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Optimal Oil Pipeline Route Selection using GIS:Community Participation in Weight derivation and Disaster Mitigation

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Abstract. This paper uses the Geographical Information Systems (GIS) technique to generate an optimal oil pipeline route in Malaysia's oil rich Baram Field. The project aims to ensure the generated route has the highest utility to the public, in addition to minimizing harmful impacts to people and the natural environment. Inputs from pipeline host communities where the pipelines will pass were seriously considered when determining the relative preferences of the various factors affecting the route (Weightings). This approach significantly increases the reliability and acceptability of the generated route. ESRI's ArcGIS spatial analyst tool was deployed for data analysis and interpretation. Consequently, a more systematic, effective, and reliable pipeline routing process was developed.

Keywords: Pipeline, GIS, Route Selection, Weight derivation

1. Introduction

Globally, vast networks of pipelines are utilized in the transportation of resources from one location to another. Crude oil, natural gas, water, finished petroleum products etc are some of the essential utilities which are often transported by pipelines. The significant impact of these transported resources on national economy and security makes it imperative to device reliable and affordable methods to transport them [1].

Pipelines are the most efficient, cost effective and environmentally friendly method used for the transportation of fluid materials. The use of pipelines helps to minimize cost, pollution, spill and highway congestion [2]. However, proper planning is essential in-order to maximize the benefits derivable from the use of pipelines. Careful planning and management of the pipeline route can save on cost, time and operating expenses to facilitate longer operational life and help prevent environmental disasters. [1].A major objective in selecting a pipeline route is to ensure the chosen route has the highest utility to the public, in addition to minimizing harmful impacts to people and the natural environment. [3].The objective of this paper is to determine an optimal pipeline route in Malaysia's Baram Oil Field using Geographical Information System (GIS) Tools.

2. Literature Review

In the past, stakeholders focused more on choosing the shortest, most direct route. This is primarily to save cost on construction and other capital expenditure reasons [4]. However, several other factors apart from cost have to be considered in the route selection process. Geophysical, environmental, political, economic, social and regulatory factors all have significant influences on the route selection process [4]. Though identifying the factors to be considered in selecting an optimal route might not be much of a challenge, prioritizing these routing criteria in order of importance is definitely a major challenge to the geospatial community. When ranking the routing criteria, most researches usually consider opinions of policy makers, contractors, engineers, environmentalists etc but little attention is paid to the views of local community members who reside in areas where the pipelines are to be located [6]. Women, youths, and other

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groups who will be directly affected by the pipelines need to be consulted and their views taken into consideration when deriving weights for the routing criteria. This paper aims to adopt a holistic approach to the pipeline route selection problem. GIS tools will be used for spatial data analyses and the routing criteria will be carefully and accurately ranked. This will significantly enhance the accuracy of the obtained result and ultimately generate an optimal pipeline route that will be acceptable to all. Such a pipeline route will be people and environment friendly, in addition to being cost-effective.

3. Pipeline Route Selection Using GIS

GIS technology is increasingly being relied on in the oil and gas industry as a veritable tool capable of assisting decision makers in selecting an optimal route when sitting new pipelines. This helps to reduce construction and operational costs, as well as minimize negative impacts to the environment during construction [5]. Similarly, the use of GIS helps protect the environment from accidental release of pipeline contents. In such projects, several diverse factors (themes and variables) are usually used as inputs in the spatial process. Some of the commonly used variables include the following [5]:

- Shortest distance from Source to Market
- Least grading (removal of tress etc)
- Cost associated with right of way
- Slope of terrain
- Number of stream, road, and railroad crossings
- Substrate (rock, soils etc)
- Existing laws and regulations (wetlands)
- Proximity to Population centers
- Utilization of existing utility corridors and easements
- Other engineering factors

Apart from these well known and commonly used factors, the following variables were used as inputs in this project; as illustrated in figures 1 to 4:

- Avoidance of prawn areas

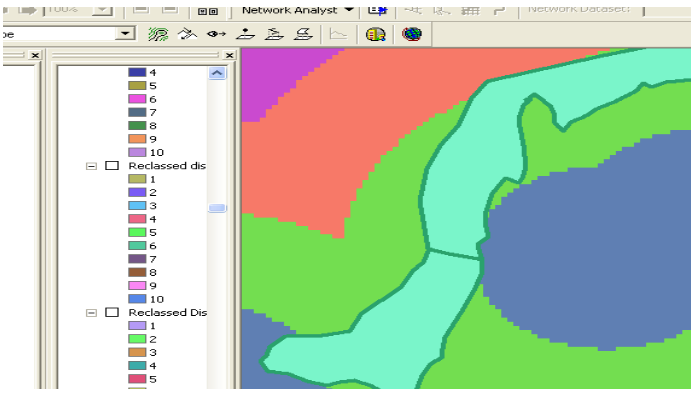


Fig. 1: Prawn areas that should be avoided by the pipelines around Baram Oil Field

