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Study on quantitative risk assessment model of the third party damage for natural gas pipelines based on fuzzy comprehensive assessment

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Abstract. As an important part of national energy supply system, transmission pipelines for natural gas are possible to cause serious environmental pollution, life and property loss in case of accident. The third party damage is one of the most significant causes for natural gas pipeline system accidents, and it is very important to establish an effective quantitative risk assessment model of the third party damage for reducing the number of gas pipelines operation accidents. Against the third party damage accident has the characteristics such as diversity, complexity and uncertainty, this paper establishes a quantitative risk assessment model of the third party damage based on Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE). Firstly, risk sources of third party damage should be identified exactly, and the weight of factors could be determined via improved AHP, finally the importance of each factor is calculated by fuzzy comprehensive evaluation model. The results show that the quantitative risk assessment model is suitable for the third party damage of natural gas pipelines and improvement measures could be put forward to avoid accidents based on the importance of each factor.

Key Words. natural gas pipelines; third party damage; quantitative risk assessment model; AHP; FCE.

1. Introduction

As natural gas pipelines have characteristics of continuous operation, cover different sites complex environments, therefore, the safety of gas transmission pipelines not only affects the safety of pipeline running, social energy supply, but also threatens people's life and living environment

The third party damage has been get extensive attention as the main reason of natural gas pipeline accidents. Tom Bajcar presents a refined way to quantify the effects of third party interference on risk that is posed on people by transmission pipelines for natural gas. The main focus is set on the influence of population density on risk[1]; Wei Liang focuses on the application of self-organizing maps(SOMs)to assess the risk of third-party interference and classify their risk patterns[2]; Xing-yu Peng based on fragility and internal & external hazard, an overall reliability model can be established as a theoretical basis for quantitative risk assessment on oil and gas pipeline systems[3]. Jun Li calculates the failure possibility of the third-party to urban gas pipeline based on AHP and FCE. However, the importance of each factor for the third-party has not been calculated. Moreover, in this thesis, the main studying object is urban gas pipeline not Long-distance Gas Pipeline [4].

Quantitative risk assessment model has been established for the third party damage used Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) in this paper. The model could compare the importance of the various factors for the third party damage and prevent accidents effectively.

2. Risk source identification of third party damage

The third party damage of natural gas pipelines generally refers to the damage caused by peoples' behavior. Primary risk factors of third party damage are divided into six different categories in this paper: legal factors, condition of pipeline patrol, related equipment of pipeline, public relations along the pipeline, peripheral activity along the pipeline and alarm system of Pipeline Company.

The author based on the research of third party damage, determining its corresponding second level risk factors of primary risk factors are shown in figure 1.

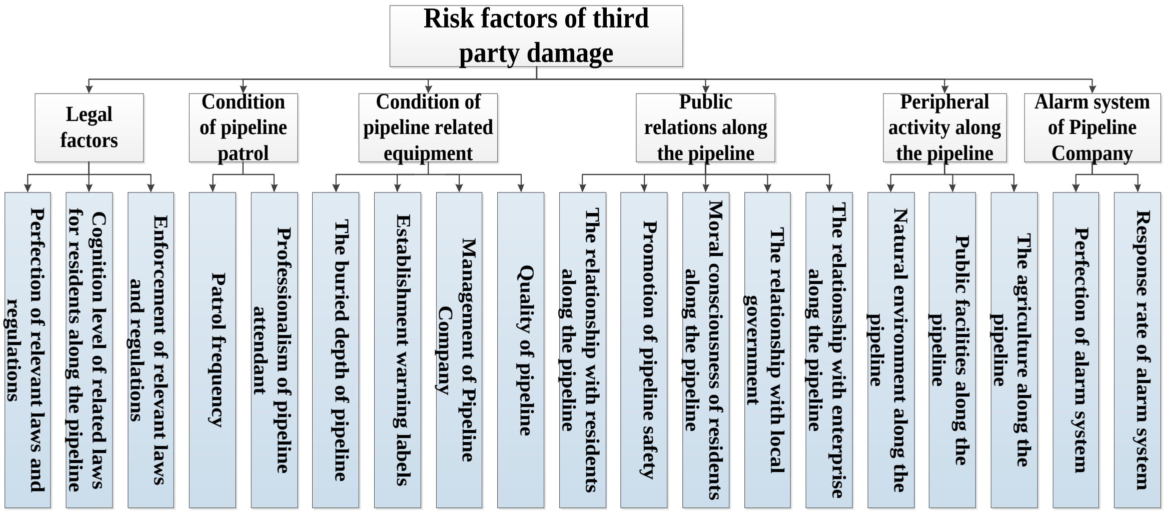

Figure 1. Risk factors of third party damage for natural gas pipelines.

