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Optimum Route election for Oil and Ga Transmission Lines Using Remote Sensing and GIS Integration

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Abstract

One of the most important developmental procedures for the implementation of oil and gas transmission projects is through pipelines. Route selection is a crucial step in the planning of transmission lines. In this regard, to choose applicable and optimal route is likely to be complicated. Many factors need to be taken into consideration hence this is a very important stage in the transmission lines project. Using remote sensing (RS) and geographic information systems (GIS), new valves for routing will be unlocked and the costs of inaccuracies and inappropriate plans will be significantly reduced. The first modeling stage for planning and routing is defining the factors that determine the route of transmission of oil pipelines. There are diverse effective factors in determining the route to the transmission pipeline projects. Also, the proportion of the impact of each of these factors must be identified. The weight of the factors, is determined by various methods. These factors include roads, rivers, landslides, faults, gradients of land, soil science, land use, geology, recreational areas and protected areas. Finally, the cost of transfer plan for each pixel is designed using the multi-criteria decision making model and the AHP method in the GIS environment. Using this map, a cumulative cost map for the origin and destination is designed.

***Keywords**:* Remote Sensing RS; GIS Geographic Information System; Routing Transmission Lines

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1. Introduction

Oil and gas are considered to be the most important sources of non-degradable energy in the world. Today it is admitted that oil and gas pipelines around the world are considered to be the key to energy security, and hydrocarbon production is economic while it transform the blessing of black gold into yellow gold and circulate the living, livelihood, economy and development (Shayan, 2008).

The use of advanced techniques, such as GIS and RS, are tools for the scientific development and acceleration of the traditional method. One of the characteristics of the optimal route is its short length. But this is not the only priority to choose the optimal route, and there must be a variety of factors and commitment to design the route. Investigating spatial relationships among different factors such as: being away from urban areas, crossing the areas with proper slopes, observing the existing facilities (pipe, road, cable, etc.), less intersection with road and rail, the least environmental damage, paying attention to the expense of land acquisition and many other factors, has made the optimal path design more complex and doing so manually and based on the expertise of the undergraduate will not result in a favorable outcome. Determining the optimal route for the oil and gas pipeline requires the availability of spatial data from various organizations and government inputs that must be carefully selected, stored and analyzed.

In designing such routes, in addition to observing the technical and economic points, attention should be paid to the environmental characteristics that some region has in particular, so that the construction of the pipe network will minimize the damage to the environment (Ahmadi, 2005). In the last century, the theory of cross-correlation phenomena has gained attention of many thinkers with a systemic attitude. Based on this view, each system is formed as a network of cross-links, in which all of its phenomena and events interact with each other, and so each work must be organized in a way that its members are assigned to a sample under a systematic connection and act as a member of one (Taghdisi, 2006).

Since the network of oil and gas pipelines extends over the place, it requires the system information that possesses the ability to process spatial data for modeling; the use of the spatial information system enables the gathering, storage, analysis and retrieval of reference location data (Delavar and Moghadam, 2005).

1.1 Importance and Necessity of Choosing the Optimal Route of Transmission Lines

Designing the optimal route for the transmission of pipelines is an important matter in the key industries of the country, which is constantly engaging with relevant organizations. The implementation of a pipeline project is costly, and wrong designs, in addition to imposing considerable material and moral damage, lead to the loss of national resources. Therefore, it is necessary to find a scientific method, low cost and high accuracy in this regard.

Undoubtedly, the scientific discussion on the application of new technologies in the design of pipelines without its results can be a good start for the use of GIS, RS. Generally, the use of remote sensing and GIS are a part of the new technology, and their application in designing the pipelines' route (according to the studies) is one of the few issues that have been addressed. On the other hand, the use of satellite images and aerial imagery to design the optimal pipeline transport route will increase the accuracy and speed of this operation.

GIS, RS "Layers" have created an impressive transformation in many applied fields. They allow separate processing and analysis of spatial data and provide tools for analyzing and modeling inter-layer interactions. Investigating several effective factors on choosing the optimal route as simultaneously topography of the area, observance of environmental principles, distance from urban areas, crossing the areas with a suitable slope, maintaining the existing facilities (pipe, road, cable, etc.), less intersection with road and rail, the least harmful effects of the environment, attention to the cost of land ownership and many other factors, based on the information of Raster, which, in very few studies conducted in this field, explores a specific factor in the design of the optimal route (Khani, 2017).