- Avoidance of Aquaculture area

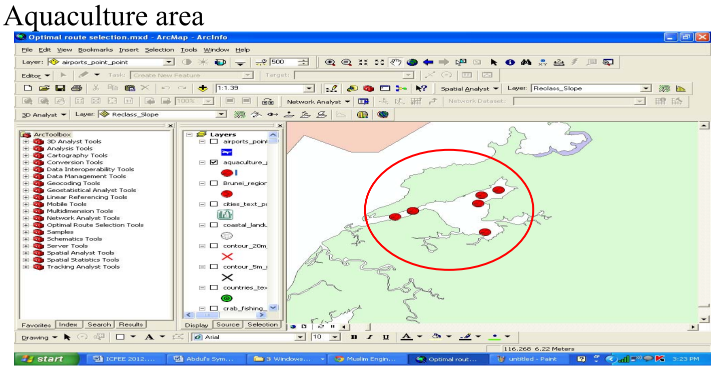


Fig. 2: Aquaculture areas that should be avoided by the pipelines around the Oil field

- Proximity to Airport

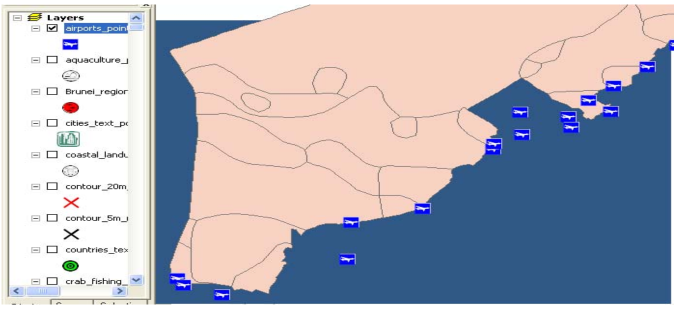


Fig. 3: The airport region that should be avoided by the pipelines within the study area

- Proximity to existing roads

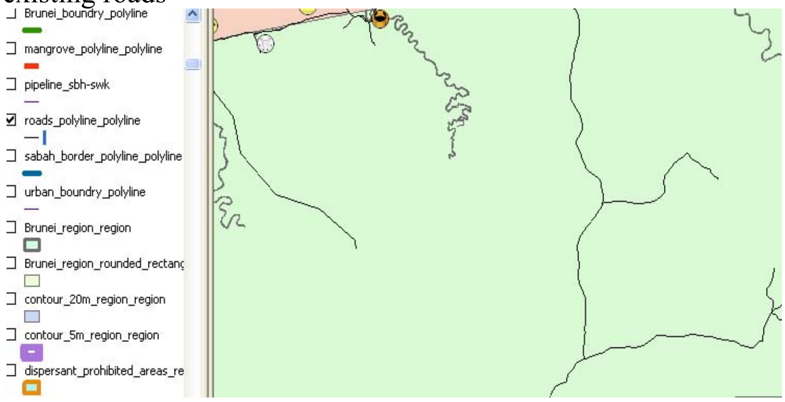


Fig. 4: The pipelines should be located close to these existing roads

- Proximity to existing offshore structures

It is important to note that any set of evaluation factors/criteria is problem specific and there are no universal methodologies to be adopted in determining a set of criteria. Examination of relevant literature, analytical study, and experts' opinions are the three most commonly used systems to develop evaluation criteria for any given project. These same procedures were used in identifying routing factors/criteria considered in this paper.

4. Methodology

The following steps were taken to generate the optimal pipeline route:

1. Rasterization of vector layers
2. Reclassification
3. Weighting of routing criteria
4. Generate Suitability Map
5. Determine Optimal route using the generated cost weighted raster

ESRI's ArcGIS 9.2 Spatial Analyst was used to perform the aforementioned operations. The spatial analyst tools are primarily designed for use on thematic raster data. Hence, the acquired vector datasets were converted to raster format via rasterization. In-order to merge all the rasterized variables into a single layer, it's necessary to convert them from their individual scales to a common measurement scale. This was done using the reclassification process. All the raster layers were set to a common scale of 1 to 10 as illustrated in Figure 5.