The risk factors of third party damage are analysed to establish quantitative risk assessment model and prevent accidents of natural gas pipelines.

3. The fundamentals of improved AHP

Analytic hierarchy process (AHP) is a structured multi-attribute decision method. The main advantage of AHP is its capability to check and reduce the inconsistency of expert judgments [4].

Generally, the process of applying AHP is divided into three steps. Firstly, establish a hierarchical structure by recursively decomposing the decision problem. Secondly, construct the pairwise comparison matrix to indicate the relative importance of alternatives. A numerical rating including nine rank scales is suggested [5], as shown in Table 1. Thirdly, verify the consistency of pairwise comparison matrix and calculate the priority weights of alternatives. Using the formula: $CR = CI/RI$, $CI = \frac{1}{n-1}(\lambda_{\max} - n)$, where, CI is consistency index; RI is average random consistency index; CR is calculate and inspect consistency ratio. If $CR < 0.10$ the constructed pairwise comparison matrix is considered acceptable and the priority weights of alternatives can be obtained through the eigenvector[6]. Otherwise, the comparison matrix needs to be reconstructed， where RI is the random consistency index related to the dimension of matrix[7], listed in Table 2.

Table 1. The 1–9 scales for pairwise comparisons in the AHP.

Definition	Equal importance	Moderate importance	Moderate importance	Moderate importance	Moderate importance	Moderate importance	Moderate importance
Importance intensity	1	3	5	7	9	2,4,6,8	Reciprocals

Table 2. RI value of matrixes with different exponent.

Order: n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

For the pairwise comparison matrix $M_{n\times n}$ with acceptable consistency, suppose $\vec{w}=[w_1,w_2\cdots,w_n]^T$ is the eigenvector of M, whose $w_i(i=1,2,\cdots n)$ is indicated as the priority weight of the ith alternative and calculated by $M\vec{w}=\lambda_{\max}\vec{w}$ [8].

The judgment of one expert is calculated and analyzed in traditional AHP. This paper proposes a method combining with Delphi method and AHP in order to calculate the weight of risk evaluation index. [9]。This method would be more accurate to invite five expert judgment methods, rather than only consider one expert opinion to calculate the weight. The analysis process of improved AHP is shown in figure 2.

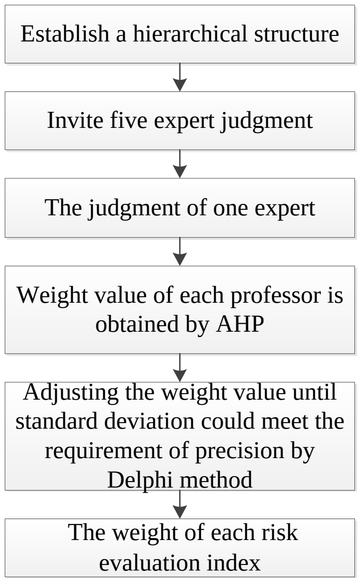

Figure 2. The analysis process of improved AHP.

Weight value of each professor has been processed by Delphi method, values are weighted average and standard deviation is calculated according to expert opinions credibility. If standard deviation could meet the requirement of precision, then the final weight of each risk evaluation index is obtained. Otherwise new data is calculated after experts' adjusting the weight value until standard deviation could meet the requirement of precision, then final result is the weight of each risk evaluation index.

4. The fundamentals of FCE

The fuzzy comprehensive evaluation method, combining fuzzy theory and mathematical model, is a useful method in quantitative risk assessment [10]. The methods for obtaining evaluation index set and weight set have been described above. The fuzzy comprehensive evaluation mainly includes the following procedures:

(1) Factor sets: $\mathbf{U}=\{u_1,u_2,\cdots,u_i,\cdots,u_n\}$

(2) Evaluation sets: $\mathbf{V}=\{v_1,v_2,\cdots,v_j,\cdots,v_n\}$

(3) Weight sets: $\mathbf{A}=\{a_1,a_2,\cdots,a_m\}$. $\sum_{i=1}^{m}a_i=1\ a_i\geq 0$.

