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Applying Indexing Method to Gas Pipeline Risk Assessment by Using GIS: A Case Study in Savadkooh, North of Iran

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ABSTRACT

Gas pipelines are environmentally sensitive because they cross varied fields, rivers, forests, populated areas, desert, hills and offshore and also different parameters in gas transmission progresses are effective. Underground gas transmission pipelines have been grown as one of the low risk methods with low cost in the world specially in middle east and Europe. Physical and chemical properties of liquid gas, pipeline properties and also its environmental condition are the main factors of increasing the technical and environmental risk. In this article the quantitative risk assessment has been done by using GIS and overlaying the information layers. For this purpose, all effective risk factors were identified and projected. In order to achieve the same and comparable results, the entire pipeline route was divided into 500 meter intervals and the risk was calculated in each interval, finally the scores of these intervals such as each criterion risk was calculated. The case study of the article is Savadkooh to PoleSefid pipeline in Mazandaran.

Keywords: *Risk Assessment*, *Pipeline*, *GIS*, *Environment*

1. Introduction

Natural gas is one of the most important energy carries [2,9,13].Considering the fact that Islamic Republic of Iran has 14 thousand kilometers of oil pipeline and more than 22 thousand kilometers of gas transmission pipeline, it has the longest network of oil pipeline in Middle East.

In fact, Gas transmission in order to deliver the economic and almost clean energy from producing sources to final consumers is one the most important tasks. Pipelines represent a linear risk source that can create controversial challenges in gas industry of the country. Therefore, pipeline risk assessment is one of the sciences that has been developed due pipelines growth.

Transmission pipelines carrying natural gas are not only on secure industrial sites, but also routed across the land. In the recent years, more and more authorities have been aware of the security problems of natural gas transmission pipelines. Due to the physical and chemical characteristics of natural gas as well as the features of pipelines, accidents of transmission pipelines carrying natural gas are quite different from other industrial accidents [14].

In fact, considering all the issues which have been mentioned above, the important issue is transferring the energy to the domestic and foreign consumers. Clearly, the usage of pipelines is the best and most economical method which has the least impact. Therefore any attempt to transfer the energy carries should be done in terms of these factors. A review on statistics of occurred accidents causes make the necessity of attention, investigation, evaluation, planning, management and monitoring of these pipelines clear.

Due to the widespread and dangerous impacts of the possible occurrence of any pipeline accident, It is essential to identify all the risks and potential hazards. Recently, risk analysis has already been extensively applied in safety science, environmental science, economics, sociology, etc. It aims at finding out the potential accidents, analysis on the causes as well as the improvements to reduce the risk. It is important to realize that decision-making regarding risks is not only a technical aspect but also political, psychological and societal processes all playing important roles. Therefore, it is much important to clearly identify the risks and check out the effects of risk reduction measures by quantitative risk assessment (QRA) [7].

When a pipeline has been assessed, in fact the hazard probability and its impacts in an exact section of the pipeline according to the environmental conditions are depicted in a precise moment [8].

Studies that have been done so far regarding energy transmission risk assessment conducted by a different approaches, and each of these methods emphasizes on a certain parameter in risk assessment. In the study that was done in Greece [10]. In this approach fuzzy logic is considered better for dealing both with linguistic variables and uncertainties. In this study a rapid assessment and relative ranking of the hazards of chemical substances, as well as units and installations, is presented in order to enter different parameters in risk assessment.

Pasanta Kumar Dey [4] in a study titled as "An integrated assessment model for cross-country pipelines" proposed various options by developing an integrated model. The model considers technical analysis (TA), socioeconomic IA (SEIA) and environmental IA (EIA) in an integrated framework to select the best project from a few alternative feasible projects.

In the opinion of two other scientists, the environmental consequence index (ECI) indices lack in consideration of all environmental consequence factors such as material hazard factors, dispersion factors, environmental effects, and their uncertainty, this is why the ETC has been applied by a new method [1].

In Iran, in a comprehensive risk assessment of petrochemical pipelines, they focused on the assessment of third party damage indicators, incorrect operation, corrosion and design [5].

Besides the available resources, the most important source of pipeline risk assessment is the valuable book by Mahlbuner [8] which is a comprehensive method, trying to assess the risk with considering all the influential parameters.

