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Front Cover Photo: **Nord Stream AG, Zug, Switzerland**

Welding and sealing of Nord Stream pipes on board of the pipelay vessel Castoro Sei

Construction of the Nord Stream Pipeline continues on track. Over 1000 km of Line 1 have been laid in the Baltic Sea and pipe-laying works have already been completed at the landfalls for Line 2.
Gas deliveries from Line 1 will begin before the end of 2011, and Line 2 will be launched in 2012.
(see also page OG 2)

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In this issue: **Buyers' Guide** for the Petroleum Industry

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NABUCCO Pipeline Route Selection through Turkey

Comparison of a GIS-based Approach to a Traditional Route Selection Approach

*By V. YILDIRIM and T. YOMRALIOGLU**

Abstract

Pipelines are one of the most effective methods of transferring energy sources like petroleum and gas. In pipeline projects, decreasing the cost, reducing environmental issues and shortening the construction time are related to determining the right route at the beginning of the project. Route determination is usually carried out manually with the help of traditional methods. However, this technique is not effective in many situations because it does not evaluate the factors that affect the route as a whole. In fact, technique, economy, environmental and sociological issues should be examined as a whole in the route determination process. Evaluation of the factors affecting the route is possible with the analysis of many spatial datasets from the same system. Geographical Information Systems (GIS) have been shown to be an effective way for analyzing these types of intensive datasets. In this study, a suggestion related to the NABUCCO Natural Gas Transmission Pipeline project has been made using the Analytic Hierarchy Process (AHP), which is a technique using GIS and multi-criteria decision making. The effectiveness of this method was proven by comparing part of the determined Optimal Route with a length of 557 km with the Proposed Route, which has currently been planned.

1 Introduction

A pipeline is one of the most effective methods for transmitting energy sources like petroleum and gas [1–4]. Thus, it is the most preferred transmission method throughout the world. Pipelines are constructed over a long distance with a large budget. Decreasing the cost of pipeline projects, reducing the environmental impact and decreasing the construction time are related to determining the right route at the beginning of the project. Route determination is a complex process because many factors must be considered at the same time, and it is an important step for Natural Gas Transmission Pipeline (NGTP) projects [5, 6]. This process affects construction, maintenance, and repairs throughout the project [1, 7].

Traditional methods are used to determine routes for pipeline projects in Turkey. Traditional methods of optimal routing in pipelines are mainly based on expensive and protracted methods. These methods are not precise, and the role of all effective parameters in pipeline routings cannot be considered easily. Most technical, economical and environmental concerns are not accounted for in design paths [1, 2]. The main step in traditional methods of route determination is to place a sign on the topographic maps related to the line that symbolizes the shortest route between the source point and destination point and is applied to the land. Drifts in a particular corridor may occur because of barriers in the route. Barriers that are not identified in advance slow the project, cause sharp turns or cause some of the project to be removed and rerouted [2, 8]. Many streams, roads and railways are encountered and increase the construction cost, the construction time and the operation cost of the project [2].

Route determination requires spatial data from different organizations and state institutions, and it also needs carefully chosen, saved, queried and analyzed spatial data. Today, this type of analysis and a quick result are possible with the Geographical Information System (GIS) [9,10]. GIS is an effective engineering tool for systematically organizing factors affecting route determination. When these factors are identified based on the length of the project, a GIS should be used to evaluate these factors simultaneously [1, 11, 12]. Additionally the GIS based visualization technologies and cartographic abilities are generally adequate to determine the effective routes [3].

Route problems, including route selection, route planning, finding the optimal route, corridor analysis and side selection, can be solved using network analysis based on GIS. GIS technologies have significantly improved recently. As one of the most important current information technologies, it is used as an effective tool in network analysis [13].

Network analysis can be carried out on both vector-based data, such as roads, streams or pipelines, and raster-based data from non-defined space [10, 14]. Nevertheless, applications of network analysis for route determination of linear engineering structures must be carried out with raster-based data because they do not have a defined space. Route determination with raster-based data is advantageous because it is simple to perform cost calculation, design, and modeling and to obtain Remote Sensing (RS) data directly in raster format [15, 16].