(4) Fuzzy relation matrix sets: Construct the membership functions, and then adopt the expert scoring method for each single factor scores of factor sets, through membership function obtain membership values rim of each single factor, establish single factor fuzzy evaluation matrix [11].

(5) Comprehensive evaluation [12]. According to the Weight sets and evaluation matrix Calculate factors layer and index layer fuzzy comprehensive evaluation sets. $\mathbf{B}=\mathbf{A}\bullet\mathbf{R}$.

5. Case analysis

5.1. fuzzy comprehensive risk assessment model

Possible destruction styles, influencing factors and the importance of risk assessment index system for third party damage to Shaan-jing pipeline are quantified based on FCE. The analysis process of fuzzy comprehensive risk assessment model for the third party damage is shown in figure 3.

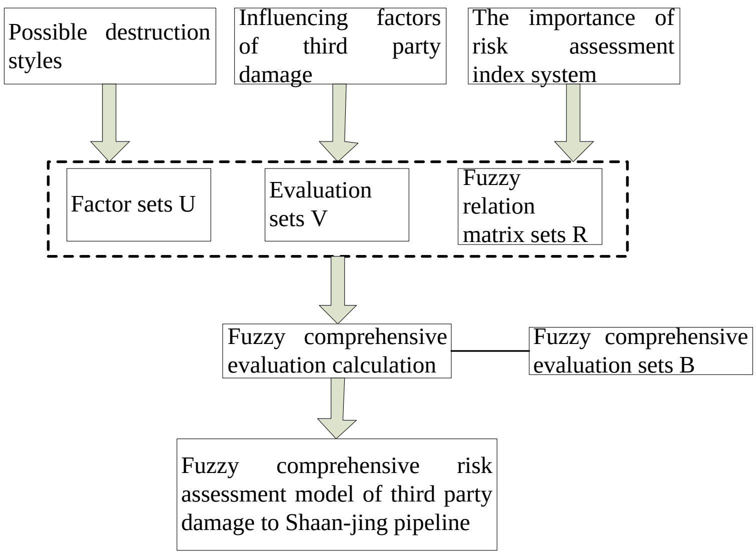

Figure 3. Fuzzy comprehensive risk assessment model of third party damage to Shaan-jing pipeline.

Possible destruction styles, influencing factors and the importance of risk assessment index system for third party damage to Shaan-jing pipeline are graded by five rich field experiences of managers and employees based on risk source identification of third party damage mentioned in section 1. The result of the grading statistics is analysed and fuzzy comprehensive risk assessment model is established based on FCE.

According to the statistical results, possible destruction styles of third party damage: excavating equipment, cultivation of agricultural machinery, artificial malicious damage, transportation vehicle, natural disaster; influencing factors of third party damage: the buried depth of pipeline、overlaying soil properties、Man-made obstacles、natural obstacles、mark stake of pipeline、patrol frequency、the nature of the region passed by pipeline、response of alarm system；the importance of risk assessment index system for third party damage：the buried depth of pipeline、ground activity of pipeline、ground facilities、warning labels、patrol frequency、Public education and publicity、alarming system. Evaluation sets is divided into four grades: low (L), medium (M), between medium and high (MH), high (H). The weight of each factor is calculated based on based on improved AHP mentioned in section 2, factor sets, evaluation sets and weight sets are shown in Table 3. The specific scoring statistics is not present in the paper due to the large number.

Table 3. The content of fuzzy comprehensive evaluation.

