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Calculating urban and rural areas risk score (URAS) in environmental risk assessment (ERA) of pipelines

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ABSTRACT

This paper presents a methodology for calculating the risks that built-environment, characteristically urban and rural areas, face in the case of pipeline failures. Bidkhoun with a URAS of 1.45 has scored the most of all due to an average distance of 961m from the pipeline. Dehno was the safest built-environment in the case of pipeline failure circumstances. The state-of-the-art method used in this study revealed partial deficits in the other pipeline environmental risks assessments not considering the issue of URA properly. It is suggested that new policies are to be implemented to reduce the negative effects of the mentioned pipeline that has not yet been constructed completely as well as the other similar pipelines on the human settlements involving the vicinity of the pipeline.

KEYWORDS

Environmental assessment;
Assalouyeh;
Gas;
Living areas.

INTRODUCTION

Risk assessment and environmental risk assessment of pipelines

Risk is the severity of the consequences of a hazardous activity considering its probability of occurrence. Concept of risk is simply showed in figure 1[13].

Pipeline failures cause severe damages. For example a list of recent accidents in the current decade and only in the U.S. is presented (Wikipedia, The Free Encyclopedia): 2007-New York City steam explosion, (July 18); 2007-Propane pipeline explodes, killing two and injuring five others near Carmichael, AL (November 1), the NTSB determined the probable cause was ERW seam failure. Inadequate education of residents near the pipeline about how to respond to a pipeline accident was also cited as a factor in the deaths; 2008-Natural gas pipeline explodes and catches fire near Hartsville (February 5), TN Believed to have been caused by a tornado hitting the facility; 2009-Natural gas pipeline explodes and catches fire near Rockville (May 5), IN, in Parke County about 24 miles north of Terre haute, IN. PHMSA indicated the possibility of external corrosion in its Corrective Action Order (CAO) to the pipeline company. Pictures have been released around the area showing the damage caused. 49 homes were evacuated in a one-mile area of the explosion. No injuries reported; 2009-Two people hurt when a natural gas pipeline exploded in the Texas Panhandle. The explosion left a hole about 30 yards by 20 yards

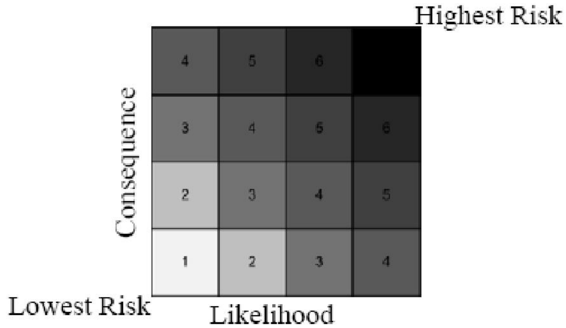

Figure 1 : Simple matrix of consequence (intensity) and likelihood (probability)

and close to 15 feet deep. The blast shook homes, melted window blinds and shot flames hundreds of feet into the air. The home nearest the blast about 100 yards away was destroyed (5 November); 2009-A new 42 inch gas transmission pipeline near Philo, Ohio fails on the second day of operation. There was no fire, but evacuations resulted (November 14).

Environmental risk assessment (ERA) involves the examination of risks resulting from natural events (flooding, extreme weather events, etc.), technology, practices, processes, products, agents (chemical, biological, radiological, etc.) and industrial activities that may pose threats to ecosystems, animals and people. Environmental health risk assessment addresses human health concerns and ecological risk assessment addresses environmental media and organisms. ERA is predominantly a scientific activity and involves a critical review of available data for the purpose of identifying and possibly quantifying the risks associated with a potential threat[1].

