Geographic Information System for Risk Area Assessment on Natural Gas Pipeline Construction in Nakhon Nayok Province

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Abstract

The objective of this study is to identify potential risk areas caused by the pipeline construction project in Nakhon Nayok province. The potential surface analysis was employed for the manipulation process using critical factors including soil drainage, clay minerals, soil texture, slope, relative humidity, air quality index, distances from bodies of water, roads, and the pipeline. The evaluation of weighting and rating scores has been proposed by experts using 2 main methods, including scaling and hierarchical methods. The risk areas have been divided into high, moderate and low levels. The outputs of these two methods are compared.

It was found that the risk areas identified by the scaling method consist of high risk areas of 316.69 square kilometers (14.77%), moderate risk area of 1,523.05 square kilometers (71.04%), and low risk areas of 304.12 square kilometers (14.19%). Meanwhile, the risk areas evaluated by the hierarchical method consist of high risk areas of 219.47 square kilometers (10.24%), moderate risk areas of 1,839.05 square kilometers (85.78%), and low risk areas of 85.34 square kilometers (3.9%). The comparison of those two methods using the Kappa index has shown the value of 0.66. Thus, those two methods were only in the relation of 66 %. The assessment on land utilization within the high risk areas was analyzed based on the output of the scaling method with larger high risk areas. The land use patterns found in the high risk area include the following areas agriculture of 200.50 square kilometers (63.31%), urban of 74.71square kilometers (23.59%), forest of 5.35 square kilometers (1.69%), water bodies 20.71 square kilometers (6.54%), and others 15.42 square kilometers (4.87%). The purpose of this study was to apply the Geographic Information System for to identify potential risk areas. Geographic Information System (GIS) are a set of computer tools for collecting, storing, transforming and displaying spatial data from the real world.

Key words: risk area / pipeline construction / potential surface analysis / scaling and hierarchical method / GIS

1. Introduction

Nowadays, as Thailand needs to import fuel from abroad while the oil price in the global market fluctuates, the economy is affected. For that reason, the government has encouraged public and private sectors to use natural gas as is more cost effective, is able to be used in the both transportation and industry. Thus the number of imported fuel has been reduced.

As the most common mean of natural gas transportation, a pipeline is also one of the safest ways, due to technological development that has continued for centuries and the closed system that remotely separates natural gas from other transportation strictly.

However, the construction of pipeline project causes several impacts on environment, social and health. According to the act of legislation encouragement and preserve the quality of environment, in 1992 (PTT, 2006), the development of petroleum business is enforced to report Environment Impact Assessment report (EIA) before and after construction established.

Buffer area of both sides of the pipeline and gas pressure can be used to investigate the impacts caused by construction, accordingly with the Techniques for Assessing Industrial Hazard a Manual, 1998 API (World Bank, 2000) for risk assessment. However, the limit of the effect area cannot be accurately estimated. It is usually analyzed by Geographic Information System (GIS) for the risk area of the construction of pipeline project. The system has the ability to manage the attribute data, which analyzes relative factor and shows result in format as a map. The responsible party (PTT and contractor) watch an affects conveniently in the community.

2. Methodology

Explain briefly what the author is going to say in methodology including (2.1) potential surface analysis, (2.2) GIS for potential risk areas analysis, (2.3) Comparison of Risk Area between Scaling and Hierarchical Method and (2.4) General economic impact based on land use patterns within potential risk area as explained below:

Data used in the study GIS software: ArcGIS Desktop 9.2

Digital files and Topographic map at 1:50,000 as follow; (1) Soil series and Land use in 2006 obtained from Department of Land Development, (2) Air Quality Index between 2003 and 2008 (PCD, 2008), (3) Relative Humidity between 1971 and 2000 from Thai Meteorological Department, (4) Slope/Gradient in 1969 (Royal Thai Survey Department, 2008), (5) Hydrological Data in 2006 from Department of Royal Irrigation, (6) Transport Route in 2007 from Ministry of Transport, and (7) Administrative in 2005 from Department of Provincial Administration.

In this investigation, Potential Surface Analysis (PSA) was used to identify potential risk areas caused by the pipeline construction project. The PSA is elaborated below.

2.1 PSA

Potential Surface Analysis is based on the Selection of Relevant Factors. The factor of risk area analysis caused by pipeline construction are soil drainage, clay minerals, soil texture, slope, relative humidity, air quality index, distances from bodies of water, roads, and the pipeline.

Weighting and Rating Values were conducted by several experts in various fields with at least 5 years experiences in their respective fields and to the educational institutes. There were 20 experts among different five fields of expertise including Geography, Petrology from Department of Land Development, Environmental Engineering, Construction Engineering and Relation Community. The total number was calculated. This study used an arithmetic average as the central tendency due to its quantitative and most reliable central tendency.