2. Methodology

2.1. Materials

The case study of this research is Savadkooh's 16 inch gas transmission pipeline in Mazandaran province in Iran which passes through the cities: Savadkooh, Zirab, Shirgah and pole Sefid and villages: Sorkh kola, Ghasem abad and zirab. The pipeline length is 606 + 30 km and will transfer gas through the Valley of Talar River from Caspian coastal areas to mountainous regions of Savadkooh in the north-to-south direction.

Starting point coordinates are x = 668,500 and y = 4,021,500 and the end point coordinates of the pipeline are x = 682,500 and y = 4,002,500 .The pipeline passes along the Firoozkooh road in some parts of the route and in some other parts passes forests around Shirgah and crosses the rivers of Kasilian and Talar and also the main asphalted road in 251 + 21 km. In terms of geology, the pipeline has been placed in central zone of Alborz and large part of the rout passes across the present era river and alluvial deposits, oligo-miocene stone formations like upper red formation equivalent currency and Qom formation and continental series.

These formations are formed mostly by marl, sandstone and continental conglomerates.

According to the geological situation of the area, corrosion fault has a great expansion in the region. On the other side, the topographical situation of the region with the exception of the primary parts and the end of the route is mountainous and steep.

Also due to placing the caste study route in mountainous climate, the permanent rivers which can cause erosion phenomenon in mountainsides are found (such as Talar river, Kasilian, Cherat and etc.) according to the presented content above; the case study region has low to moderate landslide potential. **Figure 1** shows the result of the pipeline risk assessment in the satellite image.

2.2. Methods

Different methods of risk assessment and management are used, such as hazard and operability study, fault percentage analysis, quantitative risk assessment, optional risk assessment and indexing method [8]. Each of these methods has its own strengths and weaknesses, but indexing methods are more practical than the others due to faster response, low cost analysis, supportive tool for better decisions and comprehensiveness. [8].

The base method which has been used in this article is Indexing method by Mahlbauer. This method has been applied widely in gas pipeline transmission and is compatible with pipeline project conditions in terms of accuracy and required information. According to **Graph 1**, assessment in this method is divided into two general parts of impact index and index sum.

Preparation and projection of each sector criteria is time consuming and in some cases is the same in the entire pipeline or less important. Therefore pipeline risk assessment based on mentioned criteria will have many difficulties. In order to optimize the method, the same criteria in the pipeline will be excluded from the process and also an index has been used as a substitute in terms of similarity to the some criteria. While in some cases, preparation and projection of some criteria were not possible due to limitation of the study, the criterion was removed from the assessment process.

