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# Pipeline risk assessment by using hazard risk assessment, (HAZOP) Method (Case study: Gas transmission Pipeline Of Savadkooh, Iran)

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## ABSTRACT

Iran is considered as the second country of gas resources. Transmission of gas resource in order to deliver the economic and almost clean energy from producing sources to final consumers is one the most important tasks and controversial challenges of country's gas industry and also monitoring organizations such as environment organization. Therefore, pipeline risk assessment is one of the sciences that has been developed by pipelines growth. This article is introducing hazard analysis as an appropriate quantitative method for risk assessment of these pipelines by drawing the amount of risks imposed on this type of projects to reduce hazards and consequently the subsequent financial and human damages and provide information for experts, decision makers, public and private managers involved in all discussions related to the transmission lines. The case study of this research is Savadkooh 16 inch gas transmission pipeline in Mazandaran province in Iran which identify the hazard potentials by using Hazard and Operability Study (HAZOP) method, in this method work space or understudy project is divided into smaller sections, then each hazard is evaluated and analyzed separately by using the identified hazards. High speed and low cost are the features of the method and baseline study is necessary for this method. This study determined that the method is useful in linear projects besides the industrial plant and it's result is well applicable in risk reduction and management and also accurate results obtained from this method can provide appropriate approach and strategies to reduce the risks and subsequent consequences.

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## KEYWORDS

Risk assessment;
Hazard analysis;
Pipeline hazard;
Environment,
Hazard and operability study (HAZOP) method.

## INTRODUCTION

Islamic republic of Iran possesses 14 thousand kilometers of oil pipelines and more than 22 thousand km of gas transmission pipelines and it holds the longest network of oil and gas pipelines in the Middle East, And also the pipeline projects under design and implementation in Iran (the main gas transmission lines, including lines 56 inches 4, 5, 6,7, 8 and 9 IGAT and the multiple transmission lines, crude oil and petroleum products) has made Islamic Republic of Iran as the most important country of pipe industry and pipeline projects in the Middle East and one of the important countries of the world.

Natural gas is one of the most important carrier of energy transfer[3,7,10,18]. In fact, considering all the issues which have been mentioned above, the important issue is transferring these energy resources to the domestic and foreign consumers. Clearly, the best and most economical method which has the least impact is the usage of pipelines. Historical records of accidents around the world show that a risk dimension approach is not appropriate if it only considers the human or ûnancial aspects, due to the complexity of the environmental, human and regulatory issues involved[4].

Considering these issues, it should be said that in gas transferring to consumers, economical conditions, risk, hygienic, environmental, technical and other conditions are at least the main factors which are influential and each of them is the outcome of its subset of factors. Therefore any attempt to transfer the energy carries should be done in terms of above factors. A review on statistics of occurred accidents causes make the necessity of attention, investigation, evaluation, planning, management and monitoring of these pipelines clearer. So risk management is a critical activity for many process and facilities presenting technological risks, especially for transportation systems of dangerous substances, such as natural gas pipeline networks[16].

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. Risk is identified as the consequences of a potential hazard or probability of its occurrence. In other words, risk is a process in which different techniques are used to study the probability of a risk and also its impacts, the consequences are presented based on the depth of studies and the its quantitative or qualitative phases. The process contains identifying probabilistic risks, predicting the location of occurrence, estimating the probability of occurrence and impact assessment (Judith,1999). Hazard refers to the properties which have the potential of causing a disaster while risk is hazard probability and it's severity that can cause damage. 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[14].

In this case it should be said that environmental risk assessment includes identifying the affected environment, time and spatial modeling of emissions and leakage, assessment of important ecologically components regarding environmental sensitivity, estimation of quantity of the risk compared with existing standards and identifying risk mitigative actions. (Torms, 2004) Accordingly, in addition to study and analysis various aspects of risk with full acknowledgement about the environment of the area, environmental sensitivity, and also environmental values are used in the risk analysis[14].

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[17] fuzzy method was used to rank the relative hazard of materials fire and chemical installations. In this stud, a rapid assessment approach with multiple criteria evaluation was used in order to enter different parameters in risk assessment.

In another study, Mr Astbury[1] studied characteristics and hazards of some fuels cleverly, in order to introduce a suitable alternative fuel, he studied all fuel characteristics including all fire hazard and explosion.