For both gas and liquid pipelines, some areas adjacent to a pipeline can be identified as “high-value” areas. A high-value area (HVA) can be loosely defined as a location that would suffer unusually high damages or generate exceptional consequences for the pipeline owner in the event of a pipeline failure. In making this distinction, pipeline sections traversing or other-wise potentially exposing these areas to damage should be scored as more consequential pipeline sections. HVAs might also bring an associated higher possibility of significant legal costs and compensations to damaged parties. Characteristics that may justify the high value definition include the following[6] Higher property values, Areas that are more difficult to remediate, Structures or facilities that are more difficult to replace, Historical areas, High-use areas. Identification and scoring of HVAs can be done by determining the most consequential conditions that exist and scoring according to a relative scale first introduced by Muhlbauer[6]. Note that the probability of a leak, fire, and explosion is not evaluated here–only potential consequences should such an event occur. Interpolations between the classifications should be done. A classifications use qualitative descriptions of HVA’s and environmental sensitivities to score potential receptor damages has been introduced by Muhlbauer[6] as follows: Neutral (default) =0: No extraordinary environmental or high-value considerations; Higher =0.1-0.6: Some environmental sensitivity; Extreme = 0.7-1.0. Another sample of scoring HVAs has been proposed by Muhlbauer[6]. In this scheme, various high-value areas are “valued” on a 0- to 5-point scale with higher points representing more consequential or vulnerable receptors. Attempts to gauge all property values and land uses along the pipeline may not be a worthwhile effort, especially since such evaluations must be constantly updated. The HVA designation can be reserved for extraordinary situations[6]. One of the HVAs is urban and rural areas that should be addressed considerably.

Presented a study on sensitivity analysis[9], carried out a numerical sensitivity analysis of the site effect on dynamic response of pipelines embedded in some idealized soil deposits resting on a half space covering a wide range of soil profiles encountered in practice and subjected to vertically propagating shear waves. Apart from the sensitivity by itself, in an area with different environmental units it is completely important to consider small-area units[12].

A paper described how HSE has piloted a Geographic Information System (GIS) by Brazier & Greenwood[10]. To support the expert decision making process and to assist in ensuring consistent responses within statutory deadlines. It considers both the advantages and disadvantages of a GIS over more conventional methods as well as potential developments such as the use of population data in considering societal risks, biological constraints and 3D terrain mapping.

Schiller et al.[11] presented an algorithm which emulates human expert-decisions on the classification of sensitivity classes. This will permit the necessary regular updates of ESI-determination when new field data be-

Figure 2 : Kangan city, Iran– the study area is located in

come available using automated classifications procedures.

MATERIALS AND METHODS

Study area

Being located beside the Kangan city, the capital of Assalouyeh main city, represented in figure 2, the Assalouyeh-Bandarabbas gas pipeline project is to be routed through the mentioned city and be continued along about 385km. The pipeline is to carrying natural gas with 36 inches of diameter. The case study is the first 29.872km of the project. The study area selected is located along a national park called Naayband. It is worthwhile mentioning that all geographical coordinates for locations are available in the created maps. Topography is loosely constant all over the study area so that it did not affect the method for used for the study area. The study area is partly in coastal zone. This study has been carried out during January 2010 until April 2010.

Buffer zones and risk scores (Zone-of-Influence)

General worst damage cases have reported a distance of about 500m for direct damages for gas pipeline failures that are even more explosive than that of the other materials[7]. It is essential to determine for the distance a piece of data provide evidence on adjacent lengths of pipe[6]. Considering the probabilities, the distance of the least probable indirect damages to environment, both of natural and built-environment would be 10 times more. So a distance of 5000 m is enough to assume the minimum risk[3]. As the town boundaries are considered as the indirect boundaries of the project, according to the rules of IEPO (Iran's Environmental Protection Organization), in this study a function of exponential scoring to indicate the more sensitivity of less-distant areas to the pipeline route were used. Respectively the two distances of 20m and 5000m were weighted exponentially as the project-active and direct boundaries. Balancing the two available buffer distances, it was concluded that there were necessities in order to determine the sensitivity indices and subsequently risk indices. The sensitivity index mentioned here is one of the most important ones-urban and rural areas representing the URAS. Finally a buffer up to 5000m outward and 2500m toward the park (considering the pipeline as an axis) were created (Figure 4).

Equation used for calculating urban and rural risk score (URAS)

Risk assessments generally rely on mathematical environmental fate and transport models and calculate exposure point concentrations in environmental media (e.g., soil, air, water, food), rather than collecting data. This makes sense when using "potential to emit" estimations for proposed facilities[3]. Providing a formula to calculate the index risk scores, a rational formula was created based on the following logics: 1) Relative risk score ranges would be normally around the relative score of 10 while it is rationally variable. 2) The scores should be of the same nature of the other factors so that the final calculations of risk and sensitivity are more reliable and feasible for risk communication. Risk managers use risk estimates, derived through risk assessment, to determine whether a process, activity, or site poses significant risks to human health or the environment. Risk managers may decide, for example, that estimated risks are acceptable, and no action is required, or that risks are too high and require remediation, mitigation, regulation, reduction, or prohibition. Risk managers tend to be non-scientists and may view risk estimates as indicators of "real risks," rather than mere estimates of risk. Risk managers should understand that risk estimates are one component in a multi-faceted decision making process[3]. 3) An exponential relation exists between the distance of pipeline to the urban and rural areas–the more less-distant, the more score of