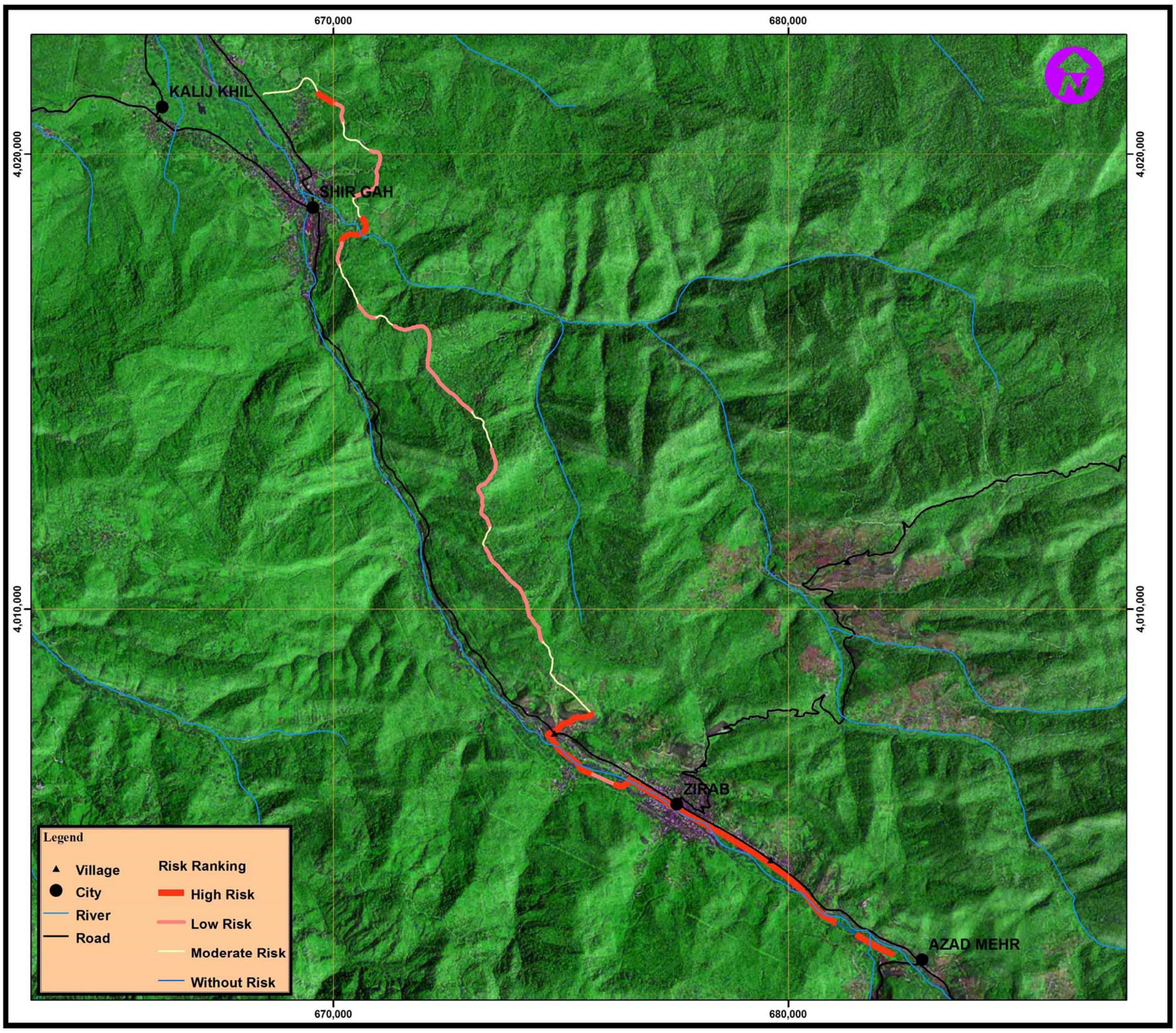


Figure 1. Pipeline placement position in the Satellite Image.

In this method, firstly, the data was collected by studying the existing records in pipeline management structure. It's an important element to interview with experts involved in different operational parts in order to obtain the final assessment index.

In order to achieve the same and comparable results, the entire pipeline route was divided into 500 meter intervals and the risk was calculated in each section and finally the interval scores such as each criteria risk was estimated.

In other words, in this phase, severity and importance of affective factors on risk potential increase. Environmental sensitivity of the project was determined by using the relative criteria and factor weighting, finally, each interval risk score and total score were calculated.

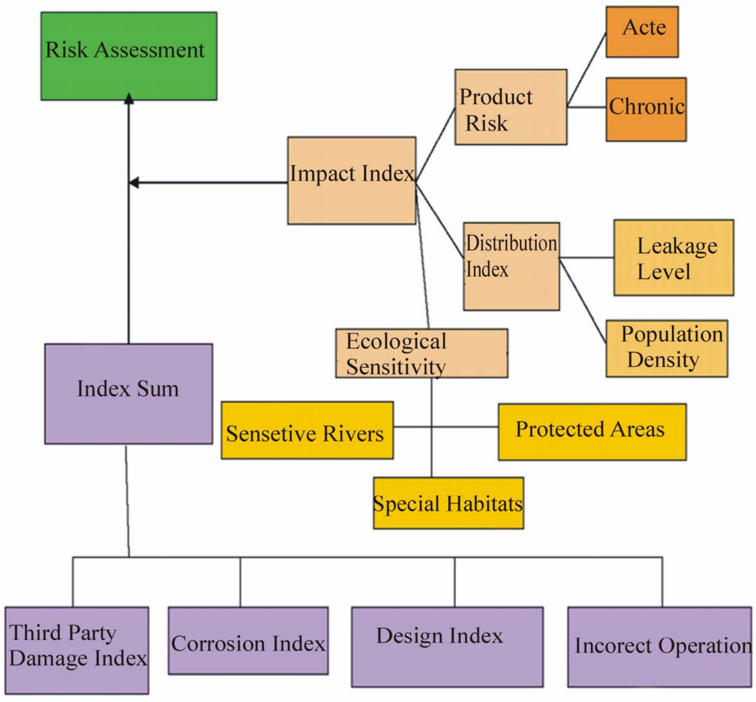
On the other hand, linearity of pipeline project causes problems in spatial and descriptive data collection, documentation and display, therefore it can be solved by applying GIS and quantitative and accurate information [3,6,11].