Category	Evaluation sets	Factor sets U	Weight of factor sets	Evaluation sets V
Possible destruction styles of third party damage	Excavating equipment B11	{Safety publicity education, The supervision of excavation, The connection of construction unit, Patrol strength}	{0.1, 0.4, 0.2, 0.3}	V1 The possibility of occurrence: {H, MH, M,L}
	Agricultural production B12	{Safety publicity education, The connection of local government, Facility of warning labels, Patrol strength}	{0.2, 0.1, 0.3, 0.4}	
	Artificial malicious damage B13	{Moral consciousness of residents along the pipeline, Safety publicity education, Moral consciousness of residents along the pipeline, Patrol strength}	{0.15, 0.15, 0.2, 0.5}	
	Transportation vehicle B14	{Protection facilities of pipeline, Pipeline route design, Facility of warning labels, Patrol strength}	{0.25, 0.1, 0.35, 0.3}	
	Natural disaster B15	{Pipeline route design, Protection facilities of pipeline, Prediction of natural disasters, Response measurements of natural disasters}	{0.7, 0.05, 0.05, 0.2}	
Influencing factors of third party damage	The buried depth of pipeline B21	{Pipeline crossing situation, The situation of warning sign, The situation of guard plate, The situation of pipe casing}	{0.5, 0.3, 0.1, 0.1}	V2 Influence level: {H, MH, M,L }
	Man-made obstacles B22	{Pipeline crossing situation, Type of protection facilities, Complete situation of protection facilities, Demand situation of protection}	{0.3, 0.2, 0.4, 0.1}	
	Mark stake of pipeline B23	{Complete situation of mark stake, Damage condition of mark stake, Perfection of mark stake, Management of mark stake}	{0.3, 0.3, 0.2, 0.2}	
	Pipeline patrol frequency B24	{Professionalism of pipeline attendant, regulation of pipeline patrol, Quality of pipeline patrol, Management unit of pipeline patrol}	{0.15, 0.15, 0.5, 0.2}	
	Property of region passed by pipeline B25	{Economic development of region, Population density, Development degree, The situation of spiritual civilization}	{0.2, 0.3, 0.2, 0.3}	
	Response of alarm system B26	{ Perfection of alarm system, Response rate, Response mechanism, Personnel assignment }	{0.2, 0.3, 0.3, 0.2}	
The importance of risk assessment index system for third	Buried depth of pipeline B31	{Pipeline crossing situation, The situation of warning sign, The situation of guard plate, The situation of pipe casing}	{0.5, 0.3, 0.1, 0.1}	V3 Importance level：{ H,
	Ground activity of pipeline B32	{The ground construction activity, The ground agriculture activity, Natural environment, Pipeline crossing situation }	{0.4, 0.3, 0.1, 0.2}	
	Ground	{Exposure of ground facilities, Protection	{0.5, 0.3,	

party damage	facilities B33	facilities, Natural environment, The situation of warning labels}	0.1, 0.1}	MH, M, L }
	Warning labels B34	{Complete situation of warning labels, Damage condition of warning labels, Density of warning labels, Management of warning labels}	{0.3, 0.3, 0.2, 0.2}	
	Patrol frequency B35	{Professionalism of pipeline attendant, Regulation of pipeline patrol, Quality of pipeline patrol, Management unit of pipeline patrol }	{0.15, 0.15, 0.5, 0.2}	
	Public education and publicity B36	{Promotion of pipeline safety, Propaganda way, Contact with local government, Periodic return visits}	{0.2, 0.2, 0.4, 0.2}	
	Alarming system B37	{ Perfection of alarm system, Publicity of alarm system, Response rate, Response mechanism }	{0.2, 0.2, 0.3, 0.3}	

5.2. possible destruction styles of third party damage

(1) Excavating equipment: B_{11}

Weight sets: $A_{11} = [0.1\,0.4\,0.2\,0.3]$

Fuzzy relation matrix sets: $R_{11} = \begin{bmatrix} 0.18 & 0.27 & 0.52 & 0.03 \\ 0.85 & 0.12 & 0.03 & 0 \\ 0.36 & 0.42 & 0.12 & 0.10 \\ 0.73 & 0.24 & 0.03 & 0 \end{bmatrix}$

$$\begin{aligned} B_{11} &= A_{11} \bullet R_{11} \\ &= [(0.1 \cap 0.18) \cup (0.4 \cap 0.85) \cup (0.2 \cap 0.36) \cup (0.3 \cap 0.73), \\ &\quad (0.1 \cap 0.27) \cup (0.4 \cap 0.12) \cup (0.2 \cap 0.42) \cup (0.3 \cap 0.24), \\ &\quad (0.1 \cap 0.52) \cup (0.4 \cap 0.03) \cup (0.2 \cap 0.12) \cup (0.3 \cap 0.03), \\ &\quad (0.1 \cap 0.03) \cup (0.4 \cap 0) \cup (0.2 \cap 0.10) \cup (0.3 \cap 0)] \\ &= [0.1 \cup 0.4 \cup 0.2 \cup 0.3, 0.1 \cup 0.12 \cup 0.2 \cup 0.24, \\ &\quad 0.1 \cup 0.03 \cup 0.12 \cup 0.03, 0.03 \cup 0 \cup 0.10 \cup 0] \\ &= [0.4, 0.24, 0.12, 0.1] \end{aligned}$$

After the normalization: $B_{11} = [0.4651, 0.2791, 0.1395, 0.1163]$

The possibility of third party damage caused by excavating equipment is H and membership is 0.4651 based on maximum membership principle.