2. Literature Review

The route design, including roads, railways, oil and gas lines, water lines, telecommunication cables, etc. using RS technology and GIS has been taken into consideration for more than two decades and in the field of optimal pipeline routing through GIS. There are various activities around the world, but inside the country, doing so is in the early stages. The routing process from the past up to now involves the use of techniques and methods that can over time improve existing deficiencies than before. Since recognizing past methods can be effective in accessing new methods, taking the set of technical or environmental characteristics into account and using remote sensing data, the Tengiz field oil pipeline route in Kazakhstan to the Black Sea coast designed in this way. The main goal of the present study is to automatically design a railway track through GIS while respecting environmental principles in order to reduce the negative environmental impacts caused by the construction of the route (Feldman, 1995).

In a study entitled "The pattern for pipeline routing using remote sensing and analysis", GIS was located on the part of the pipeline route of the oil pipeline from the Tengiz oilfield in Kazakhstan from the Caspian Sea to Nyurisk in Russia, with a 45-km length. The results of this research showed that although the route of the station is about 9 km from the direct route, the cost of the determined route decreases by 14% compared to the direct route. Reducing the cost of the designated route is due to less traffic than urban and industrial areas (Nonis et al., 2007).

In their research, they introduced a variety of factors that should be considered for India's transmission line routing. They developed the GIS in order to provide a variety of factors and automatic routing of the transmission line. The major problem with the system was the weakness of the structured methodology derived from various factors affecting routing. They developed a methodology based on the AHP model to overcome this problem. The methodology of GIS and AHP was tested in a study area in India (Chebouba et.al., 2007).

The ant colony algorithm was proposed to optimize natural gas transmission lines. This method is compared to the dynamic programming method. The results showed that optimization method using ant colony algorithm is a suitable method. The optimum size of the pipe was determined for the natural gas distribution network using the genetic algorithm. This method saved up to 1.2% of the report (Mohajeri, et al., 2012).

In an article entitled "Choosing the optimal route for gas and oil pipelines using RS, GIS in Uganda," based on the GIS methodology, to identify the optimal route of the oil and gas transmission line using the Multi Criteria Evaluation (MCE) and analysis of the shortest route. This method was conducted with the aim of evaluating different levels of cost for weighting and the constraints that determine the optimal transmission line path. Four environmental criteria, structures, security and combination were evaluated. All target options were at 12 km of the target. In this research, the optimal route of the structural criteria (205.22 km) was used as the base line for comparison with other optimal selected routes(khani,2017)

In a study conducted by the University of Tehran entitled "Optimal Routing of Oil and Gas Pipelines to Spread Offsets (GIS)" on a part of the Ahwaz-Maroon Transmission Pipeline Route, It was concluded that the proposed route is about 29% lower than the track constructed, considering the engineering and environmental conditions (Salehi and Karimi, 2007).

In a study entitled Environmental Impact Assessment (EIA) of the Hamadan gas transmission line to Bijar, emphasizing on the use of RS and GIS, two methods have been used to analyze the environmental impacts of transmission lines in Leopold's inventory checklist. In this study, they used GIS and RS to study the current status of the environment, environmental routing options, and provide a detailed map of the land use of the gas transmission route. The results of their study showed that despite the occurrence of environmental damage caused by excavation, embankment and explosion operations that will be carried out in certain areas, the project, especially in the exploitation phase, has high socio-economic benefits of local, regional and national benefits. In other words, the construction and operation of this project has been fully consistent with the goals of sustainable development at three levels (Naghibi, 2002; Salehi and Karimi, 2007).

3. Materials and Methods

3.1 Application of RS and GIS in Oil and Gas Lines in Routing and Pipe Studies

In routing the gas and oil pipelines, conventional methods are considered to be more economical and technical, and usually the costs or environmental damage that may occur on the land after construction on sensitive ecosystems around the road are not considered. The best way to reduce economic and ecological damage is to consider environmental criteria in the zero phase of initial studies or routing, and to avoid passing through ecologically sensitive areas. Of course, the interference of environmental characteristics in addition to the economic and technical characteristics of the route routing of oil and gas in conventional ways makes the process very complicated and difficult. GIS technology makes it possible to integrate a large amount of information and make it easier to understand (Taghdisi, 2006). Therefore, the routing of oil and gas pipelines should take economical, technical, social and environmental considerations into account, and always considered the horizons of the HSE in clarifying the road.