Thus, using GIS tool is essential for solving the above-mentioned problem and subsequent analysis.

The difference and distinction between this method and Mahlbauer method is usage of Geographic Information System (GIS) as a utile method which means all the mentioned indicators and criteria were projected and the calculations were performed spatially rather than statistical operations.

3. Results and Discussion

As it has been mentioned in the methodology, firstly all the parameters were identified and mapped, then these



Graph 1. Pipeline risk assessment components and process [8].

maps were divided into 500-meter intervals, finally scoring was done based on environmental conditions. Using GIS in mapping and scoring can help the presentation of all probable risks on the maps which can be used as tools to develop the existing methods and can be useful in risk management of a pipeline and prevents the occurrence of probable risks. In fact by using this method, a wide range of risks such as ecological, physical, chemical, environmental and safety can be prevented, and finally a comprehensive assessment will be achieved. The defined criteria have been mapped and scored as **Figure 2**.

Fault: the approximate incidence location of Savadkooh pipeline with existing faults are provided in **Table 1**, according to index points of survey.

Under ground water: regarding the manual bores in some sections of the pipeline route, distances listed in **Table 2** have been approached by the water, therefore these areas has risks in terms of underground water index.

Corrosion: along the pipeline route, geo electrical examinations have been done in depth of 1.5 - 3 meters, with one kilometer interval and the examinations were near the identification sinks. **Table 3** shows the corrosion levels in terms of different electrical resistivity. **Table 4** shows the final risk score in terms of corrosion index. It should be also mentioned that only the medium to high level corrosions have been weighed in this method.

Landslide: the pipeline landslide zonation has been done by combination of three methods of Grade 1, Grade 2 and Grade 3. The risk assessment final results in terms of this criterion are available in **table 5**.

High voltage transmission lines: if the pipeline has been placed parallel or under the high voltage transmission lines, the induced voltage will cause the flow into the pipe in the places that the pipeline cut the magnetic field. Due to this issue, the final risk score in terms of high voltage transmission line index has been shown in **Table 6**.

Residential areas: activity rate of this region may be studied by several indexes which population density and residential centers in the region are the important parameters. The final risk score in terms of residential areas index has been shown in **Table 7**.

River: permanent and temporary river water flow cause erosion to materials around the pipeline. Therefore the risk score in terms of this index has been shown in **Table 8.**

Roadways: Road is one of the main factors in environmental sensitivities which has also been studied in this article. The final risk score for this index is available in **Table 9**.

Gas Compressor Station: Another increasing factor in pipeline risk is land use in which gas compressor station is one of the main factors in this context. Considering this issue, three stations are located in the kilometers 500, 23500 and 30500 of the road. Three station scores are