1) Weighting technique is applied to investigate the comparison of the suitability or importance of all factors. Expert had to consider proposing scores for each factor regarding the potential risk area analysis. Weighting and rating scores were identified using two techniques including (1) Scaling Method (2) Hierarchical Method as explained below.

1.1) Scaling Method: The range of weighting score was between 0-10. Factor that gets the score of zero implies that such factor was not risk or significant for potential analysis of risk area. The score of 1 point equaled to poor level or less significant, while 5 to 10 score meant moderate and excellent or risk and important factors, increasingly.

1.2) Hierarchical Method: the range of weighting value depends on amount of factors in an analysis, for example, if the factors in the analysis comprises 9 factors, weighting value are the integer, there are value since, 9,8,7,... , to 1, which is in an order of magnitude form importance of factor, and that haven't value repeatedly.

2) Rating was the leveling of weighting factors for risk and importance comparing within the group of factors. Factor to be considered for rating used the same standard as the weighting score as explained in weighting technique. The results of the points of weighting and rating were displayed in table 1 and table 2 respectively.

Table 1 Score of the weighting and rating based Scaling method

Factor use in study	W_i	Factor	R_i	Source
1. Soil Texture	7.4	1.1 Fine group	9.2	Department of Land
		1.2 Medium group	6.2	Development
		1.3 Coarse group	3.5	
2. Soil drainage	5.8	2.1 Well drained	8.2	Department of Land
		2.2 Moderately drained	5.6	Development
		2.3 Poorly drained	3.1	
3.Relative Humidity	4.5	3.1 lowers 50%	8.2	Thai Metrological
		3.2 between 50 – 75%	5.2	Department
		3.3 more than 75 %	2.8	
4.Type of Clay Minerals	4.9	4.1 Highly	8.4	Expert Recommendation
(swelling and shrinking)		4.2 Moderately	6.4	
		4.3 Poorly	3.0	
5. Particulate Matter	6.1	5.1 AQI more than 300	9.4	Pollution Control
(comparing with AQI		5.2 AQI 200-300	7.7	Department
Index)		5.3 AQI 100-200	6.4	
		5.4 AQI 50-100	4.3	
		5.5 AQI 0-50	2.0	
6. Slope Gradient	5.3	6.1 more than 30%	9.1	Department of Land
		6.2 between 16 - 30%	7.6	Development
		6.3 between 8 -16%	5.7	
		6.4 between 3 - 8%	3.7	
		6.5 0 - 3 %	1.7	
7. Distance from Water	6.4	7.1 $\leq$ 100 meters	8.8	EIA and Expert
source		7.2 100 – 500 meters	6.2	Recommendation
		7.3 $\geq$ 500 meters	3.0	
8. Distance from road	6.1	8.1 $\leq$ 200 meters	8.4	EIA and Expert
		8.2 200 – 1,000 meters	5.5	Recommendation
		8.3 $\geq$ 1,000 meters	2.5	
9. Distance from a	8.4	9.1 $\leq$ 500 meters	9.0	EIA and Expert
pipeline construction site		9.2 500 – 1,000 meters	5.7	Recommendation
		9.3 $\geq$ 1,000 meters	2.8	

Source: The result of study

Table 2 Score of the weighting and rating based Hierarchical method

Factor use in study	W_i	Factor	R_i	Source
1. Soil Texture	8	1.1 Fine group 1.2 Medium group 1.3 Coarse group	3 2 1	Department of Land Development
2. Soil drainage	4	2.1 Well drained 2.2 Moderately drained 2.3 Poorly drained	3 2 1	Department of Land Development
3.Relative Humidity	1	3.1 lowers 50% 3.2 between 50 – 75% 3.3 more than 75%	3 2 1	Thai Metrological Department
4.Type of Clay Minerals (swelling and shrinking)	3	4.1 Highly 4.2 Moderately 4.3 Poorly	3 2 1	Expert Recommendation
5. Particulate Matter (comparing with AQI Index)	5	5.1 AQI more than 300 5.2 AQI 200-300 5.3 AQI 100-200 5.4 AQI 50-100 5.5 AQI 0-50	5 4 3 2 1	Pollution Control Department
6. Slope Gradient	2	6.1 more than 30% 6.2 between 16 - 30% 6.3 between 8 -16% 6.4 between 3 - 8% 6.5 0 - 3 %	5 4 3 2 1	Department of Land Development
7. Distance from Water source	7	7.1 $\leq$100 meters 7.2 100 – 500 meters 7.3 $\geq$ 500 meters	3 2 1	EIA and Expert Recommendation
8. Distance from road	6	8.1 $\leq$200 meters 8.2 200 – 1,000 meters 8.3 $\geq$ 1,000 meters	3 2 1	EIA and Expert Recommendation
9. Distance from a pipeline construction site	9	9.1 $\leq$500 meters 9.2 500 – 1,000 meters 9.3 $\geq$ 1,000 meters	3 2 1	EIA and Expert Recommendation