Firstly, characteristics affecting the routing of oil and gas pipelines are identified. These characteristics can include slope, geological characteristics, soil characteristics, land cover, rivers, etc. Many of this information are from land use maps, soil, fault, and many others can be collected using satellite imagery (Feldman, 1995). Then, the images are subject to necessary corrections and reference ground, and if required in some cases, the composition or classification is performed, also authentic and existing maps are analogically digitized, in the next step using the comparative method of two by two, or based on the logic of the commentary, based on the views of environmentalists and oil experts, the existing layers weighed and then assembled. Finally, based on the routing algorithms in the relevant software, analyzing and routing with the least cost, shortest distance, minimum environmental damage and the highest safety against natural disasters, and other targets are suggested. In GIS, shortest path algorithms are used in vector and network environments. This algorithm is divided into two groups of shortest single-source algorithms and shortest path algorithms to all pairs. Single-source path algorithms can be used for Dixtra algorithms and Bellman Ford algorithms, and the shortest path to all pairs is the Floyd-Marshall and Johnson algorithms (Safarpour, 2001). AHP can be used to support management decisions. The results of the use of AHP show that the routes designed in an environmentally-friendly and HSE automation are far better than manually designed routes, therefore, it is suggested that in new projects for routing oil and gas pipes use GIS technologies, RS (remote sensing) and reviews of environmentalists to reduce environmental damage and increase accuracy and speed (Beheshti et al., 2011).

3.2 Advanced Routing using Remote Sensing (RS) and Geographic Information Systems (GIS)

In general, a geographic information system is used by remote sensing to collect, store and analyze the data that their geographic location is an essential feature. In other words, these systems are used for collecting and analyzing all information that in a way to relate geographical location.

In the first step, information is extracted for the preparation of large scale maps and aerial or satellite images. In the next step, the data is collected in such a way that they are prepared to enter the geographic information system. Using the functions of storage and the retrieval, the extracted information is processed and formed in the form of various information layers in the GIS. The appropriate layers are weighed, then using weights, overlaying of the layers is obtained that optimal path is obtained over the superimposed layer.

3.3 Raster Routing

The routing methods in the Raster model are similar to those used in the modeling algorithms. However, the directional modes in the restrict networks are not simply a vector network, but it is possible. In order to find the path with the lowest cost, you must first move on to a cumulative cost level, which represents the cost of resistance to the passage from one cell to another cell cumulatively. To move on the surface of the cost, you need to combine different quantities of cells together. But this is a bit complicated, by performing algebraic operations in a GIS network, computing itself is easier (Delavar and Moghadam, 2005; Rezayee, 2008; Shafee, 2010; Safarpour, 2001). GIS software for the calculation of the shortest route, obtains the level of cost to calculate the cost of moving from the source to the destination first by function, and give each cell a cumulative amount. Thereafter, the opposite is done, from the destination to the source, in order to find the least expensive route on the cost level. Slope values can be considered as directions. Moving to neighboring cells that have the same slope is allowed, but if they are slanted in the opposite direction the motion is prevented (Delavar and Moghadam, 2005; Rezayee, 2008; Shafee, 2010; Safarpour, 2001). The process of determining the optimal path on the grid surface is:

Create Cumulative Cost Level

To produce this level, you need a surface called the surface of the weight (cost or friction) and one or more points as the source or starting points. The level of weight or friction, the cost of moving from one cell to another cell based on distance, time, cost and so on.

In this way, the centers of all pixels are connected through the edges so that it is possible to move in adjacent eight pixels. Each edge has a weight or a motion-resistance value that this resistance or charge is extracted from the level of cost or friction corresponding to that edge. Of course, the direction of the move is also very important. If we move in the four main directions, the cost of the movement cost from one cell plus the cost of moving the other cell in that area and if the diameter is moving, the cost of movement is calculated from equation (Fig. 1 and 2) and, in general, the cost of moving is calculated by the relationship 2.

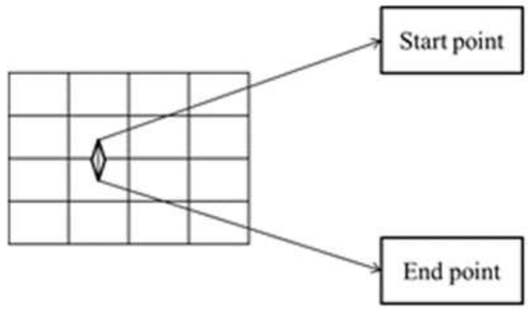

Figure 1. Move in four main directions

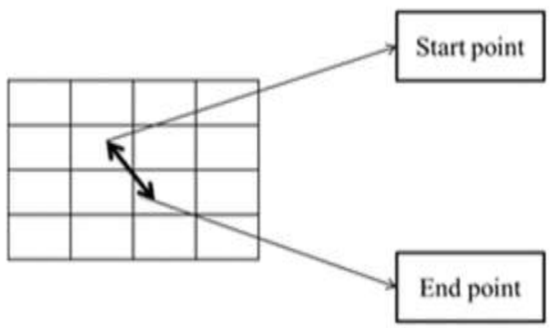

Figure 2. Diameter movement

Accum-cost2= cost1+√2* cost2
Cumulative cost of cell 2 is determined by the following formula.
Accum-cost2= cost1+√2* cost2 (1)