2 Materials and Methods

2.1 GIS-Based routing procedure

GIS has many tools to analyze spatial networks [13]. The most important tool is related to the shortest or optimal route determination (Fig. 1). It has been proven that the cost of pipeline projects using GIS-based route determination decreased by ten to twenty percent [1].

Feldman et al. [17] improved a system by using a GIS and RS to determine the pipeline route. They applied it to a short part of the Hazar Petroleum Pipeline. They found a new route and compared it with the first route; then, they examined the efficiency of the model. They proved that the cost of the project would decrease by fourteen percent if the new route was applied, even though the new route was longer than the first.

Yildirim et al. [18] proposed a new model for route determination using the GIS technology and raster data models. They adapted this model to a user-friendly interface with GIS software. They carried out a route determination for a NGTP project with a length of 46 km on the interface. They proved that the new route was shorter than the first and that the cost of the project would have been decreased by twenty-three percent.

Callan [3] emphasizes that although the easiest and cheapest way to connect supply and source is obviously via a straight line, in reality, though it is necessary to consider a large number of other constraints before being able to define the optimum pipeline route. He proves that the most common practice today is to evaluate all these issues using GIS-based constraint maps. In these maps, the different colors represent different types of constraint, such as nature reserves or archaeological areas, land use planning areas and geohazards.

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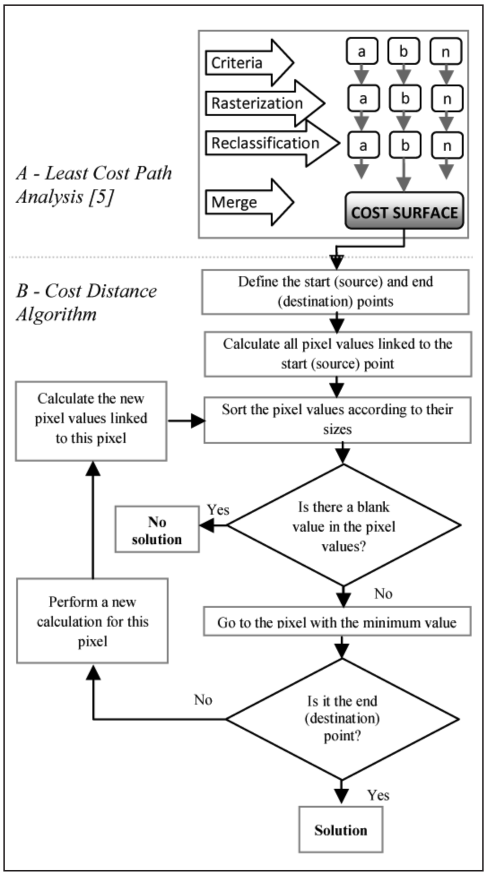

Fig. 1 **GIS-based routing procedure**

Fig. 2 **The Nabucco Natural Gas Transmission Line Project and approximate lengths**

2.2 Study area and Nabucco project

The Nabucco Natural Gas Transmission Line Project is a new natural gas pipeline that will begin at the eastern border of Turkey and will connect the Caspian Region and the Middle East via Turkey, Bulgaria, Romania, and Hungary with Austria and further with Central and Western Europe gas markets. The pipeline will be approximately 3300 km long, stretching from the Georgian/Turkish and Iranian/Turkish borders to Baumgarten in Austria (Fig. 2). Additional feeder pipelines are possible for Iraqi gas. Based on technical market studies, the pipeline has been designed to transport a maximum amount of 31 bcm/a [19]. The first aim of the project is to supply gas to the countries on the route, and then gas is to be transported to Western Europe according to the wishes of other countries in the following years.

2.3 Factors, weights, and data

Important points in the process of GIS-based route determination are identifying the factors that affect the route, calculating the degree to which the factors affect the route and obtaining spatial data related to these factors. The input data for the NGTP route determination are also used at different stages of the pipeline project, such as cost, operation, maintenance, and management. Many factors affect NGTP routes. Thus, obtaining spatial datasets and managing and analyzing them require sixty percent of the work capacity [9]. Information related to factors such as land cover, slope, geology, streams and roads that affect the NGTP route should be loaded into the system to obtain more accurate results.