Detailed calculation process will not be introduced in the paper; the specific calculation process could be best seen by reference to B_{11}.

(2) Cultivation of agricultural machinery B_{12}.

$$B_{12} = A_{12} \bullet R_{12} = [0.2, 0.1, 0.3, 0.4] \bullet \begin{bmatrix} 0.21 & 0.27 & 0.49 & 0.03 \\ 0.33 & 0.21 & 0.42 & 0.04 \\ 0.42 & 0.42 & 0.16 & 0 \\ 0.79 & 0.21 & 0 & 0 \end{bmatrix} = [0.4255, 0.3139, 0.2128, 0.0426]$$

(3) Artificial malicious damage B_{13}

$$B_{13} = A_{13} \bullet R_{13} = [0.15\ 0.15\ 0.2\ 0.5] \bullet \begin{bmatrix} 0.21 & 0.21 & 0.33 & 0.25 \\ 0.3 & 0.15 & 0.36 & 0.19 \\ 0.33 & 0.21 & 0.42 & 0.04 \\ 0.61 & 0.33 & 0.06 & 0 \end{bmatrix} = [0.4237, 0.2797, 0.1695, 0.1271]$$

(4) Transportation vehicle B_{14}

$$B_{14} = A_{14} \bullet R_{14} = [0.25\ 0.10\ 0.35\ 0.3] \bullet \begin{bmatrix} 0.36 & 0.42 & 0.22 & 0 \\ 0.12 & 0.15 & 0.54 & 0.19 \\ 0.18 & 0.48 & 0.30 & 0.04 \\ 0.24 & 0.76 & 0 & 0 \end{bmatrix} = [0.2709, 0.3552, 0.2248, 0.1491]$$

(5) Natural disaster B_{15}

$$B_{15} = A_{15} \bullet R_{15} = [0.7\ 0.05\ 0.05\ 0.2] \bullet \begin{bmatrix} 0.58 & 0.42 & 0 & 0 \\ 0.09 & 0.06 & 0.81 & 0.04 \\ 0.12 & 0.33 & 0.24 & 0.31 \\ 0.21 & 0.54 & 0.15 & 0.18 \end{bmatrix} = [0.4361\ 0.3158\ 0.1128\ 0.1353]$$

5.3. influencing factors of third party damage

(1) Buried depth of pipeline B_{21}

$$B_{21} = A_{21} \bullet R_{21} = [0.5\ 0.3\ 0.1\ 0.1] \bullet \begin{bmatrix} 0.54 & 0.21 & 0.22 & 0.03 \\ 0.30 & 0.66 & 0.04 & 0 \\ 0.42 & 0.24 & 0.27 & 0.07 \\ 0.12 & 0.09 & 0.51 & 0.28 \end{bmatrix} = [0.4464, 0.2679, 0.1964, 0.0893]$$

(2) Man-made obstacles B_{22}

$$B_{22} = A_{22} \bullet R_{22} = [0.3\ 0.2\ 0.4\ 0.1] \bullet \begin{bmatrix} 0.15 & 0.39 & 0.27 & 0.19 \\ 0.09 & 0.33 & 0.42 & 0.16 \\ 0.24 & 0.66 & 0.10 & 0 \\ 0.21 & 0.27 & 0.48 & 0.04 \end{bmatrix} = [0.2182, 0.3636, 0.2455, 0.1727]$$

(3) Mark stake of pipeline B_{23}

$$B_{23} = A_{23} \bullet R_{23} = [0.3\ 0.3\ 0.2\ 0.2] \bullet \begin{bmatrix} 0.45 & 0.24 & 0.22 & 0.09 \\ 0.54 & 0.21 & 0.25 & 0 \\ 0.30 & 0.27 & 0.39 & 0.04 \\ 0.15 & 0.21 & 0.64 & 0 \end{bmatrix} = [0.3409, 0.2727, 0.2841, 0.1023]$$