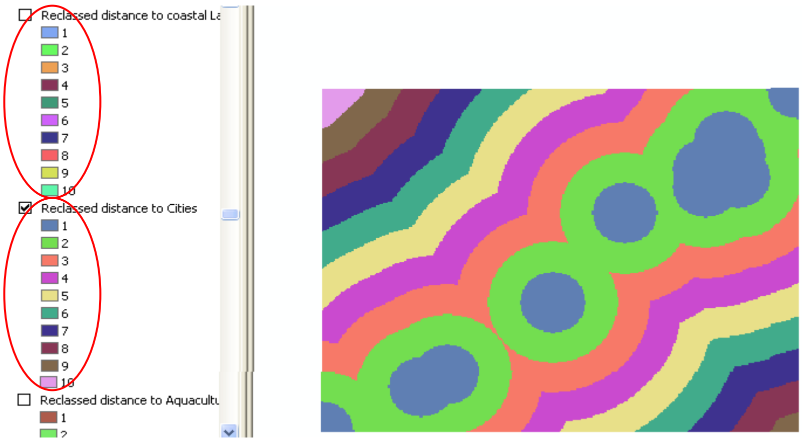
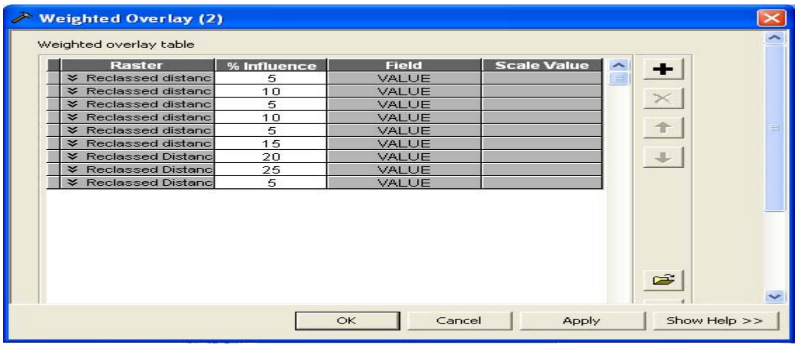


Figure 5: Reclassification of data layer representing a population center (City)

4.1. Weighting

Since there are various diverse variables being considered in the routing process, it's necessary to rank each variable in order of importance. This helps determine the amount of influence each of the variable has on the routing process. For instance, the importance of proximity to roads is not the same as the relevance of proximity to Airports etc. Hence, all variables in this project are weighted to prioritize them. Past weightings have usually been criticized for their lopsidedness and non-objectivity. To address this issue, efforts have been made to ensure the participation of the civil society living in areas where the pipelines will likely be routed through. Using questionnaires, their views are sought and incorporated in the weighting process since they will be directly affected if a pipeline failure occurs in future. Each variable is assigned a weight/rank on a scale of 1 to 100 based on their vulnerability to environmental degradation, cost and total influence on the chosen route. The weighting procedure is shown in figure 6.


Weighted Overlay (2)

Weighted overlay table

Raster	% Influence	Field	Scale Value
Reclassed distanc	5	VALUE	
Reclassed distanc	10	VALUE	
Reclassed distanc	5	VALUE	
Reclassed distanc	10	VALUE	
Reclassed distanc	5	VALUE	
Reclassed distanc	15	VALUE	
Reclassed Distanc	20	VALUE	
Reclassed Distanc	25	VALUE	
Reclassed Distanc	5	VALUE	

OK Cancel Apply Show Help >>

Fig. 6: Assigning weights to the routing criteria in order of preference(% influence)

5. Result and Discussion

The optimal pipeline route is generated from the cost weighted raster as shown below:

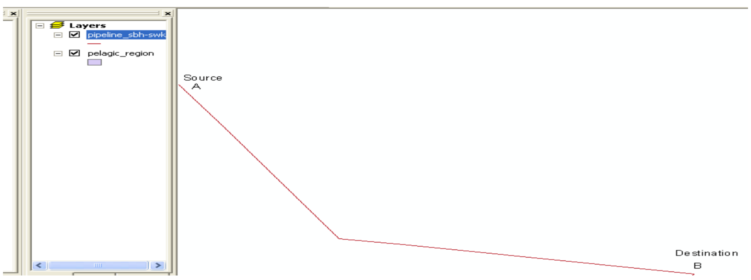


Fig. 7: Optimal pipeline route from oil source to the final destination

To transport oil product from the oil source (A) to its destination (B), there are several possible routes through which the oil pipeline could pass. However, based on the routing criteria and assigned weights, the best possible route is automatically generated as shown in Figure 7 above. This represents the optimal route through which the oil pipeline ought to pass in-order to minimize public health hazards, environmental degradation, destruction of eco-system etc. Furthermore, construction costs and maintenance costs of the pipelines when operational will be lower if this route is adopted.

6. Conclusion

So far, GIS tools have been successfully deployed in the oil pipeline routing process. By incorporating opinions of local community members in weight derivation/ranking the variables, we are able to get a realistic and reliable pipeline route which meets the needs of all concerned parties. Human, environmental and financial factors have been considered in generating this route.

This paper is a first step towards the integration of GIS and Multi-criteria decision Analysis (MCDA) in optimal oil pipeline route selection. To further validate the findings of this paper, a MCDA technique will subsequently be used to rank the routing variables. The pipeline route generated using this technique will be compared with the result of this paper. This will provide further insights on both techniques and how they can complement each other in ensuring a very high level of accuracy in the generated pipeline route.

7. Acknowledgements

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