2.3.1 Determination of weights (Analytic Hierarchy Process)

The Analytic Hierarchy Process (AHP) is a method that is widely applied in decision theory; it is a paradoxical measurement method that includes measurable or abstract criteria [17].

Normally, the relative value of two parameters is based on the preference of the decision maker. In this study, Environmental Impact Assessments (EIAs) were prepared and examined for pipeline routing, existing applications, and scientific researchers to compare factors and sub-factors. Moreover, information was obtained from interviews with masters in BOTAS (Petroleum Pipeline Corporation), which is responsible for the pipelines in Turkey, and conversations with masters or experienced people in different corporations. Furthermore, current NGTP construction works were examined, and the relative degree of importance of the factors was determined at the end of the study.

First, determining relationships between basic factors affecting the route of NGTP is important. The matrix of pair wise comparisons between layers were generated to determine which layers are affected and to what extent they are affected (Table 1). Weights for each layer in the NGTP route were calculated. Moreover, Consistency Ratios (CRs) related to the layers were calculated to determine the importance of these works.

The quality of the work is determined with the help of evaluation of obtained results in the AHP. Whether decisions support each other or whether they are meaningful can be determined. This work is carried out with CR in the AHP. Acceptable high point's value for CR is 0.10. If CR is higher than 0.10 then the decision maker has to control his comparisons again. When weights related to data layers in the NGTP route plan are examined (Tab. 1), factors such as land cover, slope, geology, soil and landslides affect the route more than the other factors. Sub-factor weights were calculated for each factor with the matrix of pair wise comparisons (Tab. 2).

Whether the weights provide true results is determined using spatial analysis, queries and cost evaluations in existing applications [18, 21]. Moreover, the optimal pipeline route determined using traditional method

Table 1 **The matrix of pair-wise comparisons to determine the weights of factors that affect NGTP routing [20]**

	A	B	C	D	E	F	G	H	I	K	Weights
A	1	1	2	3	4	7	8	5	6	9	0.256
B	1	1	1	2	3	6	7	4	5	8	0.205
C	1/2	1	1	1	2	5	6	3	4	7	0.156
D	1/3	1/2	1	1	1	4	5	2	3	6	0.116
E	1/4	1/3	1/2	1	1	3	4	1	2	5	0.084
F	1/7	1/6	1/5	1/4	1/3	1	1	1/2	1	2	0.033
G	1/8	1/7	1/6	1/5	1/4	1	1	1/3	1/2	1	0.025
H	1/5	1/4	1/3	1/2	1	2	3	1	1	4	0.061
I	1/6	1/5	1/4	1/3	1/2	1	2	1	1	3	0.044
K	1/9	1/8	1/7	1/6	1/5	1/2	1	1/4	1/3	1	0.020
CR: 0.0136 < 0.10											

A: Land Cover, B: Slope, C: Geology, D: Soil, E: Landslide, F: Stream, G: Road, H: Flora/Fauna, I: Protected Area, K: Recreation

Table 2 **Factor and Sub-Factor weights affecting the NGTP route [20]**

Factors / Sub-Factors	Weights	CR	Factors / Sub-Factors	Weights	CR
Land Cover	**0.263**	**0.0247**	**Slope**	**0.211**	**0.0108**
Forest	0.096		$<10^0$	0.031	
Cultiv. Areas (Seasonal Agriculture)	0.043		$10–20^0$	0.060	
Agricultural Areas	0.063		$20–30^0$	0.081	
Wetland (absolute barrier)	0.134	∞	$30–40^0$	0.124	
Rocky Areas	0.226		$40–50^0$	0.152	
Pasture Areas	0.028		$50–60^0$	0.185	
Settlement Areas (absolute barrier)	0.411	∞	$>60^0$	0.367	
Geology	**0.162**	**0.0443**	**Stream**	**0.040**	**0.0063**
Acid-Intermediate Intrusives	0.473		River	0.444	
Basic-Ultrabasic Rocks	0.288		Stream	0.053	
Metamorphic Rocks	0.149		Canal	0.262	
Volcanic Rocks	0.054		Brook	0.153	
Sedimentary Rocks	0.036		Creek	0.089	
Protected Area	**0.049**	**0.0290**	**Recreation**	**0.023**	**0.0167**
Level I	0.407		Upland	0.039	
Level II	0.129		Tourism Center	0.262	
Level III	0.079		Historical Monument	0.492	
Urban Protected Areas	0.052		Picnic Areas	0.069	
Historical Protected Areas	0.333		Promenade Areas	0.138	
Soil	**0.130**	**0.0278**	**Road**	**0.030**	**0.0238**
I. Class soils – Excellent Agriculture	0.269		Highway	0.486	
II. Class soils	0.251		Three Lane Road	0.222	
III. Class soils	0.193		Two Lane Road	0.121	
IV. Class soils	0.104		Stabilized Road (two lane)	0.090	
V. Class soils	0.081		Stabilized Road (one lane)	0.044	
VI. Class soils	0.045		Seasonal Road	0.037	
VII. Class soils	0.037		**Landslide**	**0.092**	**0.0334**
VIII. Class soils – Non Agriculture	0.020		Active Landsl. Areas (abs. barrier)	0.633	∞
Fault Line (absolute barrier)	∞		Potential Landslide Areas	0.260	
			Old Landslide Areas	0.106	