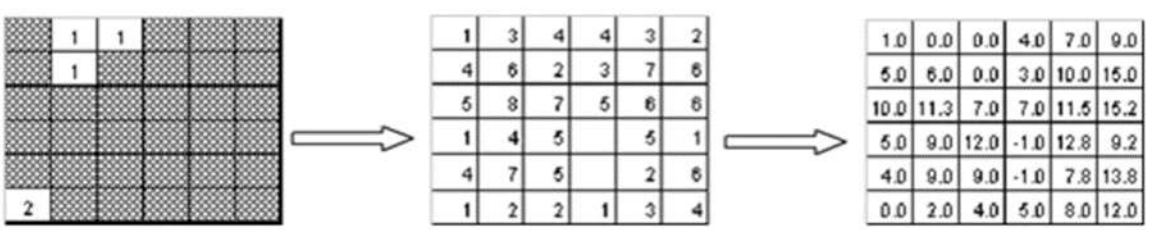

Figure 3. Costing the surface

The general formula for calculating cumulative cost using the function COST;

accum – cost ij=accum_cost ((i-α)(j-β)+√α2+β2* cost ij (2)

accum – costij, is the Cumulative cost of movement from source to cell ij. α ,β values show the direction to move.

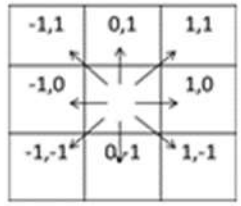

Figure 4. Eight-Movement Directions and Values of α, β

Creating a cumulative cost level using the COST function is in fact the attempt to determine the cell at the lowest cost, this is a repetitive process, aiming at valuing the surface cells based on the cost of movement from the starting point. This will continue until all cells are expended (Figure 5).

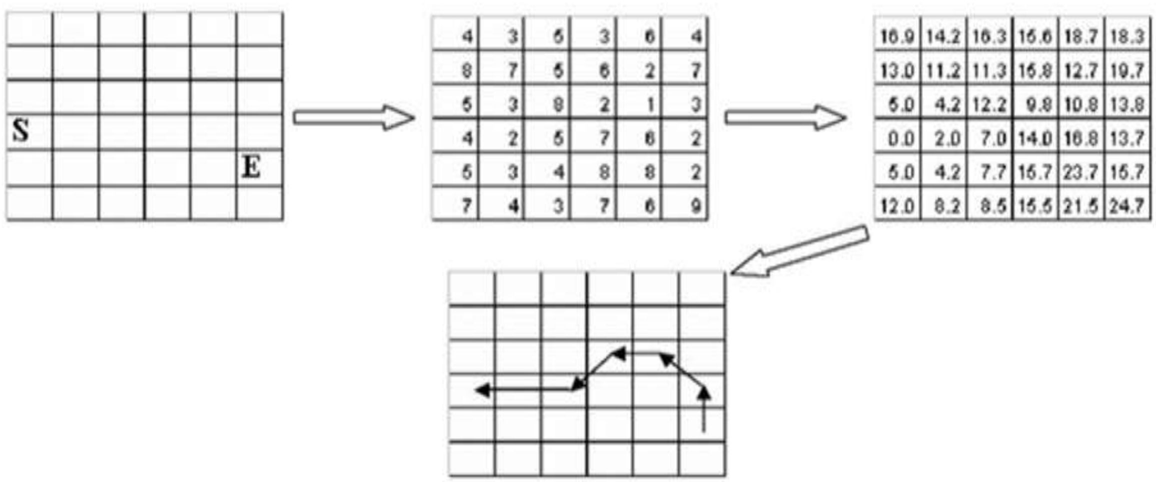

Figure 5. Route Determination Process in Raster Model

3.4 Natural Gas Pipeline Routing using Modeling

The study results demonstrated the capability of the GIS model of the Rester-based to study the routing of the transfer pipeline. In order to qualify and carry out the project, in the first phase, the data potential was tested in relation to the impact of factors on the routing of the natural gas transmission pipeline. Existing issues are particularly relevant to the collection of required spatial data based on the size of the study area. The size of the pixels is 100 meters based on the data scale. Particularly in this type of study of large-scale projects, Raster-based routing analysis is often considered as a corridor, not as a pixel-sized line. Routing using 20 to 30 meters wide by one pixel is known as a corridor. The pipeline construction pipelines, which have a width of 20 to 30 meters, can be selected for routing.