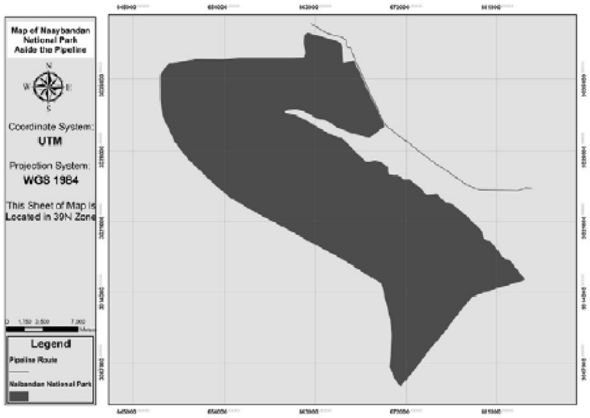

Figure 3 : Naayband national park beside the selected study area

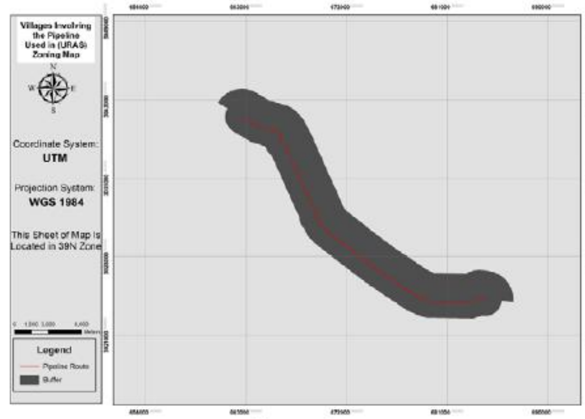

Figure 4

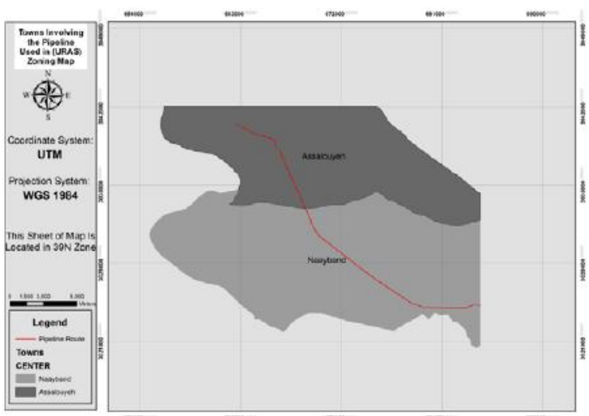

Figure 5

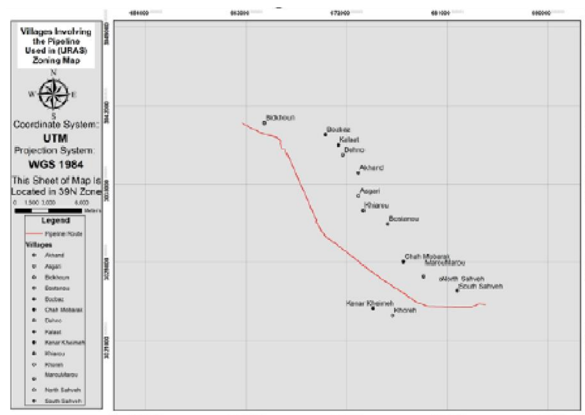

Figure 6

risk and subsequently the more sensitivity[5]. 4) The areal extent of the assessment must be defined. For example, is an off-site area included in the assessment, and to what distance off-site[3]? Assuming a distance of 5000m as the minimum risk, the minimum risk score for the index would be provided so that distances more than 5000m were not considered. 5) A 20m distance for project-active buffer zone as the maximum risk. 6) In distance-based formulas, the D refers to the least distance (LD) between two features.