Table 3 **The data used in route determination of the NGTP Project**

Data	Data Type	Data Source	Date	Scale
Elevation	Line	General Command of Mapping	2008	1/100.000
Geology	Polygon	General Directorate of Mineral Research	2008	1/500.000
Fault	Line	General Directorate of Mineral Research	2008	1/500.000
River	Line	General Directorate of Mineral Research	2008	1/100.000
Road	Line	General Directorate of Highway	2008	1/100.000
Railway	Line	Turkish State Railways	2008	1/100.000
Administrative Boundary	Point	General Directorate of Rural Services	2008	1/100.000
Lake	Polygon	General Command of Mapping	2008	1/100.000
Forest	Polygon	General Command of Forestry	2008	1/100.000

with a raster-based model and weight values were tested with real data [18]. Results and statistical proofs showed that weight values determined with the method proposed in this work were in agreement with real land data.

2.3.2 Data

As for all GIS applications, the strength of the results is directly proportional to the quality of the data in the route determination studies. Because the problem of route determination requires location detection, it may be perceived as a spatial problem. Thus, every factor affecting routes corresponds to a set of spatial data in these types of problems.
The first process of the GIS-based route determination is to obtain the needed spatial data by considering factors that affect the route. In this process, the majority of the data are the spatial data that are used to study the route determination of the NGTP Project, which are shown in Table 3.

2.4 Nabucco pipeline routing

2.4.1 Weighted cost surface

The weighted cost surface is generated by using pixel-based arithmetic processes on raster data layers formed for each surface separately. Weights needed for each layer are shown in Table 2. The value of pixels on this cost surface describes the total transition cost that belongs to the area on the surface (Fig. 3).

Pw: $Pi \times Wi$

Pw: weighted layer
Pi: ith data layer
Wi: ith data layer weight

In this implementation, the pixel size was chosen to be 250 m based on the scale of the data.

2.4.2 Routing

The accumulated weighted cost surface is formed by identifying the starting point and size of the pixel of the route according to the working principles of the raster-based network analysis algorithm. Thus, surface cost values for each pixel are determined.
According to the working principles of the route determination algorithm, direction data is formed on this surface before determining the route. Direction data shows the stream direction from the starting point to the final point. The resulting route is formed according to that data depending on the cost values for the pixels.
Beginning with the starting point, and identifying the direction information and the accumulated values of the passages of the pixels, the final point is reached and the route is determined.
The Proposed Route (PR), starts in Kars City on the east side of Turkey and ends in Canakkale City on the west side of Turkey; is known as the Anatolian Passage and is 1558 km long (Fig. 4). Canakkale Bosphorus Passage of the route requires an offshore scheme, which is why it was not evaluated.
To demonstrate effectiveness of the route planning model developed in this study, the route must be compared with another current route, and the results must be analyzed. Thus, the PR between Ankara and Canakkale cities (603 km long) is the first part of Turkey Passage of the NGTP project and is currently ready to be constructed; it is included in the system by making minor modifications. By cutting the 557 km, section between Ankara and Canakkale in the route from the model, the two routes can be compared. In this study, the route found using GIS techniques is called the Optimal Route, and the route that was found by the interested institution is called the Proposed Route (Fig. 4).

