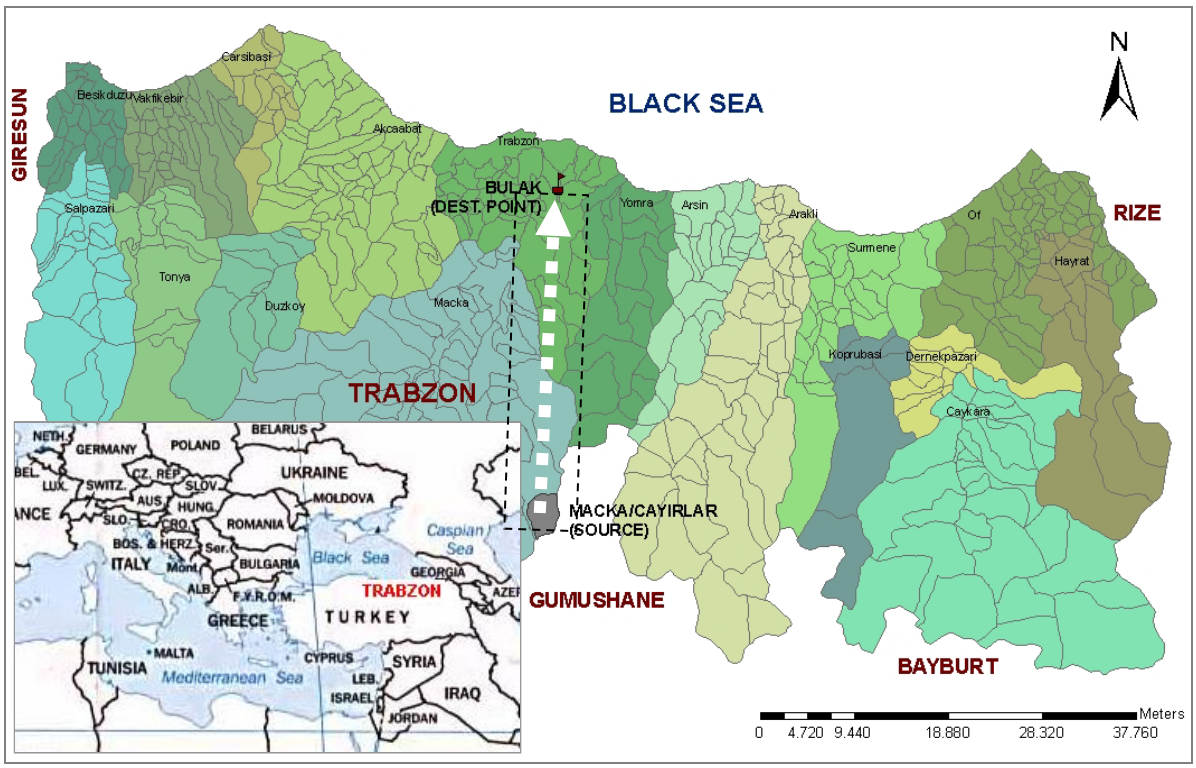

Figure1. Locations of the study areas on the maps of Trabzon Province and Turkey

4. DATA PROCESSING AND ANALYSIS

4.1. Data Collection

Maps, field work and remote sensing techniques are necessary for pipeline routing, pipeline design and construction. Topographic maps, geologic maps, and road maps (Table 1) were

used for this route. The least cost path analysis, using various data and GIS analysis, was intended to confirm the best pipeline route within this site.

Table 1. Data layers and characteristics

Data Layers	Entity Typse	Attributes	Data Sources	Scales
Slope	Line	Elevation	General Command of Mapping (GCM)	1/250.000 1/100.000
Geology	Poly	Lithology	General Directory of Mineral Research & Exploration	1/100.000
Land use – 1	Raster	Class	Landsat	1/100.000
Land use – 2	Vector	Land use	General Directory of Rural Affairs	1/100.000
Landslide	Poly	Type	General Directory of Mineral Research & Exploration, Landsat	1/100.000
Soil	Poly	Btg, Ed, Saks, At, Akks, As	General Directory of Rural Affairs	1/100.000
Stream	Line	Name, Flow	General Directory of Mineral Research & Exploration	1/100.000
Road	Line	Name, Type, Class	Landsat, GCM	1/100.000
Administrative Boundaries	Poly	Name, Population, City, District, Phone	MTA, Cadastre Offices, Field Survey	1/100.000
Tourism	Point	Type, Name	Topographical Maps, Ministry of Culture and Tourism, GCM	1/25.000 1/100.000

4.2. Data Process and Analysis

In this implementation, the best route is found for a new gas-pipeline. The steps to produce such a path are outlined below. Path is performed using ArcGIS 9.0 Spatial Analysis Module.