Source: The result of study

2.2 GIS for potential risk areas analysis

The purpose of this study was to apply the Geographic Information System for to identify potential risk areas. Geographic Information System (GIS) are a set of computer tools for collecting, storing, transforming and displaying spatial data from the real world. The potential surface analysis was firstly done by determination the relevant factors and searching for spatial data of each factor. Afterwards, the data were classified into groups of risk levels before sending to the expert for weighting scores and being rated for further potential analyze process.

The potential area analysis by multiplying the weighting of each factor (W_1) with the rating of each factor (R_{1j}) was further implemented by overlay technique (see equation 1) where 'S' = the level of total score of suitable factors related to living space potential of risk area, W_i (i=1..n) = the important value of each factor and R_i (i=1..n) = the scores of sub factor i, from the first factor to n factor. The total scores were summarized and the potential risk areas (S) were investigated.

$$\text{Risk areas (S)} = (R_1 \times W_1) + (R_2 \times W_2) + \ldots + (R_n \times W_n) \quad (1)$$

The classification of risk area levels was calculated as 3 classes; High (I_3), moderately (I_2) and low (I_1) as illustrated in equation 2 where I_1 is low risk area, I_2 is moderately risk area and I_3 is high risk area.

$$(I_1) = \bar{X} - SD$$
$$(I_2) = \bar{X} - SD \leq S \leq \bar{X} + SD$$
$$(I_3) = \bar{X} + SD \qquad (2)$$

From the equation above, levels of risk area were categorized in to 3 classes based on I_1- I_3 values. The results are as follows:

Scaling Method:	High risk area	=	$\geq$ 277.52
	Moderate risk area	=	150.44 $\leq$ S $\leq$ 277.52
	Low risk area	=	$\leq$ 150.44
Hierarchical Method:	High risk area	=	$\geq$ 78.17
	Moderate risk area	=	46.83 $\leq$ S $\leq$ 78.17
	Low risk area	=	$\leq$ 46.83

2.3 Comparison of Risk Area between Scaling and Hierarchical Method

Kappa Index was used to measure relation of the results from both scaling and hierarchical method. Kappa Index is in 0-1.00 range with larger values indicating better reliability. Generally, Kappa Index > 0.70 is considered satisfactory result.

2.4 General economic impact based on land use patterns within potential risk area

Eventually, considering an effect on potential of high risk area, if any method shows the high risk area covering and reflecting on more than the fact that method is for choosing the meditation. The potential of risk area in high-level, was studied using overlay techniques based potential surface analysis model. The results demonstrate characteristics and risk levels caused by pipeline construction. Those risk areas were indicated by economic values (yield per rai).

3. Result and Discussion

Normally, the author should give an introduction of each new section by telling what the author is going to explain in this chapter.

3.1 Risk Area Identification of the Pipeline Construction

Risk Area Identification using Scaling Method shows that most of the areas are in moderate risk level about 1,523.05 km^2 or 71.04%. The high risk areas are approximate 316.69 km^2 or 14.77%, and respectively found in following districts Onk Kharak, Ban Na, Mueang Nakhon Nayok, and Pak Phil. The low risk areas are about 304.12 km^2 or 14.19% as seen in Figure 1.

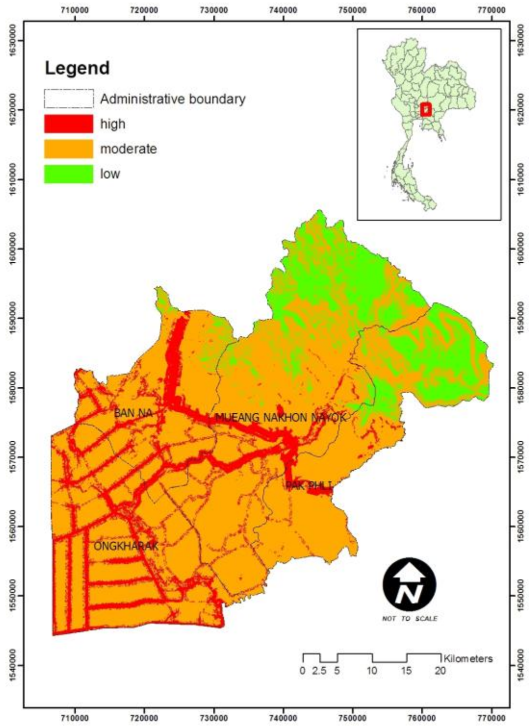

Figure 1 Potential risk area in Nakhon Nayok province based Scaling Method

Risk Area Identification using Hierarchical Method shows that most of the areas are in moderate risk level about 1,839.05 km^2 or 85.78%.The high risk areas are approximate 219.47 km^2 or 10.24%., and respectively found in following districts Onk Kharak, Ban Na, Mueang Nakhon Nayok, and Pak Phil. The low risk areas are about 85.34 km^2 or 3.98% as seen in Figure 2.