3 Results

To demonstrate the effectiveness of the developed model, some analyses and queries have been conducted among Ankara, Ahiboz Village, and Canakkale, Degirmencik Village, where both PR and OR pass through (Tab. 4).

3.1 Fault line passages

According to the "Turkey Earthquake Region's Map" published by the Prime Ministry of Disaster and the Emergency Management Presidency, approximately 40% of the proposed NNGTP is located in the first degree earthquake region [22]. In addition, according to that report, it is clear that the PR crosses the Edincik fault line (30 km) and

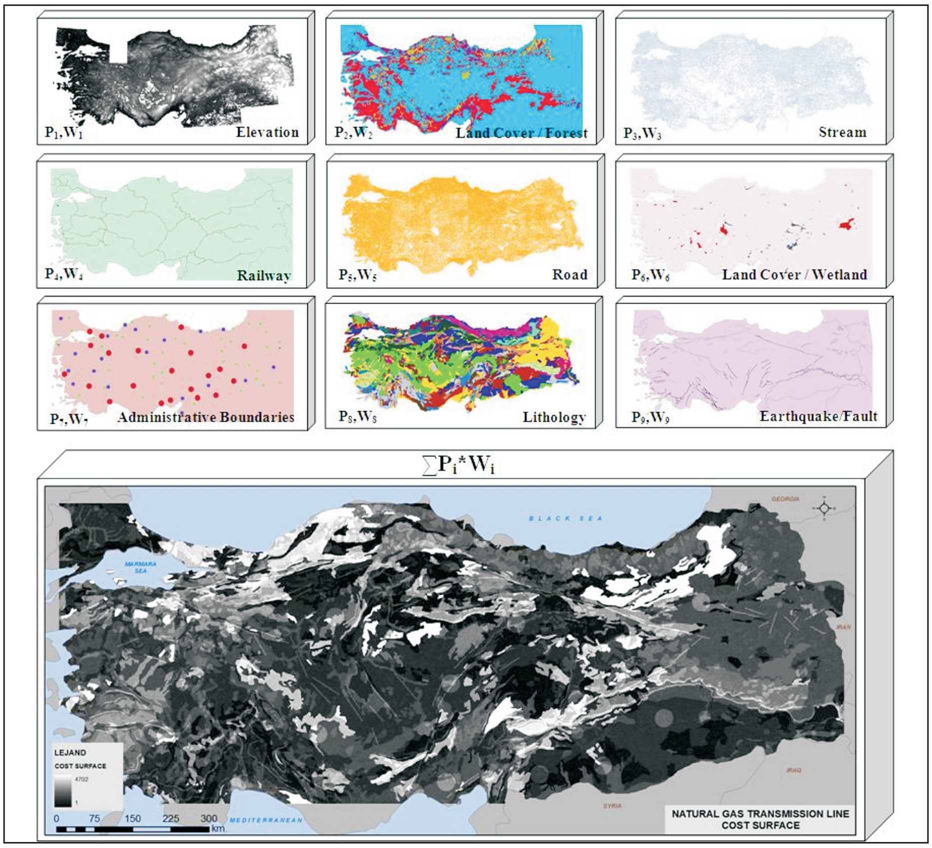

Fig. 3 Estimated weighted cost surface for the NGTP route

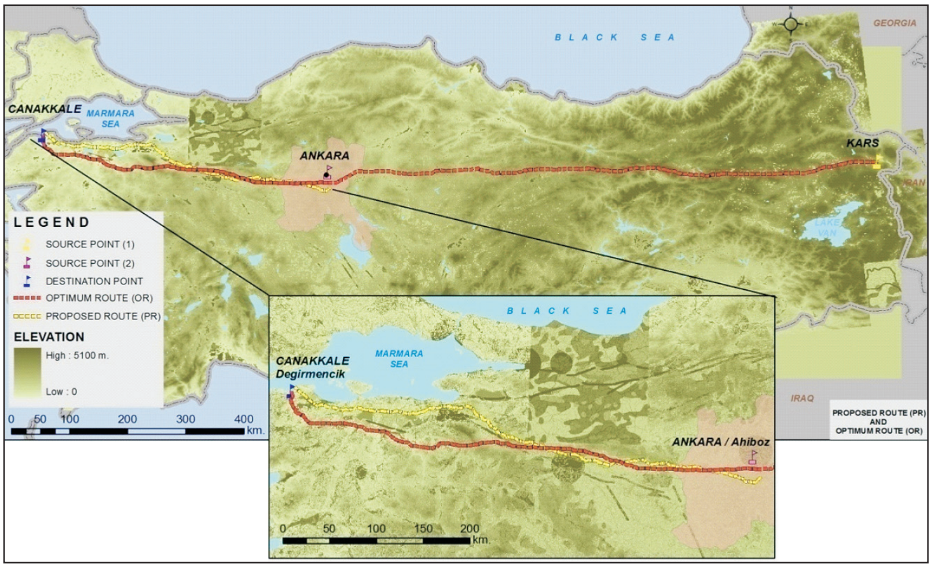

Fig. 4 Proposed Route (PR) and Optimal Route (OR)

Table 4 **Evaluation of the routes**

Examination Criteria	Proposed Road (PR)	Optimal Route (OR)	Difference (PR–OR)
Pipeline Length	603 km	557 km	46 km
Study Area (18 m. either line of side)	2170 hectares	2006 hectares	164 hectares
Road Passages	169	151	18
Stream Passages	111	69	42
Railway Passages	3	3	0
Forest Passages	134 km	96 km	38 km
Fault Line Passages	7	0	7
Hard Rocky Areas Passages	2 km	5 km	–3 km
Average Slope (%)	2,5	4,0	–1,5

Saroz-Gazikoy fault line (45 km in the sea and 45 km on land, which is 90 km total). In this route determination model, fault line passages are assessed as absolute barrier, and passages over these lines are prohibited within certain proximity. It is clear that the OR does not cut the fault line; on the contrary, the PR cuts the present fault line in seven different parts (Fig. 5).

3.2 Road and stream passages

The OR has a total of 151 road passages: 115 are seasonal roads, 1 is a stabilized road, 25 are two-lane roads and 10 are three-lane roads. On the other hand, the PR has 169 road passages: 114 are seasonal roads, 3 are stabilized roads, 34 are two-lane roads and 18 are three-lane roads (Fig. 6). Also, the OR crosses 69 streams: 67 are brooks, 1 is a river and 1 is a stream. In addition, the PR crosses 111 streams: 102 are brooks, 2 are rivers and 7 are streams.