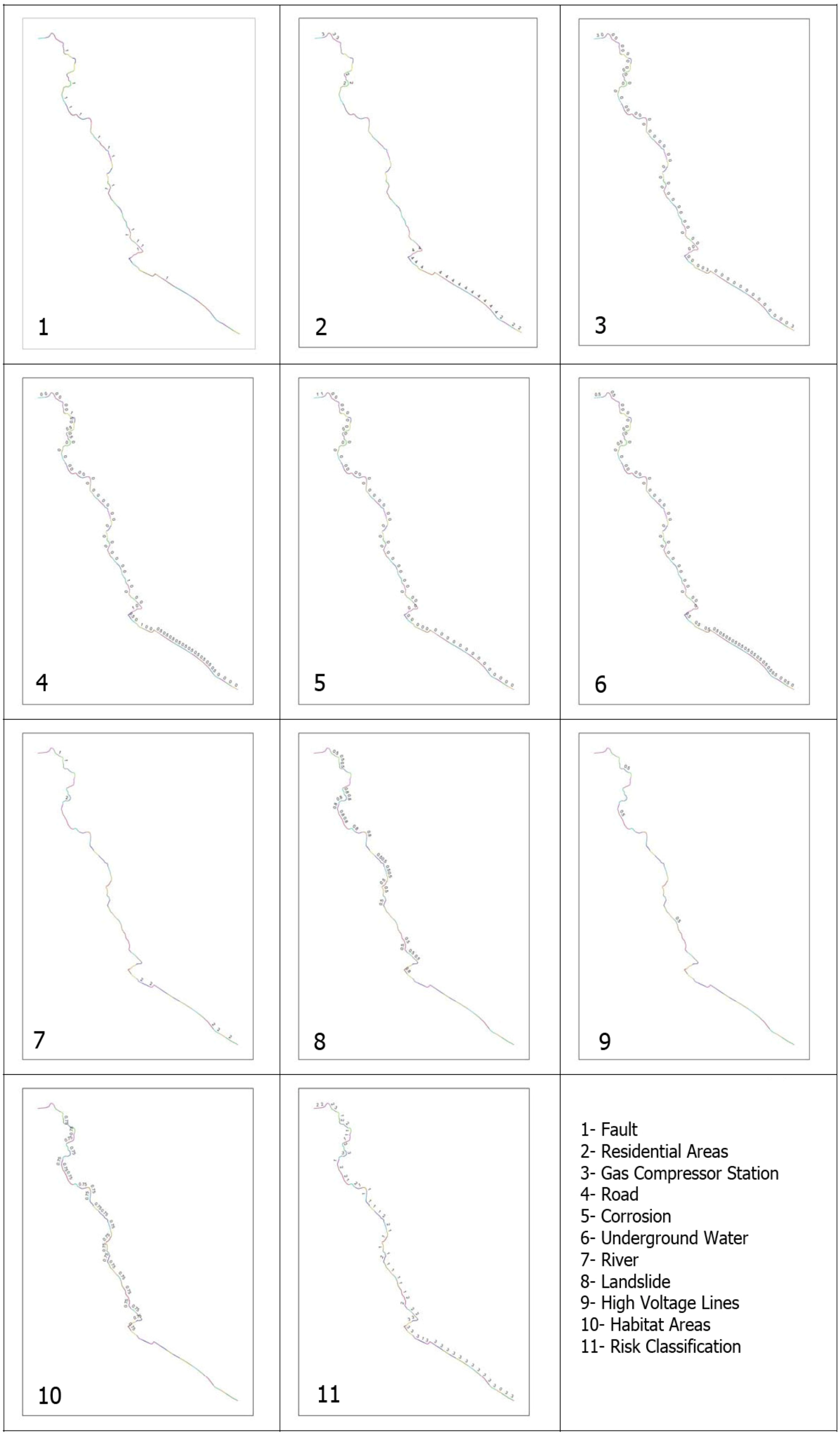


Figure 2. Pipeline risk assessment in 500 meter intervals based on mentioned criteria.

Table 1. Pipeline approximate incidence with the existing faults.

24/3	21/2	19/9	19/1	18/8	18/3	15/1	14/8	12/9	12/2	11/05	8/9	8/0	7/2	5/8	2/8	Kilometer
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Risk Score

Table 2. Final risk score in terms of underground water index.

Final score	relative weight	risk score	To (km)	from (km)
0/5		1	01 + 900	00 + 350
0/5	0/5	1	28 + 900	20 + 750
0/5		1		06 + 171
0/5		1		29 + 855

Table 3. Land corrosion description in terms of different electrical resistivities (Iranian Oil ministry, standard number 925).