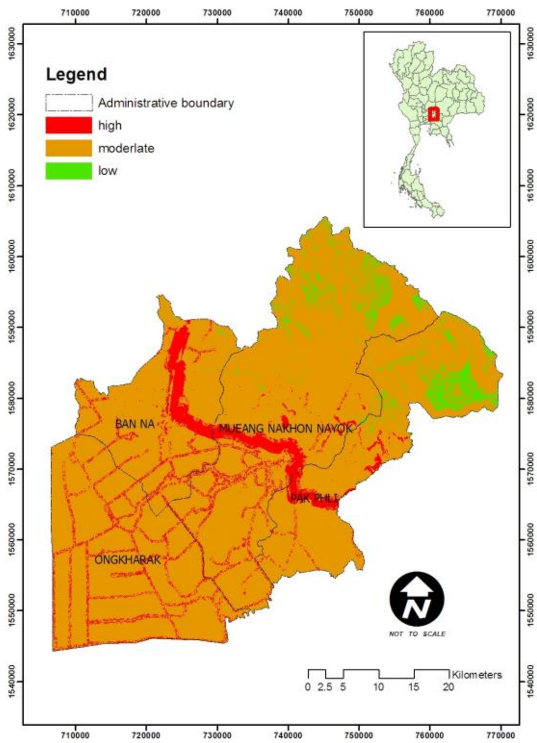

Figure 2 Potential risk area in Nakhon Nayok province based Hierarchical method

3.2 Comparison of Risk Area between Scaling and Hierarchical Method

The results of potential risk areas obtained from both scaling and hierarchical method were compared using kappa index. It was found that both scaling and hierarchical method were positive relation with the Kappa Index of 0.66.

3.3 General economic impact based on land use patterns within potential risk area

In this study, the high risk areas of the scaling method was selected to overlay with land use patterns to evaluate economic impacts, due to its percentage of the high risk areas Land use effecting by the high risk area are categorized into 5 class which are in agricultural land of 200.50 square kilometers or 63.31%, urban and built-up of 74.71 square kilometers or 23.59%, forest of 5.35 square kilometers or 1.69%, water body of 20.71 square kilometers or 6.54%, and miscellaneous area of 15.42 square kilometers or 4.87%.

Based on the Strategy of Nakhon Nayok emphasize to agricultural extension mainly which main income of province. To identify effects caused by the construction of pipeline project was investigated by economic value (yield per rai). In this research, it shows that the values of industrial drop were decreased as shown in table 3. It was found that most areas were in rice paddy have farm value of about 650.09 million baht. The farm value of Shrimp farm and fish farm were high inferior to the rice paddy.

Table 3 Effects on land use caused by the potential of the risks area (an industrial drop) in Nakhon Nayok province (Office of Agriculture Economics, 2008)

Type of Land used	Risk Area (rai)	Yield per rai (kgs)	Farm Price (Baht per kg.)	Farm Value (Million Baht)
Rice paddy	96,718.80	586.00	11.47	650.09
Eucalyptus	3,629.16	16,000.00	0.9	52.26
Orange	1,099.39	2,360.00	35	90.81
Mango	88.07	1,180.00	22.04	2.29
Guava	6.3	2,426.00	35	0.53
Santol	22.42	1,120.00	20	0.5
Sugarcane	51.27	11,153.00	0.7	0.4
Corn	3.88	624.00	7.05	0.02
Cassava	46.24	3,401.00	1.73	0.27
Banana	50.82	1,500.00	5.48	0.42
Fish farm	9,089.01	808.64	17.84	131.11
Shrimp farm	1,882.33	1,638.09	85.51	263.66

4. Conclusion

The study shows that natural gas Nakhon Nayok is mainly made up of moderate risk area. The high risk areas usually concentrate near water and fine textured soil areas. Besides, the high risk areas tend to coexist with the pipeline construction site because the weighting of distance from the pipeline influences on the other factors. The low risk area is the mountainous zone in the northern area of the province, which is not a suitable area for pipeline construction.

The potential of PSA model can identify risk area from the pipeline construction following this study which the period of construction project, moreover this model was eliminated the distance from the pipeline factor, it applied during route selection step that is to say this step chosen the most suitability route for reduce to effect with a community and an environmental at least.

5. Acknowledgement

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