3.3 The analysis of lithology

Lithological unit differences very much depend on the working area. In this study, rocks are placed in four categories. The OR crosses soft areas over 1040 pixels, which is approximately 240 km The OR crosses 19 pixels of hard rock, which is approximately 5 km The PR crosses 1509 pixels of soft areas, which is approximately 302 km The PR crosses 6 pixels of hard rock, which is approximately 2 km.

3.4 The analysis of slope

For the OR, the slope is at least 1%, a maximum of 25% and an average of 4%. While the minimum height of the pipeline is 50 m, the height value can reach 1800 m in some circumstances. The average height value of the pipeline is 760 m. For the PR, the slope is at least 1%, a maximum of 21% and an average of 2,5%. While the minimum height of the pipeline is 14 m, the height can reach 1400 m in some circumstances. The average height of the pipeline is 620 m.

According to the analysis results, it is realized that the PR passes over approximately 140 m higher than the OR does and the average slope of the PR is 1,5% higher than OR's average slope. These height and slope differences may have negative effects on pipeline construction cost. These criteria should carefully be examined with all other criteria used in route selection method and thus total cost should be re-calculated to have a better estimation of costs. However, it is obvious that as the route length, stream passages, road passages, forest passages and fault line passages, most important factors effecting construction costs, are considered, the slope and height differences would not make much difference to the construction cost.