Corrosion	Electrical Resistivity (Ohm-Cm)
Very high	500<
High	1000 - 500
Moderate	2000 - 1000
Low	10000 - 2000
Very low	>10000

Table 4. Final risk score in terms of corrosion index.

final score	relative weight	risk score	Corrosion capability	Resistance	electrode depth	location
0/5		1	Moderate Corrosion	1/78	1/5	00 + 000
	0/5		high corrosion	0/43	3/00	
0/5		1	Moderate Corrosion	2/12	1/5	00 + 996
			Moderate Corrosion	0/78	3/00	

Table 5. Final risk score in terms of landslide index.

From (Km)	To(km)	zoning type	risk score	relative weight	final score
0/5	0/5	1 + 700	2 + 800	MH	1
0/75		5 + 300	9 + 900	HH	1/5
0/5		11 + 700	14 + 400	MH	1
0/5		15 + 000	15 + 500	MH	1
0/5		18 + 300	20 + 200	MH	1
0/75		20 + 200	21 + 300	HH	1/5
	MH=Moderate Hazard Zone			HH= High Hazard Zone	

Table 6. Final risk score in terms of high voltage power transmission lines index.

final score	relative weight	risk score	approximate kilometer of intersection	voltage
0/5		1	3 + 105	high voltage
0/5	0/5	1	7 + 052	high voltage
0/5		1	19 + 683	high voltage

Table 7. Final risk score in terms of residential areas.

Final score	Relative weight	Risk Score	Distance (meter)	Kilometer	Town
2		2	500	5 + 006 - 6 + 335	Shirgah
4		4	0	23+ 654 - 26 +910	Zirab
3		3	150	0 + 585 - 1 + 590	Chali
4		4	0	20 + 397 - 22 + 358	Sorkh kola
1	1	1	1000	21 + 070 - 21 + 262	Ghasem abad
4		4	0	26 + 910 - 28 + 081	Alie Kola
2		2	300	28 + 448 - 28 + 777	Khormandi chal
2		2	300	30 + 055 - 30 + 604	Azadmehr
2		2	500	21 + 710 - 22 + 358	Kordabad

Table 8. final risk score in terms of river index.

final score	relative weight	risk score	approximate bed width(m)	approximate kilometer of intersection	waterway
1		1	2 meters main channel 5 meters flood bed	1 + 790	stream
1		1	3 meters main channel 12 meters flood bed	2 + 300	stream
2		2	15 meters main channel and 30 meters flood bed	6 + 171	Kasilian river
2		2	50 meters main channel and 80 meters flood bed	22 + 249	Talar river
2	1	2	35 meters main channel and 70 meters flood bed	23 + 362	Talar river
2		2	35 meters main channel and 65 meters flood bed	28 + 188	Talar river
2		2	30 meters main channel and 60 meters flood bed	28 + 375	Talar river
2		2	25 meters main channel and 35 meters flood bed	28 + 789	Talar river
2		2	20 meters main channel and 40 meters flood bed	29 + 855	Cherat river

Table 9. Final risk score in terms of rode index.

total score	Relative weight	risk score	distance (m)	Kilometer	Road Type
1		2	intersection	3 + 105	Soil
0/5		1	Vicinity	3 + 105 – 5 + 188	Soil
1		2	intersection	17 + 763	Soil
1	0/5	2	intersection	20 + 824	Soil
0/5		1	Vicinity	21+500 - 21+500	Asphalted
1		2	intersection	22 + 127	Soil
0/5		1	Vicinity	23 + 463 - 28 + 463	Asphalted

presented in **Table 10**.

Habitat areas: according to the previous studies, Savadkooh pipeline route passes through the plain, forested hills and mountainous regions. The pipeline crosses the forest from the kilometer 2 + 500 to 21 + 400 with about 18 kilometers length. These forest areas with different names and lengths have the same habitat value and also although there are some protected areas which exist in the project region, most of these areas have significant distance to the pipeline.

4. Conclusions

After calculating each interval risk, finally the scores were accumulated and in order to provide suitable and homogeneous information for risk management, the whole route score has been divided into four main sections and the result is presented in **Table 11**.

Generally, it is clear by the results that different parts

Table 10. Score distribution of total hazard potential factors.

Factor	water pipe			gas pipeline			oil pipeline		Soil corrosion	Soil displacement
Distance to pipeline (m)	50	150	800	50	50 - 200	500	0 - 300	100 - 200	0	0
Score	3	2	1	3	2	1	2	1	1	1

Table 11. Ratio of different environmental risks in pipeline length.