1- Create Source, Destination and Cost Datasets
2- Generate A Thematic Cost Map (Classify and Weighting)
3- Perform Cost Weighted Distance
4- Create Direction Datasets
5- Perform Shortest Path with Distance and Direction Datasets

Layers weights and rates used in this implementation are outlined bellow (Table 2).

Table 2. Weighting-rating scheme

Thematic Map	Weight	Rate
1. Landslide	**9**	
>400		∞
>300		9
>200		8
>100		7
<100		5
No Landslide		0
2. Landuse	**8**	
River Sediment		9

Agriculture		6
Fallow Land		5
Barren Land		4
Forest		4
Sparse Vegetation		1
3. Elevation	**6**	
>40		9
>30		7
>20		5
>10		3
<10		1
3. Geology	**3**	
Gama		8
Krü2, Krü1		6
Ev, Jk, Jl		5
Al, Pl		2

5. ROUTE DETERMINATION AND TESTING

There is not any constrained point in this route along Bulak Village (destination) and Cayirlar Village (source). The goal of the least cost path analysis was to compare the existing pipeline route with the route using raster based network analysis. The analysis was performed using 30-m. resolution cells (for raster layers).

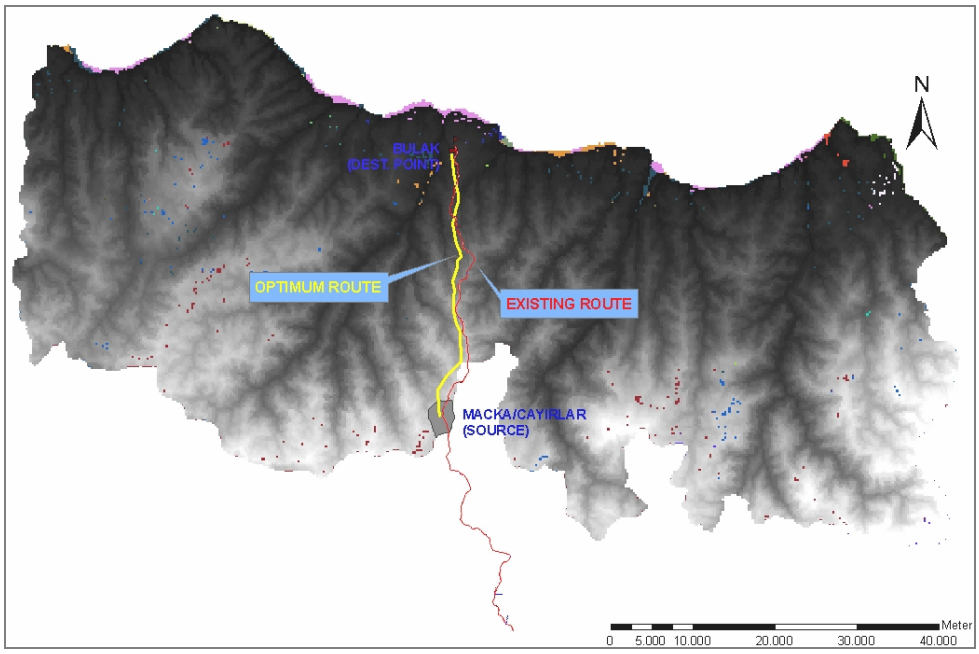

Figure 2. The comparison of optimum route and alternate route

5. CONCLUSION

The purpose of this study was to develop a tool to locate a suitable LES route between two points. The GIS approach using ground/underground parameters and raster network analysis provided to achieve this goal. Raster based map analysis procedures provide a wealth of capabilities for incorporating terrain information surrounding linear infrastructure.

The results of the least cost analysis for application are shown in Figure 2. Costs resulting from terrain, geology, land use, elevation and landslide were accumulated for these routes (traditional and GIS methods) along the cost surface. The existing pipeline path was 38 km. long and the least cost pathway was 36 km. long. Results indicate that the route which was designed applying GIS method is more environmentally effective and cheaper than traditional one. This showed a potential savings as much as 5-15% which can be obtained by automating the rote selection process. The described system of multi-criteria analysis has universal applicability. It can be used for route determination of any LES such as roads, irrigation-drying channels, power lines and railways.

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BIOGRAPHICAL NOTES

Volkan YILDIRIM graduated from the Department of Geodesy and Photogrammetry Engineering at Karadeniz Technical University (KTU) in 1999. He received his MScE degree with thesis entitled "Address Information System Design and Application: Trabzon City Case Study" in August 2003. He is studying on his PhD thesis. His research interests are geographical information systems and address information systems.

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