3.5 Generate Cost-Level Mapping

After the layers of information were generated, the map of the level of the cost of the natural gas pipeline through ARCGIS10.2 software is generated from the ESRI suite of software packages and the Spatial Analysis extension of this software. Determining the natural gas pipeline route can be done using the generated cost map. After the layers of information were generated, the map of the level of the cost of the natural gas pipeline through ARCGIS10.2 software is generated from the ESRI suite of software packages and the Spatial Analysis extension of this software. Determining the natural gas pipeline route can be done using the generated cost map. After the cost-level map is prepared, the structure of the pipeline route is constructed and is further affected by sensitive data in a corridor with a width of 250 meters. The cost-weighted surface area was generated separately using the base pixel computation process in the layered information, layered for each surface.

The required weights for each of the layers are shown in Table 1. The values of each pixel at this level describe the total amount of transfer cost per level of the surface.

$$Pw: Pi*Wi \quad (1)$$

Layer weight: Pw
Information layer: Pi
(i)th Information layer weight: Wi

Table 1. Information layers related to the effective constraints on the routing of the oil and gas pipelines

Layer constraints	Surface coating	Height	Geology	soil	River	Road	Flora and Fauna	Fault Line	Protected areas	borders	Recreational centers	railways	Ownership
NGTL length	Specify at runtime (feasibility)												
Corridors width	Specify at the feasibility stage (20-30 meters)												
Crossing agricultural areas	X			X									
Crossing the forest areas	X												
Crossing the guards	X												
Crossing the faults	X												
Crossing residential areas	X									X			
Crossing out areas with low cost of expropriation													X
Crossing areas with active landslides													
Crossing areas with fixed landslides	X		X										
Crossing areas with potential landslide	X	X	X		X	X							
Crossing the fault line			X										
Crossing the river	X				X								
Crossing the railroad road	X					X						X	
Crossing the steep slopes		X											
Crossing inappropriate lithologies			X										
Crossing the existing screws	X					X						X	X
Crossing areas with mineral potential													
Crossing the ancient and historical regions		X									X		
Crossing recreational areas											X		
Crossing Protected Natural Areas									X	X			
Crossing Protected Areas							X		X				
Crossing the water resources	X												
Crossing the Flora and Fauna							X						

After creating a cumulative cost level, the basis of this step is to determine the route to all points on the study surface. The routing functions perform a guided search step by step from the destination point to the source using a specific decision rule, and it repeats until it is needed. The output of this process is to create one or more paths from the starting point. At this point, the decision rule is to move to less valued points based on a search function, and the process from a cell that shows the position of the destination on the surface at a cumulative cost, starts with the neighboring cells with the lowest cost and the process is done until the reference point is reached.

4. Conclusion

The various parameters that exist in the design of the pipeline route are practically independent and interactive. Simultaneously, considering these parameters together can result in a better response to the independent parameters. The use of RS and GIS in data processing and the construction of a reference ground database and conducting various analyzes on it will allow the interference of all the effective parameters in determining the pipelines' route. Moreover, since GIS operates based on real data, or in other words on geo-referenced maps, it is possible to achieve realistic results and allow simulation and flight to be made on the study area. This can also provide a comprehensive vision of the region to the designer before designing the route and implementation of the project.

The use of geographic information and remote sensing in the design of the pipeline through GPS and remote sensing system (RS) can be updated continuously and steadily. GIS can also be used to store and analyze information or evaluate different applications, while many of these analyzes are not possible without the use of RS and GIS. Some of these applications can be summarized as follows:

Collecting, analyzing and processing information obtained from different methods and analyzing and overlaying different information layers for information and appropriate design vision.

Discovering water resources and studying surface waters in the route and identifying incidental points along the route, optimal design of distribution networks and determining the optimal route paths and production of location maps, selecting appropriate and optimal locations for pipeline projects, pressure boost stations, valves Cutting lines, roads and paths, expansion and development of residential buildings, and so on.

The further processing of route cost information using various information and geological processes for multiple evaluations also explores the identification of spatial interaction between the data set during the research and design period, such as understanding geochemical and geophysical characteristics of the mark, evaluating the resulting marks from satellite imagery in relation to lithology and vegetation.

Meanwhile, managing systems and resources in the pipelines and improving the quality of design and transfer, helping to reduce the design time and taking into account the large amount of obtained information, as well as making convenient changes to various events and situations in the design is focused.

Preparing slope maps, slope directions, profiles and calculating volumes, areas and lengths, and assessing the environmental impacts of the project, are the requirements of the project's applications.

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