Risk Level	Length (m)	Percentage
no risk	500	1/63
low risk	11000	36/06
medium risk	8000	26/22
high risk	10500	34/42
Very high risk	500	1/63
Total	30500	100

Table 12. Combination of effective index and environmental sensitivity and the final risk score in the project route.

			parameter										
risk description	risk level	total score	habitat areas	high voltage	lanslide	river	Under-ground Water	corro-sion	road	compres-sor station	residen-tial	fault	distance (meter)
medium	2	4					0.5	0.5		3			500
medium	2	4					0.5	0.5			3		1000
medium	2	3.5					0.5				3		1500
high	3	5			0.5	1	0.5				3		2000
low	1	1.5			0.5	1							2500
medium	2	2.25	0.75		0.5							1	3000
medium	2	2.25	0.75	0.5					1				3500
low	1	1.25	0.75						0.5				4000
low	1	1.25	0.75						0.5				4500
low	1	1.25	0.75						0.5				5000
medium	2	4	0.75		0.75				0.5		2		5500
high	3	4.5	0.75		0.75						2	1	6000
high	3	6	0.75		0.75	2	0.5				2		6500
low	1	1.5	0.75		0.75								7000
medium	2	3	0.75	0.5	0.75							1	7500
medium	2	2.5	0.75		0.75							1	8000
low	1	1.5	0.75		0.75								8500
medium	2	2.5	0.75		0.75							1	9000
low	1	1.5	0.75		0.75								9500
low	1	1.5	0.75		0.75								10000
low	1	0.75	0.75										10500
low	1	0.75	0.75										11000
low	1	1.75	0.75									1	11500
low	1	1.25	0.75		0.5								12000
medium	2	2.25	0.75		0.5							1	12500
medium	2	2.25	0.75		0.5							1	13000
low	1	1.25	0.75		0.5								13500
low	1	1.25	0.75		0.5								14000
low	1	1.25	0.75		0.5								14500
low	1	1.75	0.75									1	15000
medium	2	2.25	0.75		0.5							1	15500
low	1	0.75	0.75										16000
low	1	0.75	0.75										16500
low	1	0.75	0.75	5/0									17000
low	1	0.75	0.75										17500
low	1	1.75	0.75						1				18000
medium	2	2.25	0.75		0.5							1	18500
medium	2	2.25	0.75		0.5							1	19000
medium	2	2.25	0.75		0.5							1	19500
medium	2	2.25	0.75		0.5							1	20000
high	3	6.25	0.75		0.5						4	1	20500
high	3	7	0.75		0.75		0.5		1		4		21000
high	3	6.5	0.75		0.75		0.5		0.5		4		21500
high	3	4.5					0.5				4		22000
high	3	7.5				2	0.5		1		4		22500
low	1	0.5					0.5						23000
high	3	5.5				2	0.5			3			23500
high	3	5					0.5		0.5		4		24000
high	3	6					0.5		0.5		4	1	24500
high	3	5					0.5		0.5		4		25000
high	3	5					0.5		0.5		4		25500
high	3	5					0.5		0.5		4		26000
high	3	5					0.5		0.5		4		26500
high	3	5					0.5		0.5		4		27000
high	3	5					0.5		0.5		4		27500
high	3	5					0.5		0.5		4		28000
high	3	7				2	0.5		0.5		4		28500
high	3	4.5				2	0.5				2		29000
no risk	0	0											29500
high	3	4.5				2	0.5				2		30000
high	3	5								3	2		30500

in the pipeline have different environmental risk scores and some parts of the route do not have any risk classification. Moreover, the entire project route has the environmental risk potential due to the project essence but the classified intervals have additional environmental risk compared to the basic mode.

In other words, it can be expressed in this way that the whole pipeline has the basic risk but the classified intervals have more risks than the base condition.

Different risk classified intervals in the pipeline study have been presented in **Table 12**. As it can be seen in this table, the longest risk class belongs to low and high risks with rate of 34/42 and 36/06 percentage and then the average risk with 26/22 percentage of the road is ranked in the third place.

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