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Gas pipeline risk assessment by Internet application

Introduction

Gas pipelines are recognized as the safest mode of transportation. However sometimes they do fail often with severe consequences. Therefore there is risk of pipeline failure which cannot be totally eliminated.

An integral part of any **P**ipeline **I**ntegrity **M**anagement **S**ystem (**PIMS**) is the risk assessment process. In order to maintain gas pipeline integrity we must know and understand the risk factor. This includes analysis of the probability of failure and potential consequences. There are two approaches to estimate risk, quantitative and qualitative. Quantitative methods involve historical accidents data base or computer simulation. Qualitative methods are based on expert opinions and can gather the local experiences of pipeline operators. In this paper the model based on the qualitative risk indexing method is presented. Two groups of parameters are considered. In the first group are parameters which can probably influence failure. The second group is constituted from the parameters which can influence potential consequences.

Having the list of these parameters the relative importance of each parameter is discussed among the group of experts. Once consensus is reached a model of risk estimation of pipeline failure is created. In the next step the risk categories criteria are formulated.

The risk criteria for five risk categories were formulated.

The model and the risk categories were implemented on the web based decision support system. The pilot tests of the system were performed and the results are presented.

Managing pipeline risk

In order to manage pipeline risk Operators need to identify and estimate it. They would like to know what the risk of pipeline failure is. Pipeline Operators need to have in place an easy to use and understandable computer tool which helps them to establish a risk priority for pipeline segments of concern.

There is also the economical aspect of such an approach, because the funds, coming from an always tight budget will be spent on pipelines which really need it and are a potential source of hazard.

The elaborated model of risk assessment together with risk acceptance criteria were implemented on the web based support system called **S**ystem **O**ceny **R**yzyka **E**ksploatacyjnego **G**azociagu (**SOREG**®).

Each segment of gas pipeline is characterized, in terms of posed risk by total risk index.

Risk R is defined as the product of two variables P and Q:

$$R = P \cdot Q \tag{1}$$

Where P is the probability of failure and Q is the consequence if the risk is materialized.

The method of risk assessment

There are two approaches to risk assessment. One is qualitative and the other is quantitative. In the first one the risk level is characterized without quantifying it. In the second approach the risk level is calculated on quantified estimates failure probability and consequences.

Quantitative approach is more sophisticated and detailed. It involves the incident data base to perform statistical calculation or uses physical models to estimate risk by analytical methods.

The qualitative approach is simple and relative. One of the qualitative methods is indexing [2]. In this paper the qualitative risk indexing method is presented.

Two groups of gas pipelines and surroundings parameters are considered. In the first group are parameters which can probably influence failure. The second group is constituted from the parameters which can influence the potential consequences. Having the list of these parameters the relative importance of each parameter is discussed among the group of experts. Once consensus is reached the model of risk estimation of pipeline failure is created. In the next step the risk acceptance criteria are formulated.

The model is designed to help pipeline operators identify, analyze and mitigate the risk of pipeline failures. The model construction was done in a two stage process. In the first stage the parameters which have an impact on the probability of pipeline failure were chosen. The causes of failure as well as their frequency of occurrence were analyzed. These parameters contain information and data from five thematic groups:

- Quality systems applied,
- Physical characteristic of the gas pipeline,
- Operational and organizational factors,
- Technical condition of the gas pipeline,
- Corrosion control.

In the second stage the parameters which have an impact on the potential consequences of failure were chosen. The potential consequences of failure depend on the localization of the pipeline, crossings and interferences and population density in the vicinity of the pipeline. The applied mitigation methods of pipeline failure consequences were taken into consideration.

There are 22 parameters analyzed in the first stage and 11 in the second stage. Then the adequate weights were assigned to each parameter in accordance with the expert's judgment. The relationships between the chosen parameters were analyzed and taken into account during the weighing process. The point system was created and accepted by all parties involved in the model construction. A consensus was reached.

Risk categories were defined by the number intervals. Each analyzed segment of gas pipeline is characterized by the relative Total Risk Index (TRI). The value of TRI will decide in which risk category the considered pipeline segment falls. Moreover for each risk category some recommendations are suggested (see Table 1).

In some way, risk categories criteria define an operator's safety policy. Safety is strictly connected with cost. There is no possibility to eliminate risk completely. There is a risk level which can be acceptable. Risk level which cannot be tolerated must be reduced or transferred to other entities, e.g. an insurance company.

The next step was an implementation of the model and risk criteria into a computer system which could serve gas pipeline Operators as a computer tool. This easily understandable computer tool can help them to make rational decisions in operating and maintaining gas pipelines. Therefore the model and risk acceptance criteria were implemented on the web based support system called SOREG®.

Table 1. Risk categories and recommendations

Risk	Recommendations
Very high	Immediate replacement or withdrawal from operation
High	Needs to be included in the repair & modernization plan
Moderate	Additional diagnostics as well as modernization or repair possibility consideration
Small	Standard operational monitoring as well as additional inspection of the chosen segments of pipeline
Very small	Standard operational monitoring

Computer implementation

The SOREG® was designed as web based decision support system. The PHP language, Java scripts as well as MySQL Data Base were used to create the SOREG® [3].

There are two kinds SOREG® users. The Administrator and the Operator. There is only one Administrator. There could be more than one Operator. They both work with the system throughout their own panels. The Administrator has power over the model and the risk categories and also creates the Operators accounts in the system. It means that the Administrator has the possibility of changing the model and can set up new risk categories. The Operators logins and passwords are assigned by the Administrator. There are two kinds of Operators.

One is called the **A**ctive **O**perator (**AO**) who can define the gas pipeline in the SOREG® system, do evaluation, print reports and can also review and edit the results. The second one is called the **P**assive **O**perator (**PO**) who may only review the results. However PO does not have rights to edit them and cannot define a new gas pipeline in the system. PO is not authorized to make his own evaluations of the gas pipeline.