In a study titled as accident risk indicator, multiple criteria method was used by khan and Abbasi to rank industrial process hazard[8]. In this study, AHI index was introduced as a new system for a rapid and comprehensive assessment of the damages caused by chemical industry accidents. This index has also the ability to evaluate the impacts of accidents based on site characteristics and operational details.

Mr Pasanta Kumar Dey[9] expressed in a study titled as An integrated assessment model for cross-country pipelines that due to crossing the oil pipeline on land uses such as agricultural areas, residential areas, desert, beach, etc., these are environmental sensitive areas. In this study various options are proposed by developing an integrated framework for project feasibility analysis using the AHP method.

another study titled as calculating the value of fire and explosion(F and EI) indicators has been done by other scientists to obtain criteria for measuring leakage control[11]. This study discusses that the impact of leakage control measures is not calculated in F and EI index and is trying to enter the impact somehow in the calculations. In another study titled Development of an inherent safety index based on fuzzy logic by[12], it is discussed that the inherent safety evaluation has been based on quality principles so far and now they have been able to find the quantitative evaluation of the criteria by using the fuzzy logic.

Two other scientists in a research titled Development of environmental consequence index (ECI) using fuzzy composite programming discuss that it is so difficult to estimate the environmental impacts of hazardous material in chemical industries due to diversity of hazards type and their impact, location and uncertainty in input information. In the opinion of these two scientists, environmental parameters do not exist in the available index, this is why the ETC has been entered by a new method[13].

In Iran, half of the in research titled Risk assessment of petrochemical pipelines, scientists assessed the pipeline carrying the chlorine after studying 60 pipeline. In this risk assessment, they assessed the third party damage indicators, Incorrect operation, corrosion and design. Besides the available resources, the most important source of pipeline risk assessment is the valuable book by Mahlbuner[14] which is a comprehensive method,trying to assess the risk with considering all the influential parameters.

## MATERIALS AND METHODS

The case study of this research is Savadkooh 16 inch gas transmission pipeline in Mazandaran province in Iran which pass through the cities : savad kooh, zirab, shirgah and pole sefid and villages : sorkh kola, ghasem abad and zirab. The pipeline length is 606+30 Km and will transfer the gas through the Valley of Talar river from Caspian coastal areas to mountainous regions of Savadkooh in north to south direction.

Starting point coordinates are x=668500 and y = 4021500 and the end point coordinates of the pipeline are x= 682500 and y=4002500. the pipeline passes along the firoozkooh road in some parts of the route and in some other parts passes forests around Shirgah and cross the rivers 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 and also 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.

Also due to placing the caste study route in mountainous climate, the permanent rivers which can 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.

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 except at the primary parts and at the end of the route is mountainous and steep. It seems that the main factor that can cause slope rupture is earthquake factor that causes stimulated ruptures induced by earthquake have the possibility of occurrence in the region.

### Methods

### Hazard analysis method

Hazard analysis is a simple, useful ad rapid application which is usually used to identify potential hazard by using HAZOP method. In this method, workspace and understudy project is divided into smaller sections and then by using the identified hazard to assess any hazard separately. High speed and low cost are special features of this method and basic studies are essential components of this method.

In hazard analysis, following processes are performed respectively:

- Obtaining details about processes and project scope
- Hazard and damage potentials Identification (hazard identification)
- Determination of risk level and prioritizing the corrective actions to mitigate the risk
- Documentation and preparing risk assessment table
- Review and updating risk assessment results

Finally in order to avoid repetition of similar cases and to simplify the report, cases with same negative impacts or damage and also control actions, are concentrated in a row. Then, risk level as Risk

Precedence number or RPN is determined and the results should be assessed. To determine risk level or Risk Priority Number (RPN)(Bluvband, Grabov, Nakar,2004) risk matrix has been used considering the following four factors:

- Intensity and severity of harmful impacts are shown by A (low), B (middle) and C (high).
- Extent of harmful impacts which is shown by 1 (local expansion and limited) and 2 (Expansion in total work area or operational workshop)
- Probability of hazardous accident occurrence which is shown by a (too improbable), b (improbable) and c (probable).
- Stability and durability of hazardous accident which is shown by 1 (Short term and Transient) and 2 (Continuous and Long term)

Then, for facilitating the expression of risk precedence number In matrix, the lowest risk is given number 1 and by increasing the risk, the level will reach the highest risk umber which is 14. In fact, this matrix model is a modified version of the same general risk assessment procedure which estimates the risk level by intensity and repetition but according to environmental impact complexity and in order to increase the accuracy, two factors are used which are impact severity and extent. This environmental risk assessment method is one of the methods which is used widely specially in north American countries.