4 Conclusions

The NGTP route identification is complex and requires the analysis of an enormously

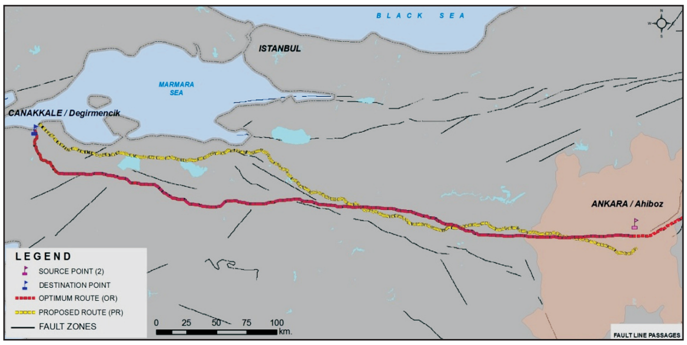

Fig. 5 PR and OR fault line passages

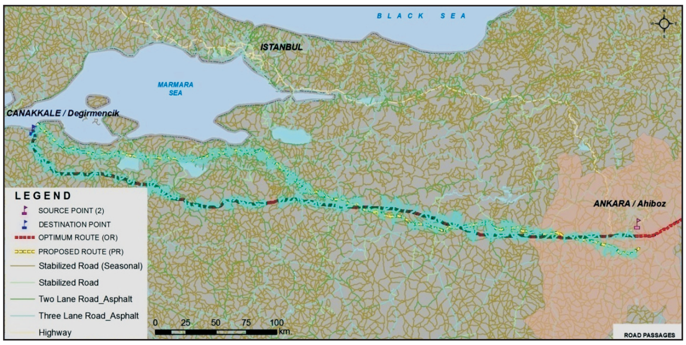

Fig. 6 PR and OR road passages

large quantity of data and many parameters depending on the length of the project. A GIS is one of the tools to perform this analysis effectively. A GIS provides a large number of various analytical functions that are capable of replacing manual and traditional methods of natural gas pipeline route planning. It is a powerful tool to integrate thematic layers in an automated environment to compute the shortest possible route with associated costs, which eventually reduces the cost and time of project execution and thus the operating expenses. The integration of GIS and the AHP provides a baseline for complex decision making in which the variant nature of criteria and stakeholders can be accounted for successfully.

Raster-based data models and raster-based network analysis are necessary to determine the surface resistance and to model the NGTP route determination appropriately. One of the basic steps of route determination is to determine the factors that affect the route and their weights. In this stage, AHP presents effective solutions.

The accuracy of the results for this model is directly proportional to the quality of the information used. Especially in Turkey spatial data should be generalized with the use of a satellite image of appropriate resolution. In this study a cost surfaces map that is 250 × 250 m pixels in size was generated based on available data and the data quality for Turkey. For any NGTP project, the most appropriate corridor of 250 m width can be determined easily with this map.

This model can easily be adapted to determine the necessary factors and calculate the weights for linear engineering structures, such as pipelines, waterlines, roads, channels, railways, and energy transfer lines.

This model is designed for NABUCCO's Turkey crossing, but the model can be applied universally. In this model surface passage criteria factor weight can be changed and alternative routes can be created. In addition the same factor weights can be used on the same surface characteristics in developed and developing countries.

References

[1] EBRAHIMIPOOR, A., R.; ALIMOHAMADI, A.; ALESHEIKH, A., A.; AGHIGHI, H.; Routing of Water Pipeline Using GIS and Genetic Algorithm. Journal of Applied Sciences 9 (23), 2009, S. 4137–4145.

[2] IQBAL, M.; SATAR, F.; Planning a Least Cost Gas Pipeline Route A GIS&SDSS Integration Approach. First International Conference on Advances in Space Technologies, Islamabad, Pakistan, 2006, S.126–130.

[3] CALLAN, T.; Pipeline Technology Today and Tomorrow. OIL GAS European Magazine 34 (3), 2008, S. 110–116.

[4] HENSEL, R.; OELHAF, R.; Optimization of Pipeline Operation Using Integrated Information Management. OIL GAS European Magazine 30 (1), 2004, S. 14–19.

[5] DEGIRMENCI, O.; From the Caspian Sea Region to the European Market – Feasibility of Crude Oil and Natural Gas Transport Via Long-Distance Pipelines or Routes Through the Caspian Sea and Their Further Continuation Links Westward. OIL GAS European Magazine 27 (3), 2001, S. 7–13.