(4) Pipeline patrol frequency B_{24}

$$B_{24} = A_{24} \bullet R_{24} = [0.15\ 0.15\ 0.5\ 0.2] \bullet \begin{bmatrix} 0.30 & 0.48 & 0.18 & 0.04 \\ 0.24 & 0.54 & 0.22 & 0 \\ 0.73 & 0.18 & 0.09 & 0 \\ 0.36 & 0.45 & 0.12 & 0.07 \end{bmatrix} = [0.5435, 0.2174, 0.1630, 0.0761]$$

(5) Property of region passed by pipeline B_{25}

$$B_{25} = A_{25} \bullet R_{25} = [0.2\ 0.3\ 0.2\ 0.3] \bullet \begin{bmatrix} 0.09 & 0.54 & 0.28 & 0.09 \\ 0.12 & 0.67 & 0.21 & 0 \\ 0.12 & 0.58 & 0.27 & 0.03 \\ 0.21 & 0.64 & 0.15 & 0 \end{bmatrix} = [0.2593, 0.3704, 0.2593, 0.1111]$$

(6) Response of alarm system B_{26}

$$B_{26} = A_{26} \bullet R_{26} = [0.2\ 0.3\ 0.3\ 0.2] \bullet \begin{bmatrix} 0.15 & 0.57 & 0.15 & 0.13 \\ 0.18 & 0.67 & 0.12 & 0.03 \\ 0.21 & 0.58 & 0.18 & 0.03 \\ 0.15 & 0.48 & 0.33 & 0.04 \end{bmatrix} = [0.2500, 0.3571, 0.2381, 0.1548]$$

5.4. the importance of risk assessment index system for third party damage

(1) Buried depth of pipeline B_{31}

$$B_{31} = A_{31} \bullet R_{31} = [0.5\ 0.3\ 0.1\ 0.1] \bullet \begin{bmatrix} 0.54 & 0.21 & 0.18 & 0.07 \\ 0.30 & 0.61 & 0.04 & 0.04 \\ 0.39 & 0.27 & 0.27 & 0.07 \\ 0.12 & 0.09 & 0.51 & 0.28 \end{bmatrix} = [0.4630, 0.2778, 0.1667, 0.0926]$$

(2) Ground activity of pipeline B_{32}

$$B_{32} = A_{32} \bullet R_{32} = [0.4\ 0.3\ 0.1\ 0.2] \bullet \begin{bmatrix} 0.42 & 0.36 & 0.12 & 0.10 \\ 0.36 & 0.54 & 0.10 & 0 \\ 0.15 & 0.21 & 0.48 & 0.16 \\ 0.15 & 0.30 & 0.45 & 0.10 \end{bmatrix} = [0.3774, 0.3396, 0.1887, 0.0943]$$

(3) Ground facilities B_{33}

$$B_{33} = A_{33} \bullet R_{33} = [0.5\ 0.3\ 0.1\ 0.1] \bullet \begin{bmatrix} 0.54 & 0.21 & 0.21 & 0.04 \\ 0.30 & 0.66 & 0.04 & 0 \\ 0.42 & 0.24 & 0.27 & 0.07 \\ 0.12 & 0.09 & 0.51 & 0.28 \end{bmatrix} = [0.4505, 0.2703, 0.1892, 0.0901]$$

(4) Warning labels B_{34}

$$B_{34} = A_{34} \bullet R_{34} = [0.3\ 0.3\ 0.2\ 0.2] \bullet \begin{bmatrix} 0.45 & 0.24 & 0.22 & 0.09 \\ 0.54 & 0.21 & 0.25 & 0 \\ 0.30 & 0.27 & 0.39 & 0.04 \\ 0.15 & 0.21 & 0.64 & 0 \end{bmatrix} = [0.3409, 0.2727, 0.2841, 0.1023]$$

(5) Patrol frequency B_{35}

$$B_{35} = A_{35} \bullet R_{35} = [0.15\ 0.15\ 0.5\ 0.2] \bullet \begin{bmatrix} 0.30 & 0.48 & 0.18 & 0.04 \\ 0.24 & 0.54 & 0.22 & 0 \\ 0.73 & 0.18 & 0.09 & 0 \\ 0.36 & 0.45 & 0.12 & 0.07 \end{bmatrix} = [0.5435, 0.2174, 0.1630, 0.0761]$$