Consisting of 2 towns (Figure 5) (Assalouyeh and Naayband) and 14 villages (Figure 6) involving the pipeline routing, provided (TABLE 1) and their distance sensitivity ranking as well, the study area has human health risk so that relative risk estimations were carried out. The more decrease of distance from the pipeline, the more safety and less sensitivity would be present. Assalouyeh has had 31319 persons and Naayband 10450 in 2006-2007. Villages are the only human settlement in the project region. Distances were measured from the center of the villages and because of settlement concentrations within an average of 500m radius of the village center, the risks were allocated to such polygons in final risk score (FSR). Besides a risk zoning map was created in order to communicate risk results in a more obvious way as well as considering holisticity (Figure 7).

$$\mathbf{URAS} = \frac{1}{\sqrt{D}} \times 45 \qquad (1)$$

where, D: (Least) Distance of URAS to the pipeline route; RRSR: 0.01-10

RESULTS AND DISCUSSION

Summarizing the results of the investigation URAS was obtained for the human settlements within the study area (TABLE 1).

Risk management and risk communications are

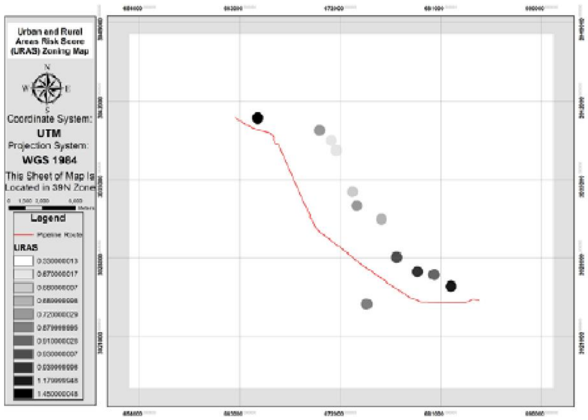

Figure 7 : Urban and rural areas risk score (URAS) zoning map

parts of risk process that are indeed the fundamental of success in an integrated risk assessment as[3] have stated as well. This issue has been addressed in the present study by considering a URAS zoning map outputted from a raster-based GIS to communicate the risks rationally and precisely as well as accurately. Being able to be guided through European legislations and directives, Iran has a similar legislative system. During the last 10 years, Europe has faced several major industrial accidents generated by various causes, e.g.: Enschede 2000-explosion of firework storage, Toulouse 2001-explosion of ammonium nitrate and Ath 2004-rupture, explosion, and fire of a gas pipeline. These incidents caused a lot of casualties and major damage to the environment, forced international authorities to examine these phenomena, and, moreover, led the European Commission to adopt legislation to prevent such events[4]. Since having a spatial risk map seems inevitable to manage the risk of pipelines that was considered chiefly here. Ramesh et al.[7] provided us with a distance of about 500m reported on the worst jet fires by natural gases that made it possible to calculate the zones of influence following our risk communication aim. Considering[6], the applicability of this method cannot be addressed in areas such as Assalouyeh with different living areas mostly the pipeline route is outside the villages and seems not to be concerning, but so.

It is worthwhile mentioning that being a new concept that here has been used, no integrated approach considering these issues in a holistic final score-at least for the surrounding environment of the pipelines[9,10,13].

TABLE 1 : Scoring for the risk of intersections between land use environmental unit and the pipeline (IRS)

Rank in LD	Settlement	LD (m)	URAS	Rank in LD	Settlement	LD (m)	URAS
1	Bidkhoun	961	1.45	8	Bozbaz	3890	0.72
2	South Sahveh	1446	1.18	9	Khiarou	3891	0.72
3	Khoreh	2201	0.96	10	Bostanou	4250	0.69
4	Marouu	2283	0.94	11	Asgari	4352	0.68
5	Chah Mobarak	2324	0.93	12	Kalaat	4502	0.67
6	North Sahveh	2434	0.91	13	Dehno	4526	0.67
7	Kenar Kheimeh	2639	0.88	14	Akhand	5167	-

CONCLUSION

The aim of this study was to assess the urban and rural areas risk score (URAS) in order to assess apply as an index in environmental risk assessment of pipelines. Based on the results of the investigations, the following conclusions were drawn:

(1) Bidkhoun with a URAS of 1.45 has scored the most of all due to an average distance of 961m from the pipeline.
(2) Dehno was the safest built-environment in the case of pipeline failure circumstances.
(3) The state-of-the-art method used in this study revealed partial deficits in the other pipeline environmental risks assessments not considering the issue of URA properly.
(4) It is suggested that new policies are to be implemented to reduce the negative effects of the mentioned pipeline that has not yet been constructed completely as well as the other similar pipelines on the human settlements involving the neighborhood of the pipeline.

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