## RESULTS AND DISCOSSION

### Environmental risk assessment of the project using Rapid Hazard Analysis

In risk assessment studies of Savadkooh gas transmission project, the HAZOP method has been used in order to identify potential hazards. In this method, work environment or the case study project has been divided into smaller parts.

Then in each section (Node), different parameters are chosen to determine risk level or risk precedence number (RPN), the risk matrix is used regarding four criteria that have been mentioned above. TABLE 1 presents the proposed criteria for determining the risk precedence number with the rating of the project.

After calculating risk precedence number, risk levels were classified as follows:

### 1-4 RPN

1-4 RPN indicates that the risk level is negligible. Potentially hazardous factors that have this rate of risk do not require the risk control actions and risk mitigations. It's just sufficient to monitor the activities and processes to take proper actions in case conditions change and risk increase to higher levels.

For example, risk due to welding heat impact on increasing the temperature and the harmful impact on the ecosystem is A1-aI which means RPN = 1 and

**TABLE 1 : Parameters and Risk Precedence number determination rating**

| Criterion | rating | | |
|---|---|---|---|
| | A | B | C |
| Severity of harmful impact | Slightly Harmful | Medium | Extremely Harmful (environmental accidents ) |
| | 1 | 2 | |
| Extent of harmful impact | Operational and immediate area | Local and Direct area | |
| | a | b | C |
| Probability of hazardous accident occurrence | too Improbable | Improbable | Probable |
| | I | II | |
| Durability of hazardous accident | Short term and Transient | Continuous and Long term | |

does not require control actions. Obviously, this risk simply describes warm weather risk and radiation risk on human or risk of fire due to welding has been investigated separately.

### 5-7 RPN

5-7 RPN Indicates low risk. The risk level is acceptable and corrective actions are not necessary but it is recommended to investigate these risks after assessing the high and medium risks and also having the resources such as time, budget and etc due to mitigate the probable damages. For example the risk due to smoke by welding pipeline is in this group of risk because of performing the welding out door but if welding is performed in closed space, the risk rate was higher.

### 8-10 RPN

8-10 RPN Indicates moderate risk. Activities that have these levels of risk may be continued but with additional control actions such as putting the special controller, preparation and implementation of specific guidelines or slowing down the work should take care of the situation and prevent accidents.

The risk control actions should be in such a way that mitigates the risk to the lowest level but it's not necessary to stop the project. For example, risks due to traffic noise, welding machines and staff auditory problems are classified in this group and can be controlled by using the Ear Plug & Ear Muff for Welding and Welding assistants and also by avoiding night work in the vicinity of residential areas so the risk rate will be negligible.

### 11-14 RPN

11-14 RPN Indicates high risk. The activities with this risk rate can not be started unless to mitigate the risk to the accepted level with appropriate control actions. Starting and continuing the project at this risk rate is illegal. Risk due to pipeline leakage during operation, fire caused by welding, presence of flammable materials near the point of welding, risks resulting from collision with other oil and gas pipelines due to lack of adequate information are in this group. However in cases where there is a legal requirement, such as crossing the environmental protected areas, relevant risk regardless of the RPN, is considered as high risk and adequate actions should be taken before the project starts in order to assure the legal authorities, inspectors and relevant organizations supervisors.

In the next step, hazard intensity can be integrated with hazard probability and a rapid risk assessment can be done by calculating risk precedence number in order to determine the accident relative risk. TABLE 2 which is the risk assessment matrix was used to determine the risk precedence number.

The purpose of this matrix is helping the experts and managers in hazard prioritizing in order to correct them. Risk classification is based on its severity and

**TABLE 2 : Risk assessment matrix in order to determine the risk precedence number**

| Severity of harmful impacts (A-B-C) | Extent rate of harmuful impacts (1-2) | (a-b-c) Probability of hazardous disaster (I to II) Durability of hazardous disaster Rate | | | | | |
|---|---|---|---|---|---|---|---|
| | | a | | b | | C | |
| | | I | II | I | II | I | II |
| A | 1 , 2 | 1 | 2 | 3 | 4 | 5 | 6 |
| B | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| | 2 | 5 | 6 | 7 | 8 | 9 | 10 |
| C | 1 | 7 | 8 | 9 | 10 | 11 | 12 |
| | 2 | 9 | 10 | 11 | 12 | 13 | 14 |