(6) Public education and publicity B_{36}

$$B_{36} = A_{36} \bullet R_{36} = [0.2\ 0.2\ 0.4\ 0.2] \bullet \begin{bmatrix} 0.24 & 0.45 & 0.18 & 0.13 \\ 0.18 & 0.63 & 0.15 & 0.07 \\ 0.52 & 0.30 & 0.18 & 0 \\ 0.15 & 0.18 & 0.58 & 0.09 \end{bmatrix} = [0.3883, 0.2913, 0.1942, 0.1262]$$

(7) Alarming system B_{37}

$$B_{37} = A_{37} \bullet R_{37} = [0.2\ 0.2\ 0.3\ 0.3] \bullet \begin{bmatrix} 0.24 & 0.21 & 0.39 & 0.16 \\ 0.21 & 0.48 & 0.21 & 0.10 \\ 0.36 & 0.27 & 0.25 & 0.12 \\ 0.58 & 0.24 & 0.15 & 0.03 \end{bmatrix} = [0.3061, 0.2755, 0.2551, 0.1633]$$

5.5. result

The result of fuzzy comprehensive evaluation to Shaan-jing pipeline is summarized in Table 4.

Table 4. The result of fuzzy comprehensive evaluation.

	Factor	Membership	Consequence	Ranking
Possible destruction styles of third party damage	Excavating equipment	0.4651	H	1
	Cultivation of agricultural machinery	0.4255	MH	2
	Artificial malicious damage	0.4237	MH	3
	Natural disaster	0.4361	MH	4
	Transportation vehicle	0.3552	M	5
Influencing factors of third party damage	Pipeline patrol frequency	0.5435	H	1
	Buried depth of pipeline	0.4464	MH	2
	Property of region passed by pipeline	0.3704	M	3
	Man-made obstacles	0.3636	M	4
	Response of alarm system	0.3571	M	5
	Mark stake of pipeline	0.3409	L	6
The importance of risk assessment index system for third party damage	Patrol frequency	0.5435	H	1
	Buried depth of pipeline	0.4630	H	2
	Ground facilities	0.4505	H	3
	Public education and publicity	0.3883	M	4
	Ground activity of pipeline	0.3774	M	5
	Warning labels	0.3409	L	6
	Alarming system	0.3061	L	7

It is shown that factors of possible destruction styles need to be noticed are excavating equipment, agricultural production and artificial malicious damage; factors of influence level for third party damage need to be noticed are pipeline patrol frequency, buried depth of pipeline and property of region passed by pipeline; factors of importance for risk assessment index system need to be noticed are pipeline patrol frequency, pipeline patrol frequency and ground facilities. To solve these basic factors, corresponding improvement measures are put forward from the following several aspects:

1. Pipeline warning belt is founded and mark stakes of pipeline are added in the region of excavating equipment and agricultural production operated frequently.
2. Pipeline patrol path is optimized, the frequency and quality of pipeline patrol is improved and careful patrol maintenance by pipeline attendant is required in the pipe section prone to third party damage.
3. Increasing buried depth in the wrong place and keeping away from the large plant growth soil area after buried depth inspection.

4. Ground facilities are inspected regularly and lost or damaged identification should be maintained and adjusted timely to ensure the accuracy and completeness.

6. Conclusions

Quantitative risk assessment model of third party damage combined with AHP and FCE is established based on fuzzy mathematic theory in this paper. The importance of each factor for third party damage is calculated and valuable prevention measures could be provided, the main conclusions are as follows:
1. In this paper, factors of possible destruction styles, influence level and importance of risk assessment index system for third party damage were considered by improved AHP/FCE. It could be more comprehensive to evaluate the third party damage of natural gas pipelines compared with other evaluation methods.
2. In the process of improved AHP/FCE, the basic factors of third party damage components were analysed, and improvement measures were proposed for the key factors.
3. In the process of improved AHP/FCE, the weight and membership of factors for third party damage is more accurate with traditional AHP/FCE. The process of improved AHP/FCE was shown and the effectiveness of quantitative risk assessment model is verified by an actual applied example.

7. Acknowledgements

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