[6] CIERNIAK, S.; GROENNER, J., HOEHNER, D.; Combining Economical and Environmental Aspects in a Long-Distance Gas Transmission System. OIL GAS European Magazine 35 (4), 2009, S. 196–202.

[7] YANG, S.; JIN, H.; YU, S.; CHEN, Y.; HAO, J.; ZHAI, Z.; Environmental hazards and contingency plans along the proposed Chinese–Russian Oil Pipeline route, NE China. Cold Regions Science and Technology 64 (3), 2010, S. 271–278.

[8] CHAUDHRI, J.; Medgaz IM Approach Predicts Cost Savings: Oil & Gas Journal 104 (32), 2006, S. 57–58.

[9] YOMRALIOGLU, T.; Cografi Bilgi Sistemleri Temel Kavramlar ve Uygulamalar. Birinci Baski, Secil Ofset, 2000, Istanbul, Turkey.

[10] PRIMAHARDHIKA, F.; Determination of the Transjakarta Busway Gas Pipeline Using Geographic Information System and Multicriteria Decision Making. Master Thesis, Bogor Agricultural Univ., Science in Information Technology for Natural Resource Management, 2007, Indonesia.

[11] LUETTINGER, J.; CLARK, T.; Geographic Information System-Based Pipeline Route Selection Process. Journal of Water Resources Planning and Management 131 (3), 2005, S. 193–200.

[12] CHAND, A.; GLOVEN, M.; Using GIS to Support New Pipeline Construction and Material Procurement. Pipeline&Gas Journal January Issue, 2009, S. 40–49.

[13] LAEFER, F., D.; PRADHAN, R., A.; Evacuation Route Selection Based on Tree-Based Hazards Using Light Detection and Ranging and GIS. Journal of Transportation Engineering, 132 (4), 2006, S. 312–320.

[14] SAHA, A., K.; ARORA, M., K.; GUPTA, R., P.; VIRDI, M., L.; CSAPLOVICS, E.; GIS-Based Route Planning in Landslide-Prone Areas. International Journal of Geographical Information Science 19 (10), 2005, S. 1149–1175.

[15] GUTIERREZ, Z., G.; RUBIO, O., A.; Quantitive Assessment for Selecting the Route for a Gas Pipeline in Yucatan, Mexico. Human and Ecological Risk Assessment 10 (2), 2004, S. 451–460.

[16] RYLSKY, I., A.; Optimization of Pipeline Routes Using GIS-Technologies. Geografiya 5 (4), 2004, S. 34–40.

[17] FELDMAN, S., C.; PELLETIER, R., E.; WALSER, E.; SMOOT, J., C.; A Prototype For Pipeline Routing Using Remotely-Sensed Data and Geographic Information System Analysis. Remote Sensing of Environment 53 (2), 1995, S. 123–131.

[18] YILDIRIM, V.; NISANCI, R.; YOMRALIOGLU, T.; UZUN, B.; Raster-Based GIS Data Guide Economic Pipeline Construction, Oil & Gas Journal 106 (13), 2008, S. 62–68.

[19] PICKL, M.; WIRL, F.; Enhancing the EU's Energy Supply Security– An Evaluation of the Nabucco Project and an Introduction to its Open Season Capacity Allocation Process. Zeitschrift für Energiewirtschaft 34, 2010, S. 153–161.

20] YILDIRIM, V.; Dogalgaz Iletim Hatlarinin Belirlenmesi Icin Cografi Bilgi Sistemleri Ile Raster Tabanli Dinamik Bir Modelin Gelistirilmesi. PhD Thesis, KTU Fen Bilimleri Enstitusu, 2009, Trabzon, Turkey.

[21] YILDIRIM, V.; YOMRALIOGLU, T.; GIS Based Pipeline Route Selection by ArcGIS. ESRI Users Group Conference, 2007, California, USA.

[22] ANONYMOUS; Nabucco Dogal Gaz Boru Hatti Projesi Turkiye Bolumu Cevresel Etki Degerlendirmesi Basvuru Dosyasi; www2.cedgm.gov.tr/cedsureci/ced_basvuru_dosyasi/699_ptd.pdf, Ankara 2010.

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