**Rezazadeh 2005 and the author analyzes**

**TABLE 3 : Risk management decision-making criteria based on risk precedence number**

| Risk management decision-making perspective | RPN | Risk Levels |
|---|---|---|
| Accepted without revision<br>Control actions are not required. The process should be monitored to provide appropriate responses in changing conditions. | 1-4 | Very low |
| Accepted with management revision<br>Control actions are recommended, but activities can be continued | 5-7 | Low |
| Undesirable, senior management decided in order to accept or reject the risk<br>activities can be continued if the control actions be doubled to mitigate the risk to the lowest level | 8-10 | Medium |

**TABLE 4-12 : Environmental risk assessment's results of gas pipeline using hazard analysis method**

| Risk rate after safeguards | | | schedule | responsible | Safeguard | Risk before safeguards | | | Consequence | Cause | Diversion, hazard or incident | Row |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RPN | Probability & Stability | Severity & Sprawl | | | | RPN | Probability & Stability | Severity & Sprawl | | | | |
| 9 | C I | B2 | Before design | Employer - Consultant | Routing of lands with low vegetation density | | | | | | | |
| | | | Design & Construction | Employer - Contractor | Prevention of unnecessary removal (removal minimum) | 14 | C II | C2 | Elimination of land vegetations & soil erosion increasing | Route preparation | Removal& degradation of Ranges | 1 |
| | | | After design | Employer - Contractor | Replacing removed vegetation with appropriate vegetation | | | | | | | |
| 10 | b II | C1 | design | Consultant | Reduction of ROW & increasing of pipeline diameter crossing farms | 14 | C II | C2 | Removal of vegetation, soil erosion increasing &public dissatisfaction | Right of way (ROW) level, leakage probability | Agricultural land degradation | 2 |

probability. Occurrence may be at a high risk level but its intensity can be low. For example, minor leakage of fuel from machinery in outdoor can be placed in this category but the hazards with very low probability and high intensity also exist, such as pipe explosion that such risks should be examined separately. Colors used in this table simply present the risk management decision-making view which will be explained more in TABLE 3.

Now by using the mentioned instances and other studies in risk assessment, the risk analysis result of Savad kuh gas transmission pipeline project is given in TABLE 4.

Of course, listing all or even a majority of the options related to potential hazards is really difficult. To mention the maximum details in addition to the technical specifications of the project in risk analysis studies, the typical safety check list of industries and large facilities or other similar check lists are used. The purpose of using the check lists, is simply finding the problem sets which are needed in hazard analysis. The Check list can help to identify hazards and hazard resources in risk analysis and assessment.

## CONCLUSION

In conclusion and by using risk management decision criteria based on risk precedence number which was mentioned in TABLE 3, it is necessary to mention these cases:

As it can be seen, all hazards leading human damage and fire, in any point of view in risk management is unacceptable which represents high risk of these hazards. In case of such hazards, stopping the process and rapid reform is essential.

All presented recommendations to control hazards should be having this ability to reach the acceptable minimum level of risk index by management review.

Risk management decisions based on risk indicators, even after the presented recommendations, usually has not been assessed at acceptable levels without management review. Unless due to technical characteristics of the route, risk of occurrence be improbable. This issue indicates the importance of risk management monitoring and the necessity to predict some appliances to prevent of reoccurring the hazard.

A part of the assessment results are presented in following table :

All involved people in pipeline management in all sectors are responsible for risk mitigation and each one has a unique role.

- Pipeline risk management and assessment is growing rapidly in order that not only the risk assessment methods are developing but also this growth is in a way that all the users utilize the given methods.
- The used methods ensures that if the pipeline is at the standard level or not and whether the methods and measures mitigate the pipeline hazard to the standard level or not.
- quantifying the risk by using the mentioned method solves one of the perennial problems in the assessment which is qualitative assessments and lack of ability to share the quantitative assessments
- The method was quantitative and spatial so in expressing the standard deviation, disaster, cause, impact, and other cases, the places of the risk can be easily identified
- Combination of this method with other methods such as scoring system, FMEA, WHAT IF, can present a more complete version of risk assessment.
- expressing the risk under the classification or the presented standard in this report can be evaluated as a basis of assessment and has the capability for the evaluator to perform changes according to his opinion under the limitation of the numbers.

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