There are two modes of working with the system. One mode refers to the managing of the gas pipelines and the other deals with the managing of the evaluations. All pipeline evaluation results are stored in the data base.

Work with the SOREG® system involves the four following steps:

1. In the first step the object of the evaluation must be defined. It means that the gas pipeline, if necessary is broken up into segments. The amount of segments and their size depend upon essential parameter value changes.
2. Put in the values of each parameter by typing them or import from other data bases.
3. The system carries out the risk assessment for the pipeline segment being analyzed.
4. Automatically two kinds of reports (tabular and graphical) are created, which can be saved, printed or displayed.

As a result, each segment of gas pipeline is characterized, in terms of posed risk by the relative Total Risk Index. The general idea of the SOREG® system is presented on Figure 1.

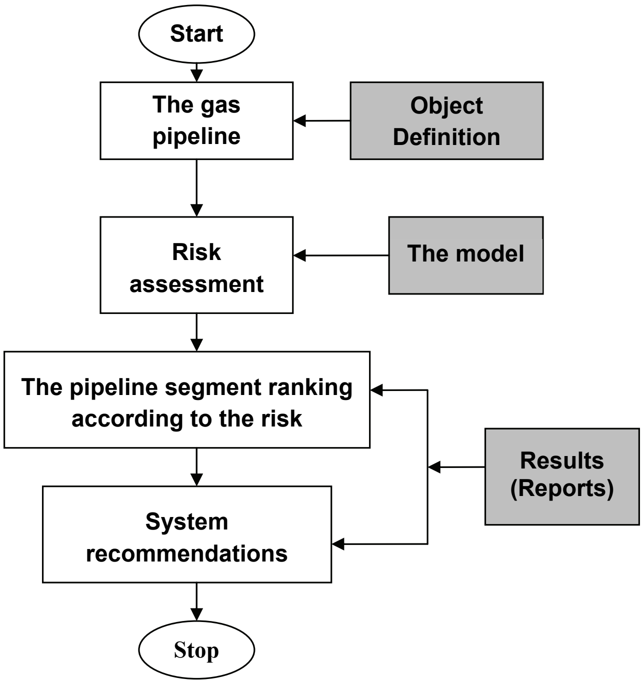

Figure1. The general idea of the SOREG® system

Additionally, if necessary there is an option to carry out "what if" analysis. By changing the value of one or more parameters one can create a new scenario which will show the influence of a change in parameters on the results.

Pilot tests and implementation

Pilot tests were conducted by three Polish gas pipeline Operators. The gas pipelines being evaluated were chosen carefully trying to cover many different situations. The technical condition of the gas pipelines being analyzed was known very well to the Operators. In most cases the results obtained from the SOREG® confirmed the knowledge of the Operators about the analyzed gas pipelines. Some small changes were made in descriptions of the parameters, assigned points and definition of risk categories. They were also some remarks concerning the functionalities of the system.

SOREG® pilot tests on 19 operational gas pipelines are promising and showed that such an approach can help operators to prioritize which pipeline segment should be first repaired or needs inspection or additional diagnostics. In spite of the promising results of SOREG® pilot tests, more work is needed. The future schedule for new tests on operational gas pipelines is elaborated. This system can be integrated with other information systems working at Operator site, e.g. **G**eographic **I**nformation **S**ystem (**GIS**). When the system is implemented then the "good practices" of the specific Operator can be incorporated into the system. The system can also be easily modified when knowledge and experience are expanded.

In the years 2010–2011 the SOREG® system was tested and implemented by "EUROPOL GAS" S.A.

Summary

Risk assessment must not necessarily be a complicated process. This paper presents an easy useable approach to cope with pipeline risk assessment. The risk involved in operation of gas pipelines can be estimated and when known, be manageable. The presented point model and its software implementation SOREG® can help gas pipeline operators to make rational decisions in their work. The gas pipeline in operation can be prioritized according to the Total Risk Index. This ranking list can be used in the elaboration process of repair and modernization plans. It can save money. The funds coming from an always limited budget will be spent on those segments of the gas pipeline which need it more than others. By using this system the Operator can compare two segments of the gas pipeline based on the same criteria and with a common method.

The system integrates and analyzes data coming from different sources. Operator can identify the potential risk and if necessary can take actions which prevent pipeline failure. Having such tool in place an operator can be active in managing risk. During the decision making process the results obtained from SOREG® will be integrated with other sources of information. By creating different scenarios and simulating some action (i.e. reparation of the deteriorated coating) a gas pipeline Operator can easily see the result of his actions on the risk. With this system, **H**igh-**C**onsequence **A**reas (**HCA**) can be identified. Then remediation and mitigation actions can be chosen and taken.

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References

[1] Dietrich A., Badowski J.: *A Web Decision Support System for Gas Pipeline Risk Assessment.* Proc. of EUROSIS International Conference – FUBUTEC’2009, Bruges, Belgium, April 15–17, 2009.
[2] Muhlbauer W. Kent: *Pipeline Risk Management Manual.* Gulf Publishing Company 1966, Second Edition.
[3] Welling L., Thomson L.: *PHP and MySQL Web Development.* Polish language edition published by Helion 2005.

Mgr Andrzej DIETRICH – kierownik Zakładu Informatyki Instytutu Nafty i Gazu w Krakowie. Zajmuje się modelowaniem matematycznym i stosowaniem metod komputerowych w przemyśle naftowo-gazowniczym. Stypendysta North Eastern University w Bostonie oraz uczestnik międzynarodowego projektu badawczego w Connecticut Natural Gas Corporation w